

RĒZEKNES TEHNOLOĢIJU AKADĒMIJA
Inženieru fakultāte

REZEKNE ACADEMY OF TECHNOLOGIES
Faculty of Engineering

VIDE. TEHNOLOĢIJA. RESURSI

XV starptautiskās zinātniski praktiskās konferences rakstu krājums
2024.gada 27.-28.jūnijs

2.SĒJUMS

ENVIRONMENT. TECHNOLOGY. RESOURCES

Proceedings of the 15th International Scientific and Practical Conference
June 27th – 28th, 2024

Volume II

Rēzekne
2024

VIDE. TEHNOLOĢIJA. RESURSI. 15.starptautiskās zinātniski praktiskās konferences materiāli. 2024.gada 27.-28. jūnijs. 2.sējums: Rēzeknes Tehnoloģiju akadēmija, Rēzekne, Latvija, 2024. 529 lpp.

ENVIRONMENT. TECHNOLOGY. RESOURCES. Proceedings of the 15th International Scientific and Practical Conference on June 27th–28th, 2024. Volume II, I: Rezekne Academy of Technologies, Rezekne, Latvia, 2024. pp. 529.

Rekomendējusi publicēšanai Rēzeknes Tehnoloģiju akadēmijas Inženieru fakultātes Dome 2024. gada 29. maijā.
Recommended for publication by the Council of Faculty of Engineering of Rezekne Academy of Technologies on May, 29th, 2024.

15.starptautiskās zinātniski praktiskās konferences “Vide. Tehnoloģija. Resursi” materiālos četros sējumos ir pārstāvēti jaunākie pētījumi vides inženierzinātnē, vides un dabas aizsardzībā, ilgtspējīgā lauksaimniecībā, enerģētikā, materiālzinātnē, mehānikā, metālapstrādē, lāzeru tehnoloģijās, matemātiskajā modelēšanā, elektrotehnikā, vides ekonomikā un vadībā, informācijas tehnoloģijās un sociotehnisko sistēmu modelēšanā, vides izglītībā un ilgtspējīgas attīstības procesos, izglītība inženierzinātnēs, aizsardzības un drošības tehnoloģijās. Krājumā pārstāvēto pētījumu joma ir daudzpusīga un starpdisciplināra, balsīta uz starptautisko zinātnieku kolektīvu sasniegumu rezultātiem. Konferences materiālos iekļauti 303 zinātniskie raksti. Konferences dalībnieki pārstāv 23 valstis.

Šī konference un konferences materiālu krājums ir veltīti konferences “Vide. Tehnoloģija. Resursi” dibinātāja un konferences ilggadējā priekšsēdētāja profesora Dr.habil.geol. Gotfrīda Novika piemiņai.

15.starptautiskās zinātniski praktiskās konferences “Vide. Tehnoloģija. Resursi” norises vieta ir "Vasil Levski" Nacionālā Militārā universitāte, Veliko Tarnovo, Bulgārija.

Proceedings of the 15th International Scientific and Practical Conference “Environment. Technology. Resources” include recent research in fields of engineering, environmental and nature protection, sustainable agriculture, energy, material science, mechanics, metalworking, laser technologies, mathematical modelling, electrical engineering, environmental economics and management, information technologies and sociotechnical systems modelling, environmental education and sustainable development, education in engineering sciences, defense and security technologies. The research area presented in the proceedings is comprehensive and cross disciplinary-based, on advances of international researchers. The proceedings comprise 303 scientific papers. Conference participants represent 23 countries.

This conference and proceedings are dedicated to the conference “Environment. Technology. Resources” founder and long-time chairman of the conference, professor Dr.habil.geol. Gotfrīds Noviks memory.

15th International Scientific and Practical Conference “Environment. Technology. Resources.” hosted by “Vasil Levski” National Military University, Veliko Tarnovo, Bulgaria.

<https://conferences.rta.lv/index.php/ETR/ETR2024>

Link to conference proceedings: <http://journals.rta.lv/index.php/ETR>



This journal is licenced under

[Creative Commons Attribution 4.0 International \(CC BY 4.0\) License](https://creativecommons.org/licenses/by/4.0/)

The author of the paper takes responsibility for the content of the paper.

Print ISSN 1691-5402

Online ISSN 2256-070X

Published by Rezekne Academy of Technologies, 2024

Scientific Committee Chairman

Dr.sc.ing. Edmunds Teirumnieks, Rezekne Academy of Technologies, Latvia

Scientific Committee Co-Chairmen

Dr. Walter Leal, Hamburg University of Applied Sciences, Germany, Manchester Metropolitan University, United Kingdom

Dr.sc.ing. Andris Martinovs, Rezekne Academy of Technologies, Latvia

Dr.sc.ing. Artis Teilāns, Rezekne Academy of Technologies, Latvia

Scientific Committee

Dr.agr. Aleksandrs Adamovičs, Latvia University of Life Sciences and Technologies, Latvia

PhD Nikolaj Angelov, Technical University of Gabrovo, Bulgaria

Dr. agr. Lidia Antypova, Mykolayiv National Agrarian University, Ukraine

PhD Ekaterina Arabska, Higher School of Agribusiness and Regional Development, Bulgaria

PhD Iluta Arbidane, Rezekne Academy of Technologies, Latvia

PhD Daniel Berchev, "Vasil Levski" National Military University, Bulgaria

Dr. hab. Ing. Tadeusz Chrzan, Poltegor Institute, Poland

PhD Nikolay Dolchinkov, "Vasil Levski" National Military University, Bulgaria

PhD Vanko Ganev, "Vasil Levski" National Military University, Bulgaria

Dr.sc.ing. Aleksandrs Gorbunovs, Riga Technical University, Latvia

Dr.sc.ing. Pēteris Grabusts, Rezekne Academy of Technologies, Latvia

PhD Grigor Grigorov, "Vasil Levski" National Military University, Bulgaria

PhD Mart Hovi, Estonian University of Life Sciences, Estonia

PhD Maria Ilcheva, Saint Cyril and Methodius University of Veliko Tarnovo, Bulgaria

Dr.paed. Ilmārs Kangro, Rezekne Academy of Technology, Latvia

Dr. paed. Janis Kapenieks, Riga Technical University, Latvia

PhD Tsanko Karadzhov, Technical University of Gabrovo, Bulgaria

PhD Aivars Kaupuzs, Rezekne Academy of Technologies, Latvia

PhD. Anna Khilya, Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, Spain

PhD Karīne Laganovska, Rezekne Academy of Technologies, Latvia

PhD Inga Ļašenko, Riga Technical University, Latvia

PhD Lazar Lazarov, "Vasil Levski" National Military University, Bulgaria

Dr.oec. Jeļena Lonska, Rezekne Academy of Technologies, Latvia

PhD Dilyan Markov, Georgi Rakovski Military Academy, Bulgaria

Brigadier General Ivan Malamov, "Vasil Levski" National Military University, Bulgaria

PhD Arturs Medveckis, Riga Technical University Liepaja Academy, Latvia

PhD Ziedonis Miklašēvičs, Rezekne Academy of Technologies, Latvia

Dr.sc.ing. Ivan Mitev, Technical University of Gabrovo, Bulgaria

PhD Cristian Emil Moldoveanu, Military Technical Academy "Ferdinand I", Romania

PhD Nikolay Nichev, Georgi Benkovski Higher Military Air School, Bulgaria

Dr.sc.ing. Neli Nikolova, Technical University of Gabrovo, Bulgaria

PhD Nikolay Padarev, "Vasil Levski" National Military University, Bulgaria

PhD Plamen Pavlov, School of Telecommunications and Posts, Bulgaria

Dr.sc.ing. Desislava Petrova, Technical University of Gabrovo, Bulgaria

Dr.agr. Liena Poiša, Rezekne Academy of Technologies, Latvia

Dr. agr. Valentīna Pole, IK Tava zeme, Latvia

PhD Todor Rachovski, Plovdiv University "Paisii Hilendarski", Bulgaria

Dr.sc.ing. Andris Skromulis, Rezekne Academy of Technologies, Latvia

PhD Krasimir Slavyanov, "Vasil Levski" National Military University, Bulgaria

PhD Nikolay Stefanov, "Vasil Levski" National Military University, Bulgaria

PhD Aina Strode, Rezekne Academy of Technologies, Latvia

PhD Gunars Strods, Rezekne Academy of Technologies, Latvia
Dr.sc.ing. Artis Teilāns, Rezekne Academy of Technologies, Latvia
Dr.sc.ing. Edmunds Teirumnieks, Rezekne Academy of Technologies, Latvia
PhD Ērika Teirumnieka, Rezekne Academy of Technologies, Latvia
PhD Plamen Teodosiev, University of Library Studies and Information Technologies, Bulgaria
Dr.-Ing. Josef Timmerberg, Jade University of Applied Sciences, Germany
Dr.biol. Rasma Tretjakova, Rezekne Academy of Technologies, Latvia
PhD Andra Ulme, Riga Technical University, Latvia
PhD Nikolay Urummov, "Vasil Levski" National Military University, Bulgaria
PhD Dragomir Vassilev, Technical University of Gabrovo, Bulgaria
PhD Valentin Vassilev, South-West University "Neofit Rilski", Bulgaria
PhD Emil Yankov, Rezekne Academy of Technologies, Latvia
PhD Tsanka Zlateva-Petkova, Technical University of Gabrovo, Bulgaria
PhD Anda Zvaigzne, Rezekne Academy of Technologies, Latvia

Organising Committee Chairman

PhD Nikolay Dolchinkov, "Vasil Levski" National Military University, Bulgaria

Organising Committee

Dr.agr. Aleksandrs Adamovičs, Latvia University of Life Sciences and Technologies, Latvia
MA Yanitsa Boyanova, "Vasil Levski" National Military University, Bulgaria
Dr.sc.ing. Aleksandrs Gorbunovs, Riga Technical University, Latvia
Dr.sc.ing. Pēteris Grabusts, Rezekne Academy of Technologies, Latvia
MA Georgi Hristov, "Vasil Levski" National Military University, Bulgaria
Dr.sc.ing. Ēriks Kronbergs, Latvia University of Life Sciences and Technologies, Latvia
Dr.sc.ing. Sergejs Kodors, Rezekne Academy of Technologies, Latvia
Dr.sc.ing. Lyubomir Lazov, Rezekne Academy of Technologies, Latvia
Dr.sc.ing. Andris Martinovs, Rezekne Academy of Technologies, Latvia
PhD Rumen Marinov, Vasil Levski National Military University, Bulgaria
PhD Magdalena Mitkova, Assen Zlatarov University Burgas, Bulgaria
PhD Valyo Nikolov, Technical University of Sofia, Bulgaria
PhD Nikolay Padarev, "Vasil Levski" National Military University, Bulgaria
MA Svetoslav Pashunov, "Vasil Levski" National Military University, Bulgaria
Dr.agr. Liena Poiša, Rezekne Academy of Technologies, Latvia
Vilnis Rantins, Member of the Council of the Association of Mechanical Engineering and Metalworking Industries of Latvia, Latvia
Dr.geol. Valdis Segliņš, University of Latvia, Latvia
Dr.sc.ing. Andris Skromulis, Rezekne Academy of Technologies, Latvia
Dr.biol. Artūrs Škute, Daugavpils University, Latvia
Dr.sc.ing. Artis Teilāns, Rezekne Academy of Technologies, Latvia
MA.sc.comp. Gundega Teilāne, Rezekne Academy of Technologies, Latvia
PhD Ērika Teirumnieka, Rezekne Academy of Technologies, Latvia
Dr.biol. Rasma Tretjakova, Rezekne Academy of Technologies, Latvia

Reviewers

Dr.agr. Aleksandrs Adamovičs, Latvia University of Life Sciences and Technologies, Latvia
PhD Nikolaj Angelov, Technical University of Gabrovo, Bulgaria
Dr. agr. Lidiia Antypova, Mykolayiv National Agrarian University, Ukraine
PhD Ekaterina Arabska, Higher School of Agribusiness and Regional Development, Bulgaria
PhD Iluta Arbidane, Rezekne Academy of Technologies, Latvia
PhD Svetlana Asmuss, University of Latvia, Latvia

Dr.sc.ing. Anita Avišāne, Riga Technical University, Latvia
PhD Stefan Bankov, The Ministry of Interior of Bulgaria, Bulgaria
PhD Daniel Berchev, "Vasil Levski" National Military University, Bulgaria
PhD Ansis Ataols Bērziņš, Riga Tehnical University, Latvia
PhD Jānis Bičevskis, University of Latvia, Latvia
PhD Rosen Bogdanov, "Vasil Levski" National Military University Sh, Bulgaria
PhD Plamen Bogdanov, Library Studies and Information Technologies University, Bulgaria
PhD Aija Brakovska, Daugavpils University, Latvia
Dr. hab. Ing. Tadeusz Chrzan, Poltegor Institute, Poland
PhD Maria Chunchukova, Agricultural University Plovdiv, Bulgaria
PhD Dimitar Dichev, Technical University of Gabrovo, Bulgaria
PhD Nikolay Dolchinkov, "Vasil Levski" National Military University, Bulgaria
PhD Vanko Ganev, "Vasil Levski" National Military University, Bulgaria
PhD Dmitri Goljandin, Tallinn University of Technology, Estonia
Dr.sc.ing. Imants Gorbāns, Riga Technical University, Latvia
Dr.sc.ing. Aleksandrs Gorbunovs, Riga Technical University, Latvia
PhD Jānis Grabis, Riga Technical University, Latvia
Dr.sc.ing. Pēteris Grabusts, Rezekne Academy of Technologies, Latvia
PhD Grigor Grigorov, "Vasil Levski" National Military University, Bulgaria
Dr. agr. Elvyra Gruzdevienė, Flax museum, the branch of Eriskiai Cultural Center of the Panevezys District, Lithuania
PhD Mart Hovi, Estonian University of Life Sciences, Estonia
PhD Iliayn Hutov, Defense Institute "Professor Tsvetan Lazarov", Bulgaria
PhD Maria Ilcheva, Saint Cyril and Methodius University of Veliko Tarnovo, Bulgaria
PhD Valery Ivanov, Defense Institute "Professor Tsvetan Lazarov", Bulgaria
PhD Amit Joshi, BA school of banking and finance, Latvia
Dr.sc.ing. Aivars Kaķītis, Latvia University of Life Sciences and Technologies, Latvia
Dr.paed. Ilmārs Kangro, Rezekne Academy of Technology, Latvia
Dr. paed. Janis Kapenieks, Riga Technical University, Latvia
PhD Tsanko Karadzhev, Technical University of Gabrovo, Bulgaria
PhD Aivars Kaupuzs, Rezekne Academy of Technologies, Latvia
PhD. Anna Khilya, Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, Spain
PhD Andrejs Koliškis, Riga Technical University, Latvia
PhD Georgi Komitov, Agricultural University Plovdiv, Bulgaria
Dr.sc.ing. Ēriks Kronbergs, Latvia University of Life Sciences and Technologies, Latvia
PhD Karīne Laganovska, Rezekne Academy of Technologies, Latvia
PhD Vjaceslavs Lapkovskis, Riga Technical University, Latvia
PhD Inga Ļašenko, Riga Technical University, Latvia
PhD Lazar Lazarov, "Vasil Levski" National Military University, Bulgaria
Dr.oec. Jelena Lonska, Rezekne Academy of Technologies, Latvia
Dr.sc.math. Maksims Marinaki, University of Latvia, Latvia
PhD Georgi Marinov, Rakovski National Defence College, Bulgaria
PhD Rumen Marinov, Vasil Levski National Military University, Bulgaria
PhD Assen Marinov, "Georgi Benkovski" Bulgarian Air Force Academy, Bulgaria
PhD Dilyan Markov, Georgi Rakovski Military Academy, Bulgaria
PhD Arturs Medveckis, Riga Technical University Liepaja Academy, Latvia
PhD Ziedonis Miklašēvičs, Rezekne Academy of Technologies, Latvia
PhD Roussi Minev, Ruse University, Bulgaria
PhD Nikolai Minkovski, University of Forestry, Bulgaria
Dr.sc.ing. Ivan Mitev, Technical University of Gabrovo, Bulgaria
PhD Linko Nikolov, "Vasil Levski" National Military University, Bulgaria
Dr.sc.ing. Neli Nikolova, Technical University of Gabrovo, Bulgaria
Dr.chem. Sergejs Osipovs, Daugavpils University, Latvia

PhD Nikolay Padarev, "Vasil Levski" National Military University, Bulgaria
PhD Jana Paidere, Daugavpils University, Latvia
PhD Hristian Panayotov, Technical University of Sofia, Bulgaria
PhD Stanimir Parvanov, "Vasil Levski" National Military University, Bulgaria
PhD Plamen Pavlov, School of Telecommunications and Posts, Bulgaria
Dr.sc.ing. Jeļena Pečerska, Riga Technical University, Latvia
PhD Penyo Penev, "Georgi Benkovski" Bulgarian Air Force Academy, Bulgaria
Dr.sc.ing. Desislava Petrova, Technical University of Gabrovo, Bulgaria
Dr.agr. Liena Poiša, Rezekne Academy of Technologies, Latvia
Dr. agr. Valentīna Pole, IK Tava zeme, Latvia
PhD Dimcho Pulov, Technical University of Gabrovo, Bulgaria
Dr. agr. Gundega Putniece, Latvia University of Life Sciences and Technologies, Latvia
PhD Todor Rachovski, Plovdiv University "Paisii Hilendarski", Bulgaria
Dr.phys. Gita Rēvalde, Riga Technical University, Latvia
PhD Jolanta Šadauskiene, Kaunas University of Technology, Lithuania
Dr.sc.math. Felikss Sadirbajevs, Daugavpils University, Latvia
PhD Andrejs Šiškins, Riga Technical University, Latvia
Dr.sc.ing. Andris Skromulis, Rezekne Academy of Technologies, Latvia
PhD Krasimir Slavyanov, "Vasil Levski" National Military University, Bulgaria
PhD Nikolay Stefanov, "Vasil Levski" National Military University, Bulgaria
PhD Julija Steinhart, BA school of banking and finance, Switzerland
PhD Stoyko Stoykov, "Vasil Levski" National Military University, Bulgaria
PhD Aina Strode, Rezekne Academy of Technologies, Latvia
PhD Gunars Strods, Rezekne Academy of Technologies, Latvia
Dr.sc.ing. Artis Teilāns, Rezekne Academy of Technologies, Latvia
Dr.sc.ing. Edmunds Teirumnieks, Rezekne Academy of Technologies, Latvia
PhD Plamen Teodosiev, University of Library Studies and Information Technologies, Bulgaria
Dr.-Ing. Josef Timmerberg, Jade University of Applied Sciences, Germany
Dr.biol. Rasma Tretjakova, Rezekne Academy of Technologies, Latvia
PhD Andra Ulme, Riga Technical University, Latvia
PhD Nikolay Urummov, "Vasil Levski" National Military University, Bulgaria
PhD Dragomir Vassilev, Technical University of Gabrovo, Bulgaria
PhD Valentin Vassilev, South-West University "Neofit Rilski", Bulgaria
Dr.habil.sc.ing. Janis Viba, Riga Technical University, Latvia
PhD Emil Yankov, Rezekne Academy of Technologies, Latvia
Dr.sc.ing. Imants Zarembo, Rezekne Academy of Technologies, Latvia
PhD Tsanka Zlateva-Petkova, Technical University of Gabrovo, Bulgaria
PhD Anda Zvaigzne, Rezekne Academy of Technologies, Latvia

Secretariat Chairman

PhD Ērika Teirumnieka, Rezekne Academy of Technologies, Latvia

Secretariat Members

Dr.agr. Liena Poiša, Rezekne Academy of Technologies, Latvia

MA.sc.comp. Gundega Teilāne, Rezekne Academy of Technologies, Latvia



**INFORMATION
TECHNOLOGIES**

SATURS CONTENTS

Information Technologies

Aigars Andersons, Rafail Prodani, Jozef Bushati, Gjulio Zefi PHYSICAL ACTIVITY RECOVERY MODEL IN POST COVID-19 PERIOD: LATVIA CASE STUDY	17
Miglēna Angelova PROS AND CONS OF USING ALGORITHMIC MANAGEMENT IN HUMAN RESOURCE	22
Ilmars Apeinans, Marks Sondors, Lienīte Litavniece, Sergejs Kodors, Imants Zarembo, Daina Feldmane CHERRY FRUITLET DETECTION USING YOLOV5 OR YOLOV8?	29
Ilmars Apeinans, Valdis Tārauds, Lienīte Litavniece, Sergejs Kodors, Imants Zarembo ANT DETECTION USING YOLOV8: EVALUATION OF DATASET TRANSFER IMPACT	34
Ilmars Apeināns OPTIMAL SIZE OF AGRICULTURAL DATASET FOR YOLOV8 TRAINING	38
Milka Asenova INCOLAB INFORMATION SYSTEM FOR BETTER MANAGEMENT OF ECOSYSTEMS IN THE TRANSBOUNDARY REGION OF THE DANUBE RIVER	43
Fayzi Bekkamov, Yashin Sharifov EXTENDED USER PROFILING APPROACHES FOR RECOMMENDATION SYSTEMS	49
Angela Rumenova Borisova NETWORK ATTACK RECOGNITION USING FUZZY LOGIC	55
Galina Chipriyanova, Mihail Chipriyanov, Kiril Luchkov INVESTIGATION AND ANALYSIS OF ATTITUDES TOWARDS THE IMPLEMENTATION OF ARTIFICIAL INTELLIGENCE IN INTERNAL BUSINESS PROCESSES	61
Akvelina Čuladytė, Aleksandra Batuchina ANALYSIS OF VIRTUAL TOURISM OPPORTUNITIES IN KLAIPĖDA, LITHUANIA	68
Maryna Davydiuk, Oksana Fushtei, Anna Khilya, Irina Sarancha THE IMPACT OF ONLINE SOCIAL COMMUNICATION ON THE TRAINING OF SOCIAL WORKERS AND EDUCATORS (UKRAINIAN UNIVERSITIES)	74
Dimitar Dimitrov, Ivan Manchev METHODOLOGICAL AND TECHNICAL ASPECTS OF MODELS FOR DIGITAL MANAGEMENT OF TRANSPORT SYSTEMS	79
Dimitar Dimitrov, Krassimir Lalov INTELLIGENT RAIL TRANSPORT MANAGEMENT SYSTEMS - METHODOLOGICAL ESSENCE, GOALS AND TASKS	83

Dimitar Dimitrov DIGITIZATION AND INTELLIGENT MANAGEMENT SYSTEMS IN TRANSPORT: AN OVERVIEW OF PROBLEMS AND SOLUTIONS	89
Elina Elere, Andra Ulme, Lucio De Paolis ARTIFICIAL INTELLIGENCE IN ARCHITECTURE AND ART EDUCATION	97
Matīss Eriņš, Zigurds Markovičs CALCULATION OF HUMAN FATIGUE IN THE ENVIRONMENT OF LINGUISTIC VARIABLES	104
Ivan Gaidarski, Neda Chehlarova MANAGEMENT APPROACHES AND APPLICATION AREAS OF INFORMATION SECURITY IN ORGANIZATIONS	110
Peter Grabusts, Oļegs Uzhga-Rebrov, Lasma Prizevoite, Inta Kotane DECISION TREE METHODS IN GRAIN YIELD FORECASTING	114
Ekaterina Hristova, Daniel Denev, Tsvetoslav Tsankov A SURVEY OF DATA QUALITY IN INDUSTRIAL NETWORKS AND ENHANCING THEIR RELIABILITY COMPLEX INDICATOR FOR THE NEEDS OF THE INDUSTRY	120
Rosen Iliev, Miroslav Kochankov A GENERALIZED NET MODEL OF COMMAND AND CONTROL SYSTEM	127
Anatolii Yarovy, Andrii Yarovy, Svitlana Kizim, Volodymyr Ozeranskyi INNOVATIVE TRENDS IN THE FIELD OF MODERN ARTIFICIAL INTELLIGENCE METHODOLOGY	132
Radoslav Yoshinov, Monka Kotseva, Anastas Madzharov, Neda Chehlarova SKILLS AND ATTITUDES TOWARDS USING AI BASED CHATBOTS	138
Ilmārs Kangro, Harijs Kalis ON SPECIAL FINITE DIFFERENCE APPROXIMATIONS FOR SOLVING SECOND ORDER DIFFERENTIAL EQUATIONS	143
Komil Kerimov, Zarina Azizova, Fayzi Bekkamov, Mekhriddin Rakhimov, Mannon Ochilov ENSURING INFORMATION SECURITY IN THE INTELLIGENT SCIENTIFIC AND TECHNICAL INFORMATION SYSTEMS	150
Komil Kerimov, Zarina Azizova METHODOLOGY OF INFORMATION SECURITY RISK ASSESSMENT OF ELECTRONIC RESOURCES UNDER UNAUTHORIZED ACCESS THREATS	155
Vitalii Kyslitsyn, Liudmyla Shevchenko, Volodymyr Umanets, Lina Sikoraka, Yaroslav Angelov APPLYING THE PYTHON PROGRAMMING LANGUAGE AND ARDUINO ROBOTICS KITS IN THE PROCESS OF TRAINING FUTURE TEACHERS OF COMPUTER SCIENCE	162
Evija Klave, Renāte Cane DIGITAL TRANSFORMATION OF HIGHER EDUCATION: INTEGRATING MULTIMEDIA SYSTEMS INTO THE STUDY PROCESS	168

Miroslav Kochankov, Rosen Iliev A GENERALIZED NET MODEL FOR ACCESSING INFORMATION RESOURCES IN A SECURE ENVIRONMENT	175
Sergejs Kodors, Guna Kanepe, Daniēls Zeps, Imants Zarembo, Lienīte Litavniece RAPID DEVELOPMENT OF CHATBOT FOR TOURISM PROMOTION IN LATGALE	179
Tetiana Koval, Nataliia Oliinyk, Tetiana Kryvosheya, Anna Khilya APPLICATION OF GAMIFICATION IN HIGHER EDUCATION: TRAINING OF EARLY CHILDHOOD AND PRIMARY EDUCATION TEACHERS IN UKRAINE	183
Inga Kudeikina, Sandra Kaija LIMITS OF THE USE OF ARTIFICIAL INTELLIGENCE IN LAW – ETHICAL AND LEGAL ASPECTS	188
Milena Kuleva, Ognyan Miladinov EXPLORING THE EFFICACY OF ONLINE PROCTORING IN ONLINE EXAMINATIONS: A COMPREHENSIVE REVIEW	192
Milena Kuleva EXPLORING THE INTEGRATION OF VIRTUAL REALITY IN PHYSICAL EDUCATION: A COMPREHENSIVE REVIEW	197
Dmytro Mamchur, Janis Peksa AN IMPLEMENTATION OF BRAIN-COMPUTER INTERFACE IN RESEARCH ACTIVITIES	202
Daniela Mirtcheva-Ivanova APPLICATION OF ARTIFICIAL INTELLIGENCE IN E-LEARNING	208
Mukhammadjon Musaev, Marat Rakhmatullaev, Sherbek Normatov, Kamoliddin Shukurov, Malika Abdullaeva INTEGRATED INTELLIGENT SYSTEM FOR SCIENTIFIC AND EDUCATIONAL INFORMATION RETRIEVAL	212
Borislav Nikolov APPROACH TO DEVELOPING A MARITIME CYBERSECURITY VIRTUAL TRAINING ENVIRONMENT	220
Oļegs Nikadimovs, Velga Vēvere THE USE OF GENERATIVE ARTIFICIAL INTELLIGENCE IN HIGHER EDUCATION: UNIVERSITY SOCIAL RESPONSIBILITY AND STAKEHOLDERS' PERCEPTIONS	226
Stanimir Parvanov RESEARCH OF DIFFERENT TURBO CODE SPEEDS, TYPES OF MODULATIONS, DECODING METHODS AND THEIR COMPATIBILITY WITH ENCRYPTION TECHNIQUES	232
Pavel Petrov, Vassil Milev ANALYSIS AND APPLICATION OF CRM SYSTEMS IN THE FIELD OF EDUCATION	237
Irena Petrova APPLIED METHODOLOGICAL ESSENCE OF PROJECT MANAGEMENT IN TRANSPORT THROUGH ARTIFICIAL INTELLIGENCE	242

Milen Simeonov, Marin Marinov DETERMINE THE LOCATION OF NODES IN WIRELESS SENSOR NETWORK BY USING GENETIC ALGORITHM	247
Svetlana Syarova, Stefka Toleva - Stoimenova, Alexander Kirkov, Samuel Petkov, Krasimir Traykov DATA LEAKAGE PREVENTION AND DETECTION IN DIGITAL CONFIGURATIONS: A SURVEY	253
Krasimir Slavyanov, Radostin Dimov APPLICATION OF FUZZY LOGIC IN CYBERSECURITY DECISION MAKING AND ANALYSIS AFTER A CYBER INCIDENT DETECTION	259
Krasimir Slavyanov FUZZY INFERENCE SYSTEM FOR INVESTMENT VALUE ASSESSMENT BASED ON HISTORICAL DATA	264
Krasimir Slavyanov ONE APPROACH FOR APPLICATION OF GEOGRAPHIC INFORMATION SYSTEMS AND FUZZY LOGIC IN BUSINESS DECISION-MAKING	268
Andrejs Snipkis, Guna Semjonova, Daina Smite USABILITY AND UTILITY OF THE SNIPTOUCH INNOVATIVE AGILITY TRAINING DEVICE PROTOTYPE IN PATIENTS WITH UPPER EXTREMITY IMPAIRMENTS AFTER STROKE: A MULTIPLE CASE STUDY	273
Diyora Talipova, Barno Ganiyeva, Sherbek Normatov, Marat Rakhmatullaev A METHOD FOR DETERMINING AND EVALUATING WEBOMETRIC INDICATORS OF PUBLIC LIBRARIES	281
Ivan Trenchev, Tereza Trencheva, Vladimir Angelov, Yordan Spirov, Yana Karshiyska, Kamelia Shumanova INTEGRATING MIXED REALITY WITH NEURAL NETWORKS FOR ADVANCED MOLECULAR VISUALIZATION IN BIOINFORMATICS: A MATHEMATICAL FRAMEWORK FOR DRUG DISCOVERY	286
Tsvetoslav Tsankov, Liliya Staneva, Ivelina Vardev, Dimitar Iliev APPLICATION OF A GENERALIZED NET MODEL IN THE COMMUNICATION OF TWO INDEPENDENT TRAFFIC IN FACULTY OF TECHNICAL SCIENCES AT KONSTANTIN PRES LAVSKI UNIVERSITY OF SHUMEN	293
Oļegs Uzhga-Rebrov, Peter Grabusts REVIEW OF METHODS FOR CLASSIFYING AND ASSESSING INFORMATION UNCERTAINTY	297
Velga Vevere, Kamaldeep Singh, Iveta Linina FRAMEWORK FOR ENHANCING CUSTOMER LOYALTY OF TELECOMMUNICATION COMPANIES IN INDIA: A CASE OF RELIANCE JIO INFOCOMM LTD	303
Olga Vindaca, Anda Abolina, Liga Danilane TRANSFORMING HIGHER EDUCATION IN THE ERA OF ARTIFICIAL INTELLIGENCE CHAT TOOLS: CASE STUDY	310

Roberts Volkovičs, Viesturs Bambāns, Ginta Majore ENVIRONMENTAL DATA AND DIGITAL TWINS FOR ROAD TRAFFIC SAFETY IN RURAL AREAS	317
--------------------------------------------------------------------------------------------------------------------------------------------	-----

Education in Engineering Sciences

Sergey Arakelov, Barno Ganieva INFORMATION AND LIBRARY EDUCATION IN THE CONTEXT OF DIGITALIZATION OF SOCIETY: PROMISING TRENDS AND REQUIREMENTS	325
Nataliia Aristova, Oleksandr Malykhin, Liudmyla Dybkova TRANSVERSAL SKILLS THAT MATTER TO COMPUTER ENGINEERING AND INFORMATION TECHNOLOGY UNDERGRADUATES AND STRATEGIES FOR THEIR DEVELOPMENT IN ENGLISH CLASSROOM	332
Olha Chaikovska, Olha Stoliarenko, Nataliia Hlushkovetska, Iryna Semenyshena ENHANCING STUDENTS' LISTENING COMPREHENSION SKILLS THROUGH AI- BASED PODCAST ACTIVITIES: A STUDY IN SELF-STUDY MODE	336
Franz Tito Coronel-Zubiate, Carlos Alberto Farje-Gallardo, Edward Enrique Rojas de la Puente ENVIRONMENTAL IMPACT OF WASTE IN DENTAL CARE: EDUCATIONAL STRATEGIES TO PROMOTE ENVIRONMENTAL SUSTAINABILITY	340
Gergana Dimcheva, Ivaylo Stoyanov MODERN PERSPECTIVES IN BULGARIAN ENGINEERING EDUCATION THROUGH THE PRISM OF EXPERTS FROM THE IT SECTOR (EMPIRICAL STUDY)	345
Vihra Dimitrova, Nikolay Nikolov, Todor Gospodinov EDUCATION IN THE ERA OF SMART CITIES: TRANSFORMATION AND OPPORTUNITIES	352
Natalia Dmitrenko, Iryna Shkola, Bohdana Saliuk, Violetta Panchenko, Svitlana Neshko CANVA PLATFORM: VISUAL CONTENT FOR DEVELOPING WRITING SKILLS OF PROSPECTIVE ENGINEERS IN ESP CLASSES	358
Georgi Dobrev, Nikolay Paunkov, Radoslava Terzieva, Misho Matsankov, Iva Naydenova, Dilyana Budakova ALGORITHM FOR DETERMINING PHOTORESIST CHARACTERISTICS	364
Mirosław Grewiński, Marek Kawa THE IMPACT OF TECHNOLOGY ON CHANGES IN LABOR MARKETS AND COMPETENCES	371
Svetlana Griбанова WHAT MOTIVATES THE CREATIVITY OF GENERATION Z EMPLOYEES? THE INFLUENCE OF EXTRINSIC AND INCRISTIC MOTIVATING FACTORS ON THE EXAMPLE OF IT SPECIALISTS FROM EU COUNTRIES	380
Bonka Karaivanova-Dolchinkova ANALYSIS OF GOOD PRACTICES IN STEM EDUCATION IN THE SCHOOLS OF THE VELIKO TARNOVO REGION IN THE SECOND YEAR OF THE NATIONAL PROGRAM	387

Bonka Encheva Karaivanova-Dolchinkova, Penka Kozhuharova MONITORING AND ANALYSIS OF THE ACHIEVED RESULTS OF USING THE STEM OFFICES IN VELIKO TARNOVO REGION AFTER THE LAUNCH OF THE NATIONAL PROGRAM	393
Vanya Katsarska SYNERGY OF COMPETENCES IN AERONAUTICAL ENGLISH EDUCATION	399
Anna Khilya, Halyna Kukharchuk, Yuliia Sabadosh, Alona Korol PRINCIPLES OF CREATING AND DESIGNING VIDEO CONTENT FOR ASYNCHRONOUS LEARNING	405
Anna Khilya, Olena Kolosova, Tatyana Kronivets, Iryna Sarancha FEATURES OF SYNCHRONOUS AND ASYNCHRONOUS E-LEARNING ON THE EXAMPLE OF TEACHING THE EUROPEAN EXPERIENCE OF SOCIAL INCLUSION	410
Eivind Laukhammer, Eugenijus Mačerauskas, Andzej Lučun, Antoni Kozič, Romanas Tumasonis APPLICATION OF AI-ENHANCED IMAGE PROCESSING METHODS FOR EDUCATIONAL APPLIED PHYSICS EXPERIMENTS	417
Oleksandr Malykhin, Nataliia Aristova, Liudmyla Dybkova TITLE ORGANISING PERSONALISED LEARNING IN THE ENGLISH LANGUAGE CLASSROOM: COMPUTER ENGINEERING AND INFORMATION TECHNOLOGY UNDERGRADUATES PERSPECTIVES	424
Oleksandr Malykhin, Nataliia Aristova, Maryna Vyshnevskaya, Kseniia Kugai, Inna Makhovych EXPLORING COMPUTER ENGINEERING AND INFORMATION TECHNOLOGY UNDERGRADUATES' VIEWS ON DEVELOPING THEIR INNOVATIVE THINKING IN ENGLISH CLASSROOM	428
Marin Jordanov Marinov SYNTHESIS OF EIGHT MIDDLE LOST MECHANISMS FINALLY DISCHARGED DISCREET POSITIONS	435
Marin Jordanov Marinov VECTOR-MATRIX COMPUTER METHOD FOR DRAFTING CIRCLING-POINT CURVES AND CENTERING-POINT CURVES OF BURMESTER	440
Jūlija Mironova, Viktoriia Riashchenko, Remigijus Kinderis, Valentina Djakona, Sevdalina Ilieva Dimitrova ETHICAL CONCERNS IN USING OF GENERATIVE TOOLS IN HIGHER EDUCATION: CROSS - COUNTRY STUDY	444
Daniela Mirtcheva-Ivanova APPLICATION OF ELECTRONIC PLATFORMS TO INCREASE THE KNOWLEDGE OF LEARNERS	448
Tatyana Odintsova ESG COMPETENCES AND SKILLS IN LIFELONG EDUCATION FOR SUSTAINABILITY	453

Nargiza Pazilova PROBLEMS AND SOLUTIONS TO IMPROVE THE EFFICIENCY OF USING ELECTRONIC INFORMATION RESOURCES AT UNIVERSITIES IN UZBEKISTAN	460
Todor Rachovski, Desislava Petrova, Ivan Ivanov AUTOMATED CREATION OF EDUCATIONAL QUESTIONS: ANALYSIS OF ARTIFICIAL INTELLIGENCE TECHNOLOGIES AND THEIR ROLE IN EDUCATION	465
Ausra Repeckiene, Renata Zvireliene, Karolina Janickiene DEVELOPING MANAGERS' INTERCULTURAL COMPETENCE IN SMALL MANUFACTURING ENTERPRISES	468
Nataliia Saienko, Olena Iliencko, Tetiana Solodovnyk, Anastasiia Ptushka, Zhanna Bogdan THE EXPERIENCE OF DEVELOPING SOCIAL RESPONSIBILITY IN THE NEXT GENERATION OF ENGINEERS AT UKRAINIAN UNIVERSITIES	474
Oleksandra Shykyrynska, Valentyna Liapunova, Olha Melnykova, Kateryna Mnyshenko, Tetiana Petryshyna READINESS OF THE FUTURE PRESCHOOL AND PRIMARY EDUCATION SPECIALISTS TO FORM THE FOUNDATIONS OF CHILDREN'S CYBER SECURITY	481
Iryna Shymkova, Svitlana Tsvilyk, Oksana Marushchak, Vitalii Hlukhaniuk, Volodymyr Harkushevskiy APPLICATION OF UPCYCLING TECHNOLOGY IN THE PROJECT ACTIVITY OF FUTURE TEACHERS OF LABOR EDUCATION AND TECHNOLOGY	485
Nataliia Sorokolit, Olha Rymar, Ivanna Bodnar, Olena Khanikiants, Alla Solovey MULTIMEDIA TECHNOLOGIES AS TOOLS FOR FOSTERING DIGITAL LITERACY IN EDUCATION	493
Eugenija Strazdiene, Aiste Laiskonyte THE APPLICATION OF PROCESS SIMULATION SOFTWARE FLEXXSIM IN TEXTILE STUDY PROGRAM	499
Tetiana Vasiutina, Liudmyla Ishchenko, Halyna Kit, Yulia Bondar, Anna Khilya ALGORITHM FOR IMPLEMENTING QUEST TECHNOLOGIES IN RESEARCH WORK WITH PRESCHOOL AND PRIMARY SCHOOL CHILDREN	503
Maya Vatzkitcheva, Plamen Savov ATMOSPHERE MONITORING SYSTEM FOR PRACTICAL TRAINING OF STUDENTS PURSUING DEGREES IN ENVIRONMENTAL SCIENCES	508
Vanda Vyshkivska, Yuliia Sylenko, Oksana Golikova, Tetiana Tsehelnik, Oksana Patlaichuk ANALYSIS OF THE EXPERIENCE AND PROSPECTS OF THE IMPLEMENTATION OF THE MOODLE PLATFORM FOR THE ORGANIZATION OF DISTANCE LEARNING IN UKRAINIAN UNIVERSITIES	512
Valentina Voinohovska, Julia Doncheva ENHANCING STUDENTS' CODING SKILLS WITH BLOOM'S TAXONOMY AND THE COMPETENCE APPROACH THROUGH EDUCATIONAL GAME DESIGN	519

Physical activity recovery model in post Covid-19 period: Latvia case study

Aigars Andersons

*Institute of Social, Economic and
Humanities Research (HESPI)
Vidzeme University of Applied
Sciences
Valmiera Latvia
aigars.andersons@va.lv*

Rafail Prodani

*Faculty of Natural and Human
Sciences, Department of Informatics
University "Fan S. Noli"
Korce, Albania
rprodani@yahoo.com*

Jozef Bushati

*Faculty of Education
University of Shkoder "Luigj
Gurakuqi"
Shkoder, Albania
gjulio.zefi@unishk.edu.al*

Gjudio Zefi

*Faculty of Education, Department of
Physical Education and Sports
University of Shkoder "Luigj
Gurakuqi"
Shkoder, Albania
gjulio.zefi@unishk.edu.al*

Abstract. Physical activity is one of the triggers to sustainable economic and social development of societies. The Political Declaration of the 2030 Agenda reflects on “the contribution sports make to the empowerment of women and of young people, individuals and communities, as well as to health, education and social inclusion objectives” [1]. COVID-19 restrictions forced the industry to find new ways to organize interregional and international events and find the ways out of the sudden crisis [2]. In this paper, authors focus on analysis of physical activity and sports recovery process after COVID-19 pandemic that has created profound challenges for youngsters and their family members. This research relies on empirical data collected from main orienteering sports events in Latvia and demonstrates original forecast model that compliments existing system dynamic simulation models affected by COVID-19 situation with respect to increased level of digitalization and extensive use of technologies. Research outcomes demonstrate that the cancellation of sports activities negatively affects such social aspects as people mobility, social cohesion, emotional satisfaction and excitement. As follows, it leads to lower physical and mental activity for individuals, especially children and youth. At the same time, the research outcomes of authors’ developed system dynamics simulation model shows that a recovery process of analysed physical activity and sports events is reasonably fast and, in the most cases, in two years reached a level of pre-COVID-19 period with tendency to positive growth in future. Created original system dynamic simulation model embraces full data sets of ten years (2014-2023), extracted from orienteering sports events published data in Latvia, as well as outcomes of several practical testing and theoretical research activities in Latvia and Albania. For collection and systemization of empirical data, authors used the concept of “Citizen

Science”. The Citizen Science is an ever-growing field of public engagement with science, and recent years have seen an increasing number of studies examining its potential [3]. The conclusions, made by authors of this research, are useful for various sports and active lifestyle events’ organizers, supporters, spectators and others, involved in the organization process of physical activity and sports events to attract more participants, spectators and tourists to their areas.

Keywords: *post COVID-19, socio-technical modelling, sports, system dynamic.*

I. INTRODUCTION

COVID-19 has caused multiple, unforeseen, and cascading impacts that have severely affected societies worldwide. Addressing these impacts in the aftermath of such a complex crisis requires collaborative approaches where the whole-of-society works together to build and strengthen its resilience [4]. Consequently, it is important to forecast the impact of COVID-19 pandemic on the sports events management and tourism industries to determine effectiveness of government policies in supporting the post-recovery process of these industries. From a business perspective, a good understanding of the effects of the pandemic is likely to provide the actors of the tourism industry substantial insights on how to build and implement effective decision-making frameworks that can, in turn, ensure rapid responses to unanticipated events that threaten the financial sustainability of their businesses [5],[6],[7]. Although the COVID-19 pandemic forced the various event organizers to adopt their events to virtual and

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8061>

© 2024 Aigars Andersons, Rafail Prodani, Jozef Bushati, Gjudio Zefi. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

hybrid formats, the concept of virtual or hybrid events is not applicable to outdoor physical activity and sports events where physical presence and active participation are mandatory elements [8].

The objective of this research is to determine an impact of COVID-19 pandemic and evaluate the recovery process of observed physical activity and sports events in Latvia. Authors are trying to find an answer to the specific research question: “What are the major trends of recovery process from COVID-19 pandemic impact for the societies, concerning specific physical activity and sports events in Latvia?”

II. MATERIALS AND METHODS

For mentioned above research purpose had been designed comprehensive logical structure to identify and analyse main factors of the physical activity recovery process on the post COVID-19 period in Latvia. An integrated set of methods and data management activities carried out by the authors of this research:

a) Theoretical literature studies on the contribution what physical training and sports make to the enhancing social inclusion objectives for individuals and communities.

b) Analysis of eight major orienteering sports events case studies with purpose to understand how physical activity and sports recovery process has been emerged before/during/after COVID-19 pandemic based on the available data sets collected by event organizers and published on: <https://lof.lv/rezultati> [10].

c) Authors collected available data sets by exploiting “Citizen Science” concept and published single data set for the period of the last 10 years (2014-2023) for seven major events and eight years for one event, all including three years period affected by COVID-19 pandemic.

d) For analysed events, authors calculated “trend-lines” and derived formulas for later use in STELLA system dynamic modelling tool as differential equations to simulate the recovery process from COVID-19 pandemic period and further development forecasting.

e) From complete data set, authors identified and adjusted three specific cases in Year 2020 when events had been postponed from regular spring activity period to the summer period with less or no-existent restrictions imposed by COVID-19.

f) From complete data set, authors adjusted two special cases in Year 2021 when events had been organised in special “COVID-19” mode with respect to all specific restrictions imposed by COVID-19 procedures in Latvia.

g) For model verification and validation purposes a cumulative trend-line had been calculated statistically from 72 events in total (6 events excluded because of COVID-19 restrictions) during the last 10 years period from year 2014 until year 2023.

h) Finally, based on collected data sets and statistically calculated polynomial trend-lines of individual events by use of specific differential equations authors created the original system dynamic simulation model in STELLA modelling environment. The purpose of model is to forecast the velocity of recovery process for physical activity and sports events in Latvia after restrictions imposed by COVID-19 pandemic.

In this research to determine the most appropriate modelling differential equations and calculated values used for converters, instead of traditional linear trend-line statistical function had been used polynomial trend-line statistical function which provides more reliable results in case of datasets where some data is missing, equal to zero or fluctuating over the time. Polynomial trend line describes a regression through equation $y = \sum_i (a_i \cdot x^i)$, with degree of polynomial is given as 2. All statistically calculated formulas of trend-lines further in this article displayed above graphs in the figures of the next chapters.

III. RESULTS AND DISCUSSION

Reliable data sets from eight major Latvian orienteering sports events had been analysed during this research by exploiting “Citizen Science” concept using data collected and calculated electronically by Latvian orienteering sports clubs within period from year 2014 until year 2023.

All available data from events authors collected in the single data set (Table 1) for the period of the last 10 years for seven major events and eight years for one event (it starts in year 2016), all data sets include full three years period from 2020 until year 2022, affected by COVID-19 pandemic.

TABLE 1 TOTAL NUMBER OF PARTICIPANTS (ALL EVENTS)

EVENT TITLE	YEAR 2014	YEAR 2015	YEAR 2016	YEAR 2017	YEAR 2018	YEAR 2019	YEAR 2020	YEAR 2021	YEAR 2022	YEAR 2023
Mazā Balva	347	441	348	347	273	512	398	489	495	549
Ozona (Rīgas) čempionāts	452	384	445	432	372	522	0	486	461	540
Aronas kauss	337	360	343	442	291	399	555	500	561	482
Ziemeļu divdienas	520	508	501	518	434	439	575	407	548	650
Kurzemes pavasaris	669	630	808	738	708	728	0	296	838	900
LČ garajā distancē	441	529	495	539	528	583	665	517	525	489
Latvijas Skolu kauss	N/A	N/A	642	268	668	666	0	331	562	501
Rīgas kauss	910	785	746	633	805	868	0	0	0	599
IN TOTAL	3676	3637	4328	3917	4079	4717	2133	3026	3990	4710
AVERAGE PER EVENT	525	520	541	490	510	674	533	432	570	589
<i>Special notes:</i>	3 events original data (change) 2 events in limited "covid" mode									

The total number of participants in all eight events in year 2019 grows up until 4717 people and after have significant decrease in the first year of Covid-19 pandemic until 2133 participants. Data shows also quick adaptation of organizers to the specific situation and number of participants steadily grow up during the next three years and in year 2023 almost are levelling the situation before Covid-19 pandemic (Fig.1).

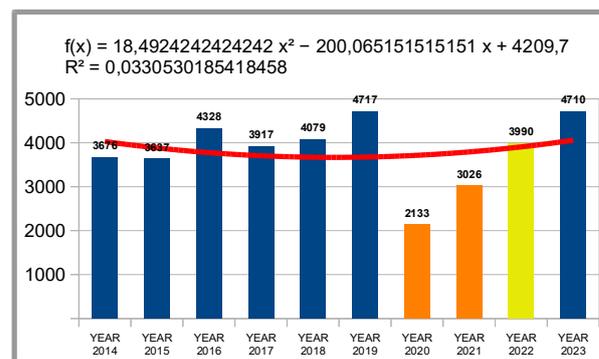


Fig. 1. Total number of participants in all events

Cumulative data set and pre-calculated polynomial trend-line formula attributes in this research authors' use further for the verification and validation stages of the activity forecast model.

Trend-line calculation formulas and mathematical values for use as STELLA convertors and differential equations authors' calculated separately for each event. Fig. 2 reveals that "Mazā Balva" event did not have significant loss in number of participants, mostly because of activity in summer time with less Covid-19 pandemic restrictions.

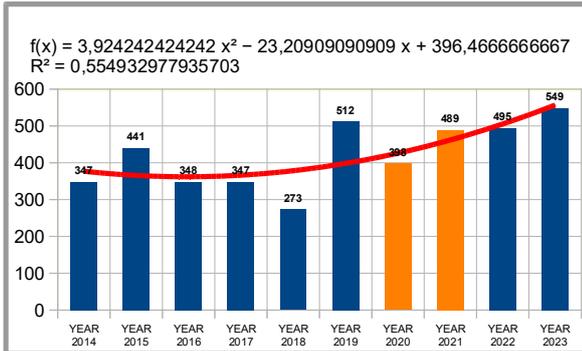


Fig. 2. Number of participants in "Mazā balva" event.

Covid-19 restrictions critically influenced "Ozona (Rīgas) čempionāts" event (Fig. 3) in year 2020 and organizer decided to cancel this event completely. Change of activity time from spring to summer in 2021 had positive effect with almost no impact from Covid-19 restrictions.

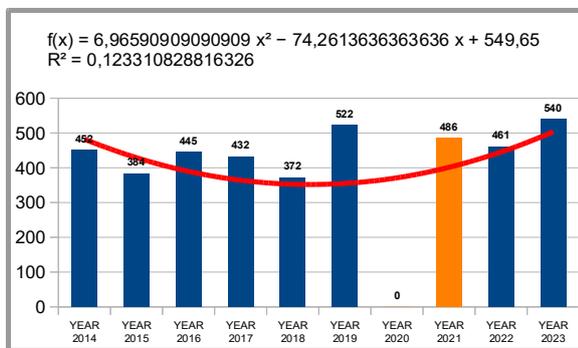


Fig. 3. Number of participants in "Ozona (Rīgas) čempionāts" event.

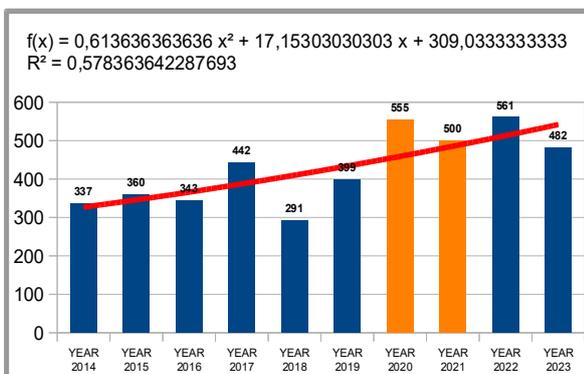


Fig. 4. Number of participants in "Aronas kausis" event.

"Aronas kausis" event (Fig. 4) did not suffer significantly from Covid-19 restrictions because postponed this event and organized it later in autumn when the most of restrictions imposed by Covid-19 had been cancelled.

Organized as traditional late springtime event "Ziemeļu divdienas" (Fig. 5) some problems experienced in year 2021, with decrease in number of participants approximately 20% but successfully recovered during the next year and continue growing.

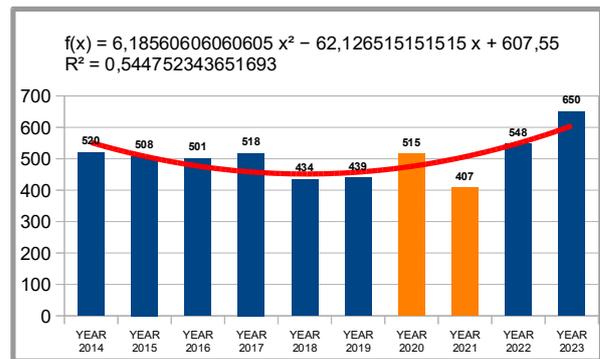


Fig. 5. Number of participants in "Ziemeļu divdienas" event.

As a season opening event in the first days of April, significant impact had "Kurzemes pavasaris" orienteering event (Fig. 6) in year 2020 when it was cancelled completely as well as in year 2021 when it had been organized in a very limited "protective distancing" mode. However, in years 2022 and 2023 this event recovered in full extent with figures even higher than in pre-Covid-19 period.

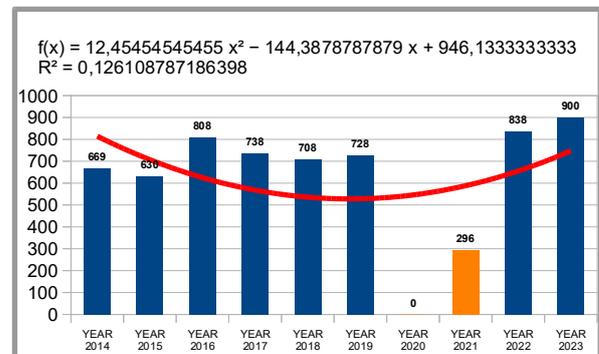


Fig. 6. Number of participants in "Kurzemes pavasaris" event.

Different trends display events "LČ garajā distancē" (Fig. 7) organized in late autumn period, with almost no impact during pandemic but with slower velocity of recovery in years 2022 and 2023 when the most of pandemic restrictions was non-existent.

Orienteering event "Latvijas Skolu kausis" (Fig. 8) shows trend similar to "Kurzemes pavasaris" event. Both events planned their activities in April with significant reductions in year 2020 and 2021. In year, 2020 organizers cancelled this event, but in year 2021 they got just half from number of participants than before Covid-19 limitations. The heaviest impact from Covid-19 restrictions met event "Rīgas kausis" (Fig. 9). Because of competition area

locations close to the capital Riga it was forbidden to organize in spring bigger scale events for three years period from 2020 till 2022.

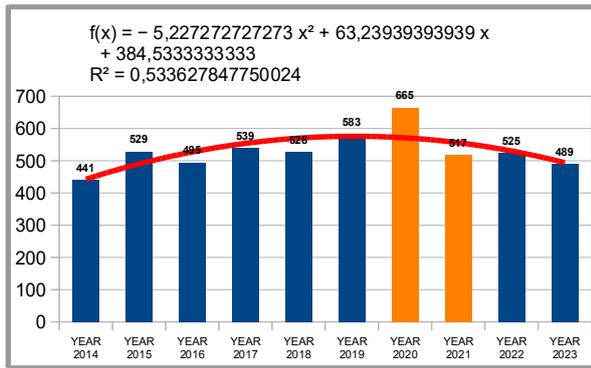


Fig. 7. Number of participants in "LC garajā distancē" event.

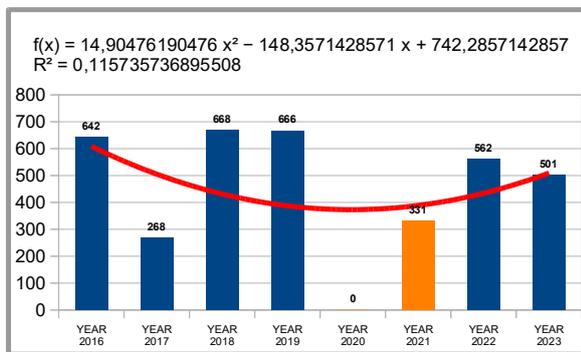


Fig. 8. Number of participants in "Latvijas skolu kausis" event.

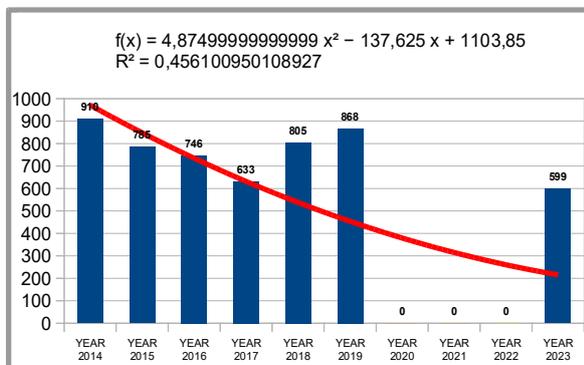


Fig. 9. Number of participants in "Rīgas kausis" event.

All statistical trend-line functions and calculation formulas authors used in the next modelling step to create the final cumulative system dynamic simulation model in STELLA modelling environment (Fig. 10).

Latvian physical activity events recovery model outcome (as a cumulative recovery forecast line) after Covid-19 limitations period shows a positive development trend and, as expected, during the next two years it will exceed the level of pre-Covid period by total number of participants in Latvia organized physical activity events.

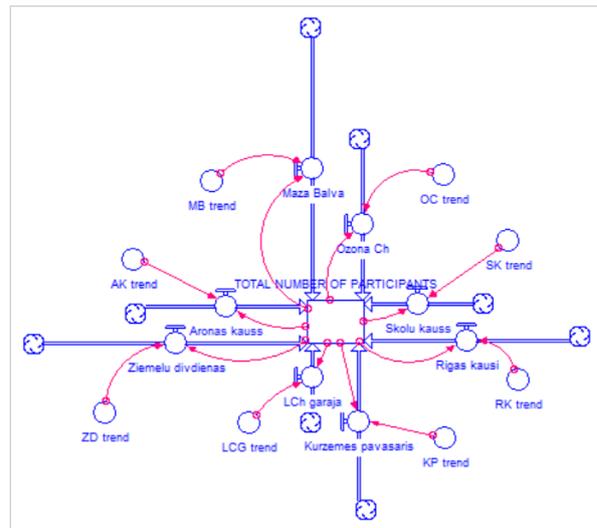


Fig. 10. Cumulative forecast simulation model in STELLA.

IV. CONCLUSIONS

Limitations and prohibitions imposed during the COVID-19 pandemic had negative impact to the most of outdoor sports and physical activities as in lower quality of events as well as in decreased number of participants and athlete performance aspects [11],[12].

The system dynamic simulation model in STELLA shows that physical activity and sports events in Latvia have started showing the significant positive trends of recovery after three years of the COVID-19 pandemic and have stable growing tendency in total number of attracted participants of organized events (Fig. 11).

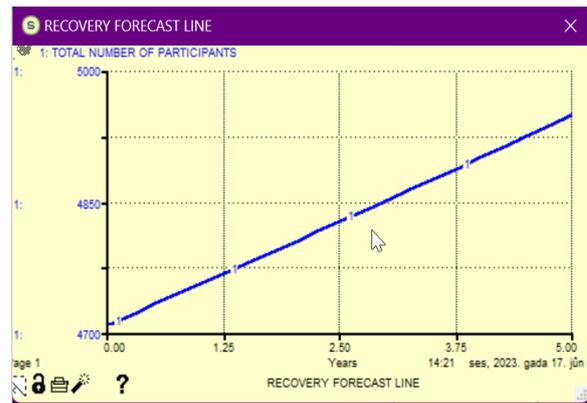


Fig. 11. Cumulative forecast trend-line (predicted total number of participants from 2023 until 2028) in STELLA.

The result of created STELLA model proves the validity of authors' originally created system dynamic simulation model, the cumulative statistical trend-line from analysed events has similar tendency as STELLA produced forecast line concerning predicted number of participants in physical activity and sports events for the next five years.

REFERENCES

- [1] World Health Organization, "Shanghai declaration on promoting health in the 2030," Agenda for Sustainable Development (No. WHO/NMH/PND/17.8). World Health Organization, 2017.
- [2] G. Bukovska, A. Mezgaile, and A. Klepers, "The Pressure of Technological Innovations in Meeting and Event Industry under the Covid-19 Influence", ETR, vol. 2, pp. 44–50, Jun. 2021, doi: 10.17770/etr2021vol2.6623.
- [3] L. Finger, V. Van den Bogaert, L. Schmidt, J. Fleischer, M. Stadtler, K. Sommer and J. Wirth. "The Science of Citizen Science: a Systematic Literature Review on Educational and Scientific Outcomes", *Frontiers in Education*, 2023, doi:10.3389/educ.2023.1226529.
- [4] The Manchester Briefing on COVID-19: international lessons for local and national government recovery and renewal, Issue 44 (2021), Understanding 'whole-of-society' resilience. Available at: <https://www.alliancembs.manchester.ac.uk/research/recovery-renewal-resilience-from-covid-19/briefings/> [Accessed: Jan. 17, 2024].
- [5] A. Fotiadis, S. Polyzos, T. C. Huan, "The Good, the Bad and the Ugly on COVID-19 Tourism Recovery", *Annals of Tourism Research*, Volume 87, 2021, 103117, ISSN 0160-7383, doi:10.1016/j.annals.2020.103117.
- [6] P. Sajjad and M. Perić. "The future of sports tourism in the light of the COVID-19 pandemic – Developing a new paradigm model." *Journal of Tourism Futures*, 2023, doi:10.1108/jtf-09-2022-0236
- [7] T. Daniels and T. M. Tichaawa. "Rethinking Sport Tourism Events in a Post-Covid-19 South Africa." *African Journal of Hospitality, Tourism and Leisure*, 2021, doi:10.46222/ajhtl.19770720-160.
- [8] A. Andersons, S. Ritter, R. Prodani, and J. Bushati, "Enhanced Participants' Registration Model on Open Public Events", ETR, vol. 2, pp. 13–20, Jun. 2021, doi: 10.17770/etr2021vol2.6587.
- [9] [11] X. Y. Tang, C. X. Wang, X. N. Pu and J. W. Feng, "Orienteering Timing System Based on Sub-G Band Wireless Sensor Network", In 2019 IEEE 3rd International Conference on Circuits, Systems and Systems and Devices (ICCS) (pp. 124-131). IEEE, Aug., 2019, doi: 10.1109/ICCS.2019.8843156
- [10] Latvian Orienteering federation, "Online database of event statistics", Available at: <https://lof.lv/rezultati> [Accessed: Dec. 11, 2023].
- [11] M. Scerri, V. Grech, Discussion: COVID-19's impact on sports and athletes. *Ger J Exerc Sport Res* 51, pp. 390–393, 2021, doi: 10.1007/s12662-021-00726-6.
- [12] G. Raiola and F. Di Domenico, "Physical and sports activity during the COVID-19 pandemic", *Journal of Physical Education and Sport*, 21, pp. 477–482, 2021, doi:10.7752/jpes.2021.s1049

Pros and Cons of using Algorithmic Management in Human Resource

Miglena Angelova

Management Department

University of National and World Economy

Sofia, Bulgaria

m.angelova@unwe.bg

Abstract. The opportunities that Artificial Intelligence and the principles of Algorithmic management provide to modern managers bring undeniable advantages for the development of a competitive business in today's extremely difficult business environment. At the same time, however, the effect of their use should be carefully analysed from the point of view of the compliance of the employees opinion in the enterprise - mainly in line with the observance and guarantee of basic rights of the employees. In this regard, the European Parliament and the European Council launched a legislative initiative to define harmonized rules within the Community on the use of artificial intelligence. Concepts such as "algorithmic discrimination" were introduced quite purposefully at the regulation level, given the risk of possible abuses associated with the use of AI. This report aims to ascertain the views of employers and employees on the use of artificial intelligence in Human Resource Management. The report presents and analyses data from an empirical study conducted among managers and employees in leading ICT enterprises in Bulgaria. According to our responders, one of the biggest advantages of using AI in Human Resources Management is related to the elimination of subjectivity in performance evaluation and the possibility of fair play in the procedures of internal selection of employees. At the same time, employees with more experience (over 10 years) are more sceptical of the idea of their work performance being evaluated solely by AI, while younger workers show more trust in AI solutions. However, both managers and workers recognize that it is best for the final decision in determining career development to be made by a person, but justified by the analyses made by AI. The report draws conclusions and recommendations that can serve both researchers and business managers. Certainly, AI is yet to undergo a very large development and application, including in the Human Resource Management, but at the same time it should not be at the expense of affected rights.

Keywords: *Algorithmic management, Artificial Intelligence, Human Resource Management, ICT companies.*

I. INTRODUCTION

The opportunities that Artificial Intelligence (AI) and the principles of algorithmic management provide to modern managers bring undeniable advantages for the development of a competitive business in today's extremely difficult business environment. At the same time, however, the effect of their use should be carefully analysed from the point of view of the compliance of the employees' opinion in the enterprise - mainly in line with the observance and guarantee of basic rights of the employees. In this regard, the European Parliament and the European Council launched a legislative initiative to define harmonized rules within the Community on the use of artificial intelligence. Concepts such as "algorithmic discrimination" were introduced quite purposefully at the regulation level, given the risk of possible abuses associated with the use of AI. This report aims to ascertain the views of employers and employees on the use of artificial intelligence in Human Resource Management. The report presents and analyses data from an empirical study conducted among managers and employees in leading ICT enterprises in Bulgaria.

The empirical study and results, presented in this paper, are part of an overall project, financed by the University of National and World Economy, dedicated to the Developing Strategies for Digital Human Resource Management in Innovative Business Organizations. The idea of developing and focusing specific research especially for ICT companies as supportive results for the preparation of the biggest empirical research (covering different companies in all sectors of economy), came as a logical next step for the project activities and achieving project results.

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8031>

© 2024 Miglena Angelova. Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

II. MATERIALS AND METHODS

A. Literature review

Although the Algorithmic management (AM) has its origin back to the 20th century, it could be argued that it's a relatively new concept that has become a very important topic among both practitioners and scholars, respectively, due to the fast development of Artificial Intelligence (AI) and its implementation in various aspects of business activities. Yu Zhou, Lijun Wang, Wansi Chen [1] explore the potential negative effects using AM. They delve into the negative impacts of AI-enabled HRM by focusing on three key algorithmic features: comprehensiveness, instantaneity, and opacity. Langer and König [2] also warn that opacity is one of the biggest problems and at the same time – key characteristic of algorithm-based HRM. They proposed a specific strategy based on complex measures combining technical solutions, set of training and education and regulations in this field. For Ötting and Maier [3] the most important thing in decision making process is to guarantee the procedural justice, no matter who has made the decision – human or some kind of intelligence system. They admit that the type of agent responsible for decision does not moderate justice effects. Lukács and Váradi [4] explore the European framework in data protection and the AI based automated decision-making in the employment process. Authors claim that despite its limitations, the AI Act represents a significant step forward in establishing a framework for regulating AI and fostering the development of trustworthy AI systems. They also admit that this Act provides a foundation for shaping global norms and standards surrounding AI usage. By promoting AI systems that align, to some extent, with human values and interests, it aims to enhance accountability, transparency, and ethical considerations in AI deployment. In essence, the AI Act serves as a crucial starting point in addressing the complexities and challenges associated with AI governance, ultimately contributing to the advancement of responsible and beneficial AI technologies.

Manroop, Malik and Milner [5] pay attention on the ethic features of using big data in HRM, especially analyzing personal data for pure corporate purposes. Andrieux, Johnson, Sarabadani and Slyke [6] also explore the ethical aspects of generative AI in HRM and propose a set of recommendations for practitioners, where the continuous learning is a key understanding of the overall process of securing the ethic standards in generative AI based HRM. A comprehensive analyse on the use of generative AI in HRM is provided by Lukaszewski and Stone [7], also considering the ethical and moral principles of management. They admit that it is not necessary to have specific legislation in this field, but the organizations should act proactively and to develop and adopt special strategy and procedures securing their potential employees, present staff and the entire company in general.

When we consider the use of AI in HRM, one of the serious questions is the decision for career development (respectively decisions for promotion and punishments, including the most severe – for job termination). Interesting findings in this aspect are proposed by Bartosiak and Modlinski [8], Kong, Yin, Baruch and

Yuan [9]; Gryniewicz, Zygala and Pilch [10]; Dimcheva and Stoyanov [11].

The use of AI in strategic HRM and securing high quality standards is presented by Aguinis, Beltran and Cope [12]. They provide examples how generative AI could be used successfully as an assistant in different HRM procedures. Marler [13] studies the possibilities of using AI and algorithms to develop and apply a compensation strategy of a business company, recognizing that they could improve the ability of organization to attract, retain and motivate employees. Compensation is one of the six workable areas of using algorithms and AI in HRM, outlined by Parent-Rochelleau and Parker [14], the rest are the following: monitoring, goal settings, performance management, scheduling and job termination. Specifics of the minimum wage formation for long period in Bulgarian context is comprehensively analyzed by Mancheva and Stamatev [15]. ICT and more specifically AI and algorithms are profoundly studied by Anguelov [16], who admits that it is impossible to imagine today a competitive and progressive business company without using AI in HRM in its everyday routines, despite a lot of difficulties and new challenges. Interesting observations in terms of HRM digitization activities are presented by Mihova, Ivanova, Anguelov in [17].

In summary of the literature review it could be concluded that the discussion on the usage of algorithms and AI in HRM is a complex problem combining different aspects: from legislation ones through ethical and moral questions, to the securing sustainability and competitiveness of the company and level of employees' motivation and satisfaction.

B. Methodology of the research

The current research has for the main objective to understand the opinion of employees, employers and managers on the use of Algorithmic Management (AM) and Artificial Intelligence (AI) in Human Resource Management (HRM). We purposefully chose to study the specified target groups from the field of ICT companies operating in Bulgaria. The reasons for this choice are as follows: First, ICT is an extremely dynamic sector of the economy, which is characterized by a high level of innovation, which means that companies in this sector have to by default embrace new trends in order to survive in the competitive market. Second, given the high dynamics of work and the level of stress, the people working in these companies are mostly young and motivated (especially comparing to the staff in business organization from a traditional sector), ready to prove themselves, but also ready to accept changes. Thirdly, in Bulgaria in the field of ICT there is a wide variety of companies both in terms of their size (micro, small, medium and large), but also in terms of the way in which they are created - with Bulgarian financing, with a help of a foreign investor, a subsidiary of an international company, etc., which could give a valuable information on the practice. And finally: this choice is conditioned by the fact that the ICT sector in Bulgaria can be perceived as an indicator of the future development of the other, not so rich in innovation and change sectors of the economy.

In order to achieve the main objective of the study, I chose to conduct an empirical study using a specially designed questionnaire. The questionnaire consists of 14 questions, most of them are closed and only 2 are open. All closed-ended questions were mandatory for respondents to answer, while open-ended questions were left to the discretion of the respondents in case they had something to share. The predominant choice of closed questions is in line with the fact that the survey is distributed among actively working people in one of the most dynamic sectors of the economy, and in order to get more responses, the completion of the survey should not be time-consuming while not requiring to make unnecessary efforts on the part of the respondents. In order to protect personal data, sensitive information, such as names, social security numbers, etc., is not collected from respondents. The survey was distributed in an electronic environment among those working in leading ICT companies in Bulgaria, by sending a link from Google Forms. It was explicitly explained to everyone that the survey was anonymous and voluntary, and that the collected information would be used solely and exclusively for scientific purposes.

The research goes through the main three phases:

Preparatory Phase - held in November 2023. Activities carried out:

- Formulation of the questionnaire.
- Testing of the questionnaire, in order to establish the effectiveness of the choice of questions, their content, sequence, level of understanding by the respondents and comprehensiveness of the expected answers.
- After testing the questionnaire and making corrections for its improvement, its final version is reached, which allows the actual conduct of the research.

Main Phase - held in the period December 2023 – January 2024. Activities performed during the stage:

- Designing the questionnaire and preparing it to be completed by respondents in an online environment.
- Preliminary testing of the functionalities of the questionnaire, in order to limit gaps.
- Achieving questionnaire visibility across different devices used by respondents.
- Defining the number of companies and collecting e-mail addresses for potential responders
- Conducting various activities securing the spread of the information for the survey and questionnaire among working people in ICT sector: different special meetings with managers, phone calls etc.
- Distribution of the questionnaire in an online environment.
- Completion of the questionnaire by the respondents.

Final Phase: February 2024

- processing and analysis of the obtained results
- on the basis of the received data and their analysis - conclusions and recommendations made

III. RESULTS AND DISCUSSION

As a result of efforts to distribute the questionnaire to the widest possible range of ICT companies in Bulgaria, and given the time constraints, we received a total of 135 responses, of which 74 were from men and the remaining 61 were from women. The rest components from the responders' profile are presented on table 1.

TABLE 1 PROFILE OF THE RESPONDERS

Component	Possible options for answers	Number of answers received	Answers in %
Age	From 18 to 30	72	53
	From 31 to 40	52	39
	Over 50	11	8
Work position	Employee	79	59
	Manager	41	30
	Owner	15	11
Place of work	Sofia	83	61
	Big city	42	31
	Small town	10	7

As it can be seen from the Table 1, the major part of our responders (53%) are between 18 and 30 years old. This fact could be easily explained due to the traditional profile of employees in ICT company from one side, and from the other – young people usually are more willing to participate in such type of studies than their older colleagues. The group between 31 and 40 years old represent 39% of our responders. The rest people (8%) are over 50 years old. In terms of work position, it is not surprising the finding that 59% of responders are employees, another 41 people (or 30%) claim that are manager, which also could be analysed in the line that in our questionnaire we do not justify the different managers positions within one ICT company. Therefore, the achieved result on this question is understandable. The smallest group are people who admit that they are owners of the business. We attribute this relatively high response rate from people in such a position to the efforts we made to meet face-to-face with the top management of a number of companies. The majority of our responders work in Sofia (61%) which findings is relevant to the situation in Bulgaria from one side and for the efforts for personal meeting in the preparational phase of the study, from the other side. The cumulative profile of the company is presented on Table 2.

TABLE 2 PROFILE OF THE RESPONDERS' COMPANIES

Component	Possible options for answers	Number of answers received	Answers in %
Major financial resource of the company	Only Bulgarian	33	24
	Both Bulgarian and foreign	39	29
	Only Foreign investments	57	42
	I am not sure	6	4
Company Size	Micro	18	13
	Small	86	64
	Big	31	23
Location of the Headquarters of the company	In Bulgaria	38	28
	In another European country	65	48
	Outside Europe	32	24

For the purpose of the study it is interesting to understand where the main funding of the companies comes from. According to the received answers, the biggest group of the responders work in the company with only foreign investments (42%), while another 29% claim that the company they work for is financed both by Bulgarian and foreign resources. Only 24% of our responders work in company with only Bulgarian investments. A very small percentage of respondents (4%) are not sure about the basic funding of the company, which is also possible if we consider the newly appointed employees in the organizations with small experience.

The major part of responders admit that their organization is small (64%), followed by people working in big companies (23%) and finally – responders in micro companies are 13%. This result again is not surprising for the ICT sector, considering the fact that we have serious foreign investments and divisions of multinational ICT companies in Bulgaria. This observation is only deepened considering the response in the next question – for the headquarter of the company of our responders. Here the picture is even clearer – only 28% of the companies of our responders are in Bulgaria, versus 48% - from country in Europe (excluding Bulgaria) and another 24% who claim that the headquarter of their companies is outside Europe.

The next question explores the level of experience of our responders in the field of ICT. The answers are presented on fig. 1.

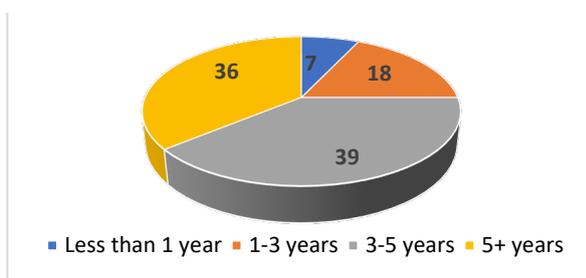


Fig. 1. Level of experience of the responders in the ICT field, in %

As it can be seen from the figure, the majority of responders is distributed among two almost equal groups - 39% of people claim that their experience is between 3-5 years, while 36% have 5+ years of experience in ICT. Only 7% of responders have less than 1 years in ICT. The

result of this question is not very difficult to understand, having in mind that serious companies in ICT have their own specific policy of attracting young people and usually have different programmes with universities for scholarship or other forms of partnership.

The next question is the following “How familiar are you with the concepts of algorithmic management and AI in Human Resource Management (HRM)?”. (fig. 2). Here in the two super opposite answers we have relatively modest accumulation of answers. Only 5 % admit that they are not familiar at all, while another 12% claim that extremely familiar. The majority of the responders again is allocated in two general, almost equal groups – 37% of our responders assured that they are very familiar with the concept and another 35% consider themselves as moderately familiar.

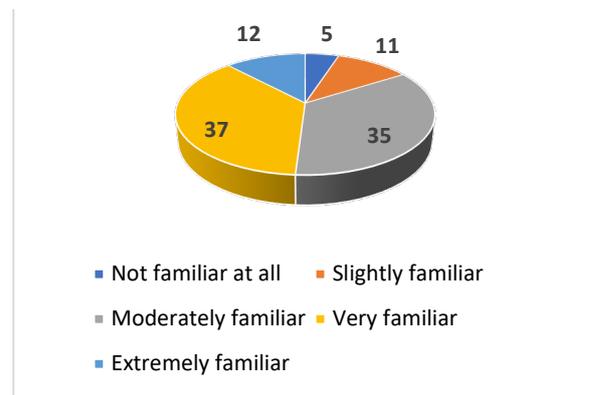


Fig. 2. Level of self-evaluation on the concept of AM and AI in HRM, in %

The next question assesses the personal opinion of responders in different predefined areas of advantages of using AI and AM in HRM. The question is “What, in your opinion, are the main advantages of using algorithmic management and AI in HRM in ICT companies?”. Responders have to select between 5 scale where 1 is the weakest rating and 5 is the strongest. Results are cumulative presented in fig. 3.

The next question is similar to the previous, but this time responders are asked to assess the disadvantages of the AM and AI in ICT, (using the same scale from 1 to 5 where 1 where 1 is the weakest rating and 5 is the strongest). Results are cumulative presented in fig. 4.

As it can be seen from the fig. 5, respondents are relatively reserved about the disadvantages of using AI and MA in HRM, especially comparing to the results, achieved in the previous question. Here the first three serious disadvantages, according to the results are the following: Privacy Concerns (regarding the collection and analysis of sensitive personal data for purposes such as performance evaluation, workforce planning, and talent management), with highest score of 4,6 (in maximum 5). The second disadvantage is defined the potential for Data Breaches and Security Risk, with score of 4,3. Storing and processing large volumes of employee data for algorithmic management and AI in HRM poses security risks such as data breaches, unauthorized access, and misuse of personal information, especially in ICT companies with valuable intellectual property and sensitive client information. On the third place comes the Loss of Human Judgment and Creativity with score of 3,

6. Over-reliance on algorithmic decision-making may diminish the role of human judgment, intuition, and creativity in HRM, potentially stifling innovation and problem-solving in ICT companies that thrive on ingenuity and out-of-the-box thinking. At the bottom of this ranking are Lack of Human Touch (with score of 1,7), Resistance to Change (1,3) and Loss of Organizational Engagement (1,1).

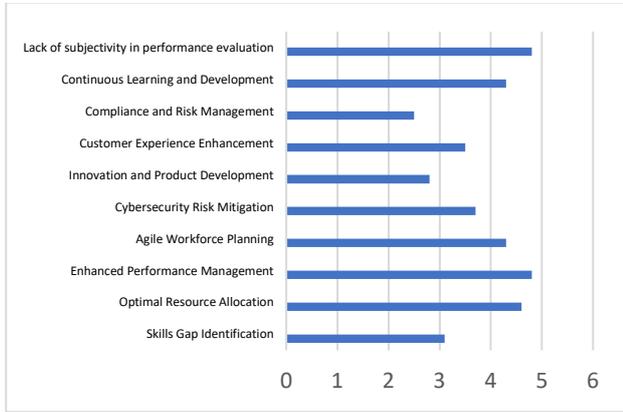


Fig. 3. Evaluation on the benefits of using AI and AM in HRM

The next question follows the same logic of the previous two, but this time the responders are asked to assess the interaction between AM and AI in the context of the employee-manager relationship. The question is “How do you evaluate the level of impact that AM and AI could have on the employee-manager relationship in ICT company?”. Responders use the same scale from 1 to 5, where 1 is the weakest impact rating and 5 is the strongest impact rating). Results are cumulative presented in fig. 5.

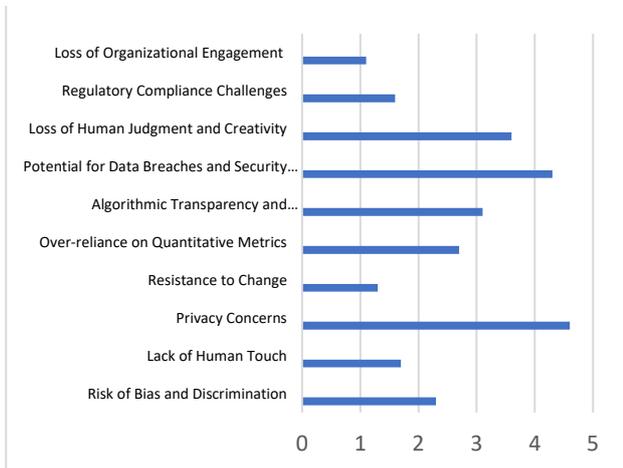


Fig. 4. Evaluation on the disadvantages of using AI and AM in HRM

The main three strongest impact, according to the obtained results are Efficient Project Management (with 4,7 score), alignment with Technical Goals and Objectives (4,5 score) and Enhanced Technical Support and Guidance (with 4,2). The weakest impact our responders defined for the Identification of skills gaps and Development needs.



Fig. 5. Interaction between AM and AI in the context of the employee-manager relationship

The last two questions are open in order to collect opinion for the two important field. The first one open question is the following: How do you perceive the role of human judgment and intervention in HR processes that utilize algorithmic management and AI?

According to our responders, one of the biggest advantages of using AI in Human Resources Management is related to the elimination of subjectivity in performance evaluation and the possibility of fair play in the procedures of internal selection of employees. At the same time, employees with more experience (over 10 years) are more sceptical of the idea of their work performance being evaluated solely by AI, while younger workers show more trust in AI solutions. However, both managers and workers recognize that it is best for the final decision in determining career development to be made by a person, but justified by the analyses made by AI. At the same time some people admit that human judgment is important including in terms of adaptation in rapid changing environments and addressing unforeseen situations.

The very last question of the questionnaire is “How do you envision the future of HRM in ICT companies with the increasing integration of algorithmic management and AI?”. Here the variation of answers was again in line further deepening the Human – AI/ AM collaboration, leveraging their strengths. Some of people truly believe that in near future the recruitment process will be fully automated, while others claim that Talent Management will be even more in focus. The central place of the answers remains the idea of the data-driven decision-making process.

IV. RECOMMENDATIONS

The results obtained from the empirical research on the use of Algorithmic Management and Artificial Intelligence for the purposes of Human Resource Management, conducted among ICT companies in Bulgaria, unequivocally show that employees, management and business owners positively define their need and implementation. At the same time, the respondents show a comparative understanding of the outlined disadvantages in the use of AM and AI, believing that with the development of technologies these shortcomings could be overcome. In this line, our recommendations could be summarized in the following several proposals:

Developing advanced predictive analytics for workforce planning in ICT companies

The development of advanced predictive analytics for workforce planning represents a strategic imperative for ICT companies seeking to thrive in an increasingly competitive and dynamic environment. By leveraging AI algorithms to predict future workforce trends, skills gaps, and talent needs, organizations can gain a significant competitive advantage by aligning their human capital strategies with business objectives and market demands. Through collaborative efforts, continuous learning, and ethical practices, the vision of proactive workforce planning and talent management can be realized, driving innovation, growth, and success in the ICT sector.

Dynamic skill matching for optimal resource allocation in ICT companies

The development of AI-powered platforms for dynamic skill matching represents a strategic opportunity for ICT companies to optimize resource allocation, enhance project outcomes, and foster employee growth and satisfaction. By leveraging real-time data and AI algorithms, organizations can ensure that the right talent is deployed for each task, maximizing efficiency and productivity. Through continuous learning, transparency, and a focus on fairness and privacy, the vision of dynamic skill matching can be realized, driving innovation, agility, and success in the ICT sector. AI-powered employee feedback systems: Develop AI-driven feedback systems that collect, analyze, and synthesize employee feedback from various sources, including performance reviews, surveys, and social media. This will provide valuable insights into employee sentiment and engagement, enabling HR teams to take proactive measures to address concerns and improve employee satisfaction.

Establishing ethical AI guidelines for HRM in ICT companies

Establishing ethical AI guidelines specific to HRM in ICT companies is essential to foster trust, fairness, and accountability in AI-driven HRM processes. By promoting transparency, mitigating bias, and upholding ethical principles, organizations can harness the transformative potential of AI while safeguarding against potential risks and ethical concerns. Through collaboration, education, and continuous improvement, the vision of responsible AI governance in HRM can be realized, driving positive outcomes for employees, candidates, and organizations alike within the ICT sector.

Implementing explainable AI for decision support in HRM

Implementing Explainable AI for Decision Support in HRM is crucial for enhancing transparency, trust, and accountability in algorithmic decision-making processes. By enabling stakeholders to understand how AI algorithms analyze data and generate recommendations, organizations can foster collaboration, informed decision-making, and ethical AI governance in HRM. Through continuous improvement, transparency, and collaboration, the vision of XAI-enabled HRM can be realized, driving positive outcomes for employees, managers, and organizations alike.

Developing collaborative human-AI workflows for HRM

Developing collaborative human-AI workflows represents a strategic opportunity for HRM to leverage the strengths of both humans and AI systems, driving efficiency, innovation, and value creation. By fostering a culture of collaboration, learning, and ethical AI governance, organizations can harness the full potential of AI while preserving human-centric values and ensuring that decision-making processes remain empathetic, ethical, and inclusive. Through continuous improvement, interdisciplinary collaboration, and human-centric design, the vision of collaborative human-AI workflows can be realized, driving positive outcomes for HR professionals, employees, and organizations in the digital age.

Implementing AI-driven talent acquisition strategies in ICT companies

Implementing AI-driven talent acquisition strategies represents a strategic initiative for ICT companies seeking to attract and retain top talent in a competitive market. By leveraging AI technologies to automate and optimize recruitment processes, organizations can improve efficiency, enhance candidate quality, and foster diversity and inclusion. Through ethical considerations, continuous learning, and data-driven decision-making, the vision of AI-driven talent acquisition can be realized, driving positive outcomes for HR professionals, candidates, and organizations in the ICT sector.

V. CONCLUSION

The ICT sector is one of the most dynamically developing, with fierce competition and a passion for future progress. People working in ICT companies are used to the dynamics of the external and internal environment and, therefore, are more inclined to embrace new technologies, innovations and trends. In this connection is the proposed study related to the possibilities of using Algorithmic Management and Artificial Intelligence for the purposes of Human Resource Management in ICT companies. Their experience could subsequently be used in the development of digitalization of HRM strategies for companies from other economic sectors.

Our proposals for the future development of AM and AI in HRM in ICT companies are the following: Developing advanced predictive analytics for workforce planning in ICT companies; Dynamic skill matching for optimal resource allocation in ICT companies; Establishing ethical AI guidelines for HRM in ICT companies; Implementing explainable AI for decision support in HRM; Developing collaborative human-AI workflows for HRM; Implementing AI-driven talent acquisition strategies in ICT companies.

ACKNOWLEDGMENT

The present paper is published with the financial support of the University of National and World Economy (Sofia, Bulgaria), under the Project N NID-NI-10/2023/A (Developing Strategies for Digital Human Resource Management in Innovative Business Organizations)

REFERENCES

- [1] Y. Zhou, L. Wang and W. Chen, The dark side of AI-enabled HRM on employees based on AI algorithmic features, *Journal of Organizational Change Management*, Volume 36, Issue 7, 2023, Pages 1222-1241, ISSN 0953-4814, <https://doi.org/10.1108/JOCM-10-2022-0308>.
- [2] M. Langer and C. J. König, Introducing a multi-stakeholder perspective on opacity, transparency and strategies to reduce opacity in algorithm-based human resource management, *Human Resource Management Review*, Volume 33, Issue 1, 2023, 100881, ISSN 1053-4822, <https://doi.org/10.1016/j.hrmr.2021.100881>.
- [3] S. K. Ötting and G. W. Maier, The importance of procedural justice in Human–Machine Interactions: Intelligent systems as new decision agents in organizations, *Computers in Human Behavior*, Volume 89, 2018, Pages 27-39, ISSN 0747-5632, <https://doi.org/10.1016/j.chb.2018.07.022>.
- [4] A. Lukács and S. Váradi, GDPR-compliant AI-based automated decision-making in the world of work, *Computer Law & Security Review*, Volume 50, 2023, 105848, ISSN 0267-3649, <https://doi.org/10.1016/j.clsr.2023.105848>.
- [5] L. Manroop, A. Malik and M. Milner, The ethical implications of big data in human resource management, *Human Resource Management Review*, 2024, 101012, ISSN 1053-4822, <https://doi.org/10.1016/j.hrmr.2024.101012>.
- [6] P. Andrieux, R. D. Johnson, J. Sarabadani, and C. V. Slyke, Ethical considerations of generative AI-enabled human resource management, *Organizational Dynamics*, 2024, 101032, ISSN 0090-2616, <https://doi.org/10.1016/j.orgdyn.2024.101032>.
- [7] K. M. Lukaszewski and D. L. Stone, Will the use of AI in human resources create a digital Frankenstein?, *Organizational Dynamics*, 2024, 101033, ISSN 0090-2616, <https://doi.org/10.1016/j.orgdyn.2024.101033>.
- [8] M. L. Bartosiak and A. Modlinski, Fired by an algorithm? Exploration of conformism with biased intelligent decision support systems in the context of workplace discipline, *Career Development International*, Volume 27, Issue 67, 2022, Pages 601-615, ISSN 1362-0436, <https://doi.org/10.1108/CDI-06-2022-0170>.
- [9] H. Kong, Z. Yin, Y. Baruch and Y. Yuan, The impact of trust in AI on career sustainability: The role of employee–AI collaboration and protean career orientation, *Journal of Vocational Behavior*, Volume 146, 2023, 103928, ISSN 0001-8791, <https://doi.org/10.1016/j.jvb.2023.103928>.
- [10] W. Gryncewicz, R. Zygala and A. Pilch, AI in HRM: case study analysis. Preliminary research, *Procedia Computer Science*, Volume 225, 2023, Pages 2351-2360, ISSN 1877-0509, <https://doi.org/10.1016/j.procs.2023.10.226>.
- [11] G. Dimcheva and I. Stoyanov, "Challenges to the Application and Decision-Making using Artificial Intelligence (AI): Analysis of the Attitudes of Managers in Bulgarian Service Companies," 2023 4th International Conference on Communications, Information, Electronic and Energy Systems (CIEES), Plovdiv, Bulgaria, 2023, pp. 1-5, doi: 10.1109/CIEES58940.2023.10378811.
- [12] H. Aguinis, J. R. Beltran and A. Cope, How to use generative AI as a human resource management assistant, *Organizational Dynamics*, 2024, 101029, ISSN 0090-2616, <https://doi.org/10.1016/j.orgdyn.2024.101029>.
- [13] J. H. Marler, Artificial intelligence, algorithms, and compensation strategy: Challenges and opportunities, *Organizational Dynamics*, 2024, 101039, ISSN 0090-2616, <https://doi.org/10.1016/j.orgdyn.2024.101039>.
- [14] X. Parent-Rochelleau and S. K. Parker, Algorithms as work designers: How algorithmic management influences the design of jobs, *Human Resource Management Review*, Volume 32, Issue 3, 2022, 100838, ISSN 1053-4822, <https://doi.org/10.1016/j.hrmr.2021.100838>.
- [15] M. Mancheva and S. Stamatov, Trends and Impacts of Minimum Wage in Bulgaria after 1999, *Ikonomiceski i Sotsialni Alternativi*, University of National and World Economy, Sofia, Bulgaria, issue 1, 2017. pages 28-45, February.
- [16] K. Anguelov, ICT as the New Age of Development of HR Management, *People Management - Highlighting Futures*, Intech Open, 2023, ISBN: 978-1-80355-043-5, 2022, DOI: 10.5772/intechopen.106929
- [17] T. Mihova, I. Ivanova and K. Anguelov, Impact of HRM activities digitisation on the competitiveness of industrial enterprises, *AIP Conference Proceedings* 2449, 070002 (2022); <https://doi.org/10.1063/5.0090974>, Published Online: 01 September 2022S.

Cherry Fruitlet Detection using YOLOv5 or YOLOv8?

Ilmārs Apeināns

Institute of Engineering
Rezekne Academy of Technologies
Rezekne, Latvia
ilmars.apeinans@rta.lv

Marks Sondors

Institute of Engineering
Rezekne Academy of Technologies
Rezekne, Latvia
ms20094@edu.rta.lv

Lienīte Litavniece

Research Institute for Business and
Social Processes
Rezekne Academy of Technologies
Rezekne, Latvia
lienite.litavniece@rta.lv

Sergejs Kodors

Institute of Engineering
Rezekne Academy of Technologies
Rezekne, Latvia
sergejs.kodors@rta.lv

Imants Zarembo

Institute of Engineering
Rezekne Academy of Technologies
Rezekne, Latvia
imants.zarembo@rta.lv

Daina Feldmane

Institute of Horticulture (LatHort)
Dobele, Latvia
daina.feldmane@llu.lv

Abstract. Agriculture 5.0 incorporates autonomous decision-making systems in order to make agriculture more productive. Our study is related to the development of the autonomous orchard monitoring system using unnamed aerial vehicles for automatic fruiting assessment and yield forecasting. Respectively, artificial intelligence must be developed to count fruits in an orchard. The modern solutions are mainly data-based. Therefore, we collected and annotated cherry dataset with natural images (CherryBBCH81) for neural network training. The goal of the experiment was to select the optimal "You Look Only Once" (YOLO) model for the rapid development of fruit detection. Our experiment showed that YOLOv5m provided better results for CherryBBCH81 – mean average precision (mAP) at 0.5 0.886 in comparison with YOLOv8m mAP@0.5 0.870. However, additional tests with dataset Pear640 showed that YOLOv8m can outperform YOLOv5m: 0.951 vs 0.943 (mAP@0.5).

Keywords: Agriculture 5.0, artificial intelligence, deep learning, yield estimation.

I. INTRODUCTION

Sweet cherries (*Prunus avium* L.) are among the top 5 most sought after fruits in the world. According to industry information, the demand for fresh cherries will grow by 7.5% in the period from 2022 to 2027, reaching 84.3 billion dollars [1].

Analogous to all industries, agriculture has also evolved over the centuries from Agriculture 1.0, where economic activity was based on the physical strength of people and animals, to Agriculture 5.0, where the essence of economic activity is characterized by smart and more energy-efficient management [2]. The European Commission set the year

2021 as the official start of the "Industry 5.0" era [3]. Agriculture 5.0 can also be called "digital agriculture", which aims to maximize yields and other agricultural results by applying the latest methods and tools. Agriculture 5.0 is characterized by: the efficiency of data collection, accuracy of data, and timeliness of data acquisition in order to make correct and data-based decisions. Data-driven decision-making is essential because as the planet's population grows, it is necessary to produce more food while respecting the principles of sustainability.

The aim of the project lzp-2021/1-0134 is to develop an autonomous decision making smart fruit growing solution for apple (*Malus × domestica* (L.) Borkh), pear (*Pyrus communis* L.) and sweet cherry (*Prunus avium* L.) orchard management that could provide an accessible and low cost smart horticulture solution for commercial orchard owners. The system is aimed to enable an automatic and autonomous orchard monitoring capabilities using unnamed aerial vehicles (UAV) and allow automatic flowering and fruiting assessment. The digital twin paradigm is applied to orchard management in combination with an UAV and artificial intellect (AI) solution [4]. UAV autonomously collects orchard data. Transmits it back to the base station, which, in turn, sends the data to the server where the AI solution performs yield estimation. Finally, orchard managers can interact with the yield forecast via a web interface on their computer and make decisions accordingly.

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8013>

© 2024 Ilmars Apeinans, Marks Sondors, Lienīte Litavniece, Sergejs Kodors, Imants Zarembo, Daina Feldmane.
Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

When it comes to implementation of a yield forecasting solution based on artificial intelligence in the autonomous orchard system, the yield forecasting is based on the yield estimation results. The orchard monitoring is completed by UAV, while the images are processed by object detection algorithms like “You Look Only Once” (YOLO) to estimate the visible amount of fruits. Meanwhile, the fruit load on trees is predicted by a post-processing algorithm using yield data from multiple images. For example, citrus yield prediction solution was presented, utilizing YOLO and four post-processing algorithms: the gradient boosting regression, random forest regression, linear regression and partial least squares regression; showing the following results, respectively: 41.12%, 41.47%, 35.59% and 35.84% mean average precision (mAP) [5]. Another example, the wild blueberry (*Vaccinium angustifolium* Ait.) yield prediction was implemented using YOLO and nonlinear regression model, which achieved a mean absolute error of 24.1% [6].

YOLOv8 was released in 2023. Despite the existence of studies on YOLOv8, e.g. [7] and [8], the number of experiments in smart agriculture remain limited at the moment. The publications mostly cover the problems of fruit and vegetable quality assessment and disease detection. For example, YOLOv8 was used to inspect the quality of tomatoes (*Lycopersicon esculentum* Mill.) [8]. The trained convolutional neural network (CNN) achieved mAP of up to 99.5%, with the precision of 96.3% and the recall of 96.1% [8]. Meanwhile, the authors of “Tomato Maturity Detection and Counting Model Based on MHSA-YOLOv8” [7] improved YOLOv8 by adaptation of the multi-head self-attention mechanism (MHSA), which is used to enhance the network’s ability to extract diverse features. The MHSA improved YOLOv8 results on recall, F1-score, and mAP@0.5 by 0.044, 0.003, and 0.004 compared to YOLOv8. The MHSA-YOLOv8 was compared with other YOLO family algorithms: YOLOv3, YOLOv4, YOLOv5, YOLOv7 and YOLOv8. The comparison results showed that the best algorithm for classical object detection is YOLOv8 with precision of 84.7% compared to runner up, YOLOv5 with 84.0% and mAP@0.5 of 0.859 for YOLOv8 compared to 0.778 for YOLOv5. The results of the comparison revealed that YOLOv8 outperforms in classical object detection, achieving a precision of 84.7%, slightly higher than its closest competitor, YOLOv5, which scored 84.0%. Additionally, YOLOv8 boasts a mAP@0.5 of 0.859, surpassing YOLOv5’s 0.778.

Another modification of YOLOv8 was YOLOv8-Seg developed for tomato disease detection [9]. YOLOv8-Seg was used to detect tomato fruits, and classify them according to health status, and if they are infected with disease, then classify disease that is discovered. YOLOv8-Seg goes a step further than object detection and involves identifying individual objects in an image and segmenting them from the background. Then each object is classified into classes based on the health status of fruit. The publication describes how the algorithm was further improved to get better results. The improved YOLOv8s-Seg algorithm achieves precision, recall, F1-score, and segment mAP@0.5 of 91.9%, 85.8%, 88.7%, and 0.922, respectively. Compared to the YOLOv8s-Seg algorithm,

the improvements were 1.6%, 0.4%, 1.0%, and 2.4%, respectively.

Our project team has already experimented with the different models of YOLOv5 and YOLOv7 to select the optimal solution for the rapid prototyping of fruit detection CNN. Our previous experiment showed that YOLOv5m is the most suitable model for fruit detection [10]. Now, we want to update our experiment results comparing the YOLOv5m with the new CNN models of YOLOv8 architecture, as well as, to present the new dataset called “CherriesBBCH81” under CC-BY 4.0 license.

The aim of study is to experimentally compare YOLOv5m with YOLOv8n, YOLOv8s and YOLOv8m to select the most suitable of them for the fruit detection tasks.

The novelty of publication:

- The new natural image dataset called “CherryBBCH81” is presented, which contains annotated images of cherry fruitlets BBCH81 prepared for YOLO model training.
- The best results were obtained by using YOLOv5m for CherryBBCH81 and by using YOLOv8m for Pear640.

II. MATERIALS AND METHODS

CherryBBCH81 collection and annotation:

The photo fixation of cherry fruitlets was done in the LatHort orchard in Dobeles, at the beginning of fruit coloration (BBCH stage 81) [11]. Two photo images were taken for each tree – perpendicularly, in a tree-facing view and in an oblique view. To determine the number of fruits in the tree, the fruits were counted on sample branches and multiplied by the number of such type branches in the tree. The photo images were annotated (See Fig. 1), adding the information of tree identity (tree number) and basic parameters of the tree and orchard (cultivar, rootstock, canopy type, planting distances, tree dimensions). The images were taken from the cultivars ‘Arthur’, ‘Artis’, ‘Bryansk 3-36’, ‘Doneckiy 42-37’, ‘Paula’, ‘Radica’ and ‘Techlovan’ grown under the cover, and from the cultivars ‘Aija’, ‘Aleksandrs’, ‘Elfrida’, ‘Bryansk 3-36’, ‘Bryanskaya Rozovaya’, ‘Kompaktnaya Venyaminova’ and ‘Paula’ grown in open orchard.

Then the annotated images 6016x4000px were automatically cropped out on 640x640px images with overlap 30%. 640x640px images provide sufficient detail for object detection while still being viable in terms of computing resources, but image resizing was not possible due to small bounding boxes, which could achieve size until 25x25px. Once the annotation process for all the images was completed, they were saved in a YOLO format. The dataset is available in Kaggle repository under CC-BY 4.0 licence [12].

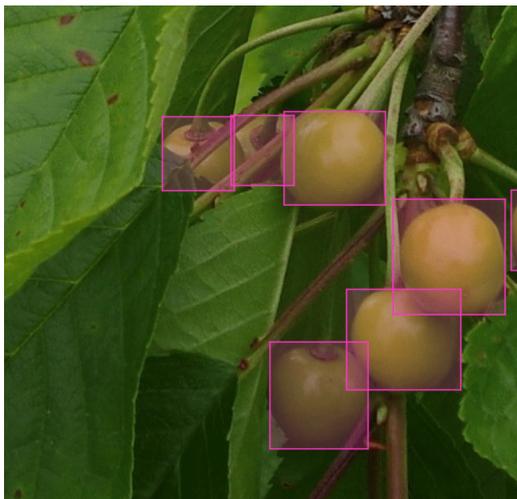


Fig. 1. CherryBBCH81 image example.

Comparison dataset Pear640:

Pear640 dataset [13] consists of 712 images (See Fig. 2.) containing 8340 pear objects. Digital images of pear fruits in this dataset were collected at the Lathort Institute's experimental site using 'Suvenirs' and 'Mramornaya' cultivars planted on 'Kazraushu' seedling rootstocks. The images were taken in field conditions, capturing the whole canopy as separate objects, around noon under clear sky conditions. This dataset provides a comprehensive collection of images taken under similar conditions as the CherryBBCH81 dataset so it makes for a reliable comparison dataset and it also was annotated using YOLO format, furthermore it is also in resolution of 640x640px.

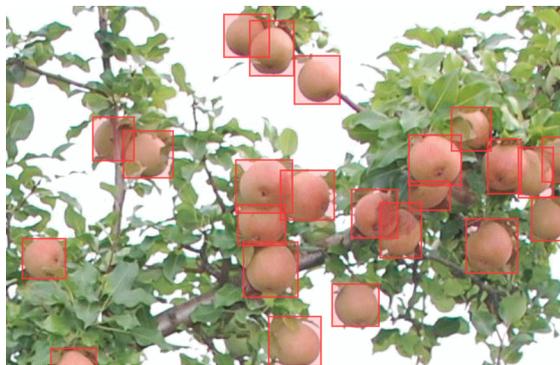


Fig. 2. Pear640 image example.

Experiment design:

In this experiment, we applied YOLOv5m [14] and YOLOv8 [15] models, specifically YOLOv8n, YOLOv8s, YOLOv8m. The experiment was conducted on an NVIDIA RTX 2070 GPU, which provided sufficient performance for training and testing the models.

The CherryBBCH81 dataset was randomly divided into training and validation folders using the random shuffle method in Python. This process was carried out five times to create five unique data splits. Each data split contained the same images, but they were located in different folders. In each split, 80% of the images were assigned to the training folder and 20% to the validation folder. The same

procedure was also applied to the comparison dataset Pear640.

In the experiment, the default augmentation was modified. Mix-up was adjusted to zero, as was the mosaic and shearing. However, these augmentation modifications were only applied to the training of YOLOv5m. For YOLOv8, the optimizer was set to "auto" to highlight its potential since it demonstrated enhancements.

For every data split, both YOLOv5m and YOLOv8 models were separately trained, leading to the creation of five distinct trained models for each model type. Subsequently, the results were collected and examined.

The experiment was designed similarly "Rapid Prototyping of Pear Detection Neural Networks with YOLO Architecture in Photographs" [10] to get comparable results.

III. RESULTS AND DISCUSSION

If we analyze the results of each dataset separately, starting with the newly created dataset CherryBBCH81 that consists of images of cherry fruitlets. The best results were achieved with the YOLOv5m model with mAP@0.5 of 87.7% (Tab. 1, median). In comparison, YOLOv8 results were worse: 85.5%, 86.9%, 86.2% for YOLOv8n, YOLOv8s and YOLOv8m respectively. Important to note, the results improved as the size of YOLOv8 increased.

Importance of consistency in machine learning results is crucial as it indicates the model's reliability and robustness across different datasets or under varying conditions, ensuring that the insights derived are dependable. Furthermore, consistent performance facilitates the fine-tuning and generalization of models, making it easier to identify areas of improvement and build trust in the model's outputs for decision-making.

If we analyze results on the basis of consistency, difference between min and max results of CherryBBCH81 dataset then it can be seen mAP@0.5 88.6%, mAP@0.5:0.95 40.1%, precision of 0.85 and recall of 0.82 that even though YOLOv5m produced the best results of training, consistency is worse with result variance of 1.9% between the best and the worst results achieved. In comparison results of YOLOv8m were the best with deviation of 1% between the best and the worst results. Deviation for YOLOv8s is 1.2% and for YOLOv8n is 1.7%. Based on the results achieved, in terms of consistency of training, YOLOv8m is better than the rest of the models in this experiment.

By looking at the previous experiment with Pear640 dataset [10], results of YOLOv5 showed 4.1% better mAP@0.5 compared to YOLOv7 model versions. During experiments with YOLOv5 and YOLOv8, the difference in results is not as impressive as it was in the previous experiments. Improvement that was achieved by YOLOv8 is only 0.9% (Tab. 2, median). YOLOv5m model mAP@0.5 is 93.8%, while YOLOv8m provides

the best results with $mAP@0.5$ of 94.7%. However, the previous experiment showed the maximal YOLOv5m $mAP@0.5$ equal to 0.951 [10], which is equal to the best result of YOLOv8m in this experiment.

In scope of model versions of YOLOv8, the best results were with YOLOv8m with $mAP@0.5$ of 94.7%, however difference to other versions is insignificant, as YOLOv8s results were 94.4% and YOLOv8n 94.6%. It shows that all results of YOLOv8 at $mAP@0.5$ outperformed YOLOv5 in the case of.

Results of YOLOv8 were, in general, better than YOLOv5, but another aspect that can be seen in results is consistency of results (See Fig. 3). If we look at the results of YOLOv5m, the difference between min and max values achieved is 1.6%. Close second is YOLOv8n with a difference of 1.5%. The best results were achieved with YOLOv8s and YOLOv8m with results of 0.9%. Considering potential usage of trained models and amount of work that will be assigned to it, consistency of results is an important factor in decision making.

YOLOv8 models resulted in better recognition percentage with the Pear640, in comparison with YOLOv5, but at same time YOLOv5 resulted in better object recognition then YOLOv8 using CherryBBCH81 dataset. If results are examined in scope of consistency, then best results were achieved by YOLOv8m.

TABLE 1 EXPERIMENT RESULTS WITH CHERRYBBCH81

YOLO	Test Dataset CherryBBCH81 ($mAP@0.5$)			
	v5m	v8n	v8s	v8m
min	0.867	0.847	0.853	0.860
mean	0.878	0.857	0.867	0.864
median	0.877	0.855	0.869	0.862
max	0.886	0.864	0.875	0.870

TABLE 2 EXPERIMENT RESULTS WITH PEAR640

YOLO	Test Dataset Pear640 ($mAP@0.5$)			
	v5m	v8n	v8s	v8m
min	0.927	0.932	0.938	0.942
mean	0.935	0.941	0.939	0.947
median	0.938	0.946	0.944	0.947
max	0.943	0.947	0.947	0.951

IV. CONCLUSIONS

In this article we presented our public dataset CherryBBCH81 (which is available in Kaggle under CC-BY 4.0 licence), and the YOLO model comparison experiment results.

The objective of the experiments conducted during the writing of this article was to develop a yield estimation solution. To further the realization of the goal we wanted to identify the optimal YOLO model for the rapid development of fruit detection neural networks. The experiments were done using our own datasets Pear640 and CherryBBCH81. Our experiment showed that YOLOv8m provided best consistency of training, yet looking at training results, the best results were obtained by using

YOLOv5m with CherryBBCH81 dataset: $mAP@0.5$ 88%, $mAP@0.5:0.95$ 42% and YOLOv8m for Pear640: $mAP@0.5$ 95%, $mAP@0.5:0.95$ 56%.

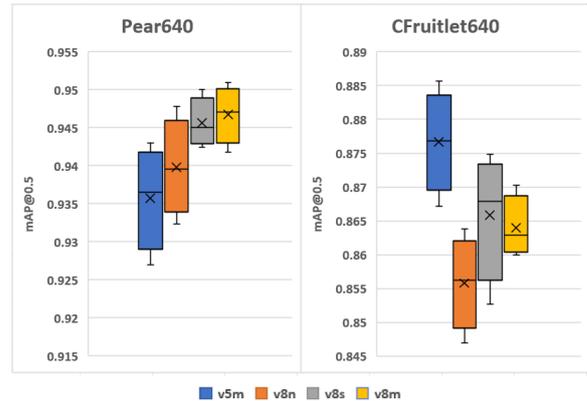


Fig. 3. Box-plot diagram of YOLO model accuracy ($mAP@0.5$).

ACKNOWLEDGMENTS

This research is funded by the Latvian Council of Science, project “Development of autonomous unmanned aerial vehicles based decision-making system for smart fruit growing”, project No. lzp-2021/1-0134.

REFERENCES

- [1] Fresh Cherries Market – Forecast (2023 - 2028). 2021. [Online]. Available: <https://www.industryarc.com/Research/Fresh-Cherries-Market-Research-511079> [Accessed: Dec. 12, 2023]
- [2] K. Ragazou, A. Garefalakis, E. Zafeiriou and I. Passas, “Agriculture 5.0: A new strategic management mode for a cut cost and an energy efficient agriculture sector,” *Energies*, vol. 15, no. 9, p. 3113, Apr. 2022, <https://doi.org/10.3390/en15093113>.
- [3] A. Ahmad, R. Damaševičius, *Agriculture 5.0 and Remote Sensing. Encyclopedia*. 2023. [Online]. Available: <https://encyclopedia.pub/entry/11655> [Accessed: Nov. 6, 2023]
- [4] I. Zarembo, S. Kodors, I. Apeināns, G. Lācis, D. Feldmane and E. Rubauskis, “DIGITAL TWIN: ORCHARD MANAGEMENT USING UAV”, *ETR*, vol. 1, pp. 247–251, Jun. 2023, <https://doi.org/10.17770/etr2023vol1.7290>.
- [5] V. Vijayakumar, Y. Ampatzidis and L. Costa, ‘Tree-level citrus yield prediction utilizing ground and aerial machine vision and machine learning’, *Smart Agricultural Technology*, vol. 3, p. 100077, Feb. 2023. <https://doi.org/10.1016/j.atech.2022.100077>
- [6] C. B. MacEachern, T. J. Esau, A. W. Schumann, P. J. Hennessy and Q. U. Zaman, ‘Detection of fruit maturity stage and yield estimation in wild blueberry using deep learning convolutional neural networks’, *Smart Agricultural Technology*, vol. 3, p. 100099, Feb. 2023. <https://doi.org/10.1016/j.atech.2022.100099>
- [7] P. Li, J. Zheng, P. Li, H. Long, M. Li and L. Gao, “Tomato Maturity Detection and Counting Model Based on MHSA-YOLOv8,” *Sensors*, vol. 23, no. 15, p. 6701, Jul. 2023, <https://doi.org/10.3390/s23156701>.
- [8] T. Dao, N. Nguyen and V. Nguyen, “CNN-YOLOV8 - Based Tomato Quality Inspection System - a case study in Vietnam”, *SSRG International Journal of Electrical and Electronics Engineering*, 10(7), 31–40, 2023, <https://doi.org/10.14445/23488379/ijeee-v10i7p103>
- [9] X. Yue, K. Qi, X. Na, Y. Zhang, Y. Liu and C. Liu, “Improved YOLOv8-Seg Network for Instance Segmentation of Healthy and Diseased Tomato Plants in the Growth Stage,” *Agriculture*, vol. 13, no. 8, p. 1643, Aug. 2023, <https://doi.org/10.3390/agriculture13081643>.

- [10] S. Kodors, M. Sondors, G. Lācis, E. Rubauskis, I. Apeināns and I. Zarembo, "RAPID PROTOTYPING OF PEAR DETECTION NEURAL NETWORK WITH YOLO ARCHITECTURE IN PHOTOGRAPHS", *ETR*, vol. 1, pp. 81–85, Jun. 2023, <https://doi.org/10.17770/etr2023vol1.7293>.
- [11] G. Zhao, Y. Gao, S. Gao, Y. Xu, J. Liu, C. Sun, Y. Gao, S. Liu, Z. Chen and L. Jia, "The Phenological Growth Stages of *Sapindus mukorossi* According to BBCH Scale," *Forests*, vol. 10, no. 6, p. 462, May 2019, <https://doi.org/10.3390/f10060462>.
- [12] lzp-2021/1-0134, Cfruitlets81-640, 2023. [Online]. Available: <https://www.kaggle.com/datasets/projectlzp201910094/cfruitlets81-640> [Accessed: Nov 12, 2023]
- [13] lzp-2021/1-0134, Pear640, 2023. [Online]. Available: <https://www.kaggle.com/datasets/projectlzp201910094/pear640> [Accessed: Nov 12, 2023]
- [14] Ultralytics, YOLOv5-7.0 GitHub repository. [Online] Available: <https://github.com/ultralytics/yolov5> [Accessed: Nov 15, 2023]
- [15] Ultralytics, YOLOv8 GitHub repository. [Online] Available: <https://github.com/ultralytics/ultralytics> [Accessed: Nov 15, 2023]

Ant Detection using YOLOv8: Evaluation of Dataset Transfer Impact

Ilmārs Apeināns

*Institute of Engineering
Rezekne Academy of Technologies
Rezekne, Latvia
ilmars.apeinans@rta.lv*

Valdis Tārauds

*Rezekne Academy of Technologies
Rezekne, Latvia
vt16011@edu.rta.lv*

Lienīte Litavniece

*Research Institute for Business and
Social Processes
Rezekne Academy of Technologies
Rezekne, Latvia
lienite.litavniece@rta.lv*

Sergejs Kodors

*Institute of Engineering
Rezekne Academy of Technologies
Rezekne, Latvia
sergejs.kodors@rta.lv*

Imants Zarembo

*Institute of Engineering
Rezekne Academy of Technologies
Rezekne, Latvia
imants.zarembo@rta.lv*

Abstract. In order to avoid having to fight with aphids and plant virus diseases caused by them in gardens, it is very important to notice ant colonies. As a result we decided to train artificial intelligence to detect ant colonies, then this artificial intelligence can be integrated into an autonomous orchard monitoring system using unmanned aerial vehicles. However, there is restricted availability of open datasets, which contain natural images and region specific species. In the scope of pilot study we decided to train convolutional neural network using ANTS dataset and to test it on small domain-specific dataset to identify the need to collect new dataset. The experiment was completed using the popular architecture YOLOv8. The YOLOv8n and YOLOv8m models trained on ANTS showed accuracy 98% and 99% mAP@0.5. Meanwhile, their accuracy was only 6% and 5% mAP@0.5 respectively testing on our dataset called “WildAnts”. Our pilot study experimentally proves that it is important to collect natural dataset of ant images to train robust artificial intelligence for orchard monitoring using unmanned aerial vehicles. This study will be interesting for all machine learning specialists, because it numerically shows accuracy decrease in the result of dataset transfer.

Keywords: ant, deep learning, pests, precision farming

I. INTRODUCTION

Agricultural yields are affected not only by unstable climatic conditions, but also by various pests. Although Latvia is a relatively small country, the spread of pests can vary in different regions. In general, all pests can be divided into those that multiply and damage specific crops and those that multiply and damage those plants that are available. Agricultural crops in Latvia are affected by pests such as spider mites (*Tetranychus urticae*), aphids (*Aphididae*), pear blight beetles (*Xyleborus dispar*) and many others. If the aforementioned are unequivocally considered as pests, then

there are continuous discussions regarding ants (*Formicidae*) and it is an actual question whether to consider them as pests or, nevertheless, important insects in agriculture [1].

Ants enjoy the sweet juice found in many sweet berries and fruits such as strawberries, cherries, pears, etc., resulting in damage to fruit and berry crops. However, the most significant ant damage is related to aphids. Aphids suck sap and transmit plant viral diseases. Ants, on the other hand, like the liquid secreted by aphids, so they use these pests to their advantage and protect them from natural enemies. Therefore, farmers, in order to free their gardens from aphids, destroy their defenders - ants.

In order to avoid having to fight with aphids and plant virus diseases caused by them in gardens, it is very important to notice ant colonies in time to prevent the spread of aphids.

One of the approaches to ant detection can be autonomous garden monitoring by application of unmanned aerial vehicles (UAVs). A specially designed web-based information system can automatically schedule garden surveillance flights on a regular basis and notify garden personnel as soon as pests have been detected on the imagery of garden plants. To set up such a monitoring the system operator first has to enter their garden details into the system (garden location and boundaries, tree or plant rows, restricted areas, UAV base station location) and the flight mission planner will calculate an optimal surveillance flight plan taking into account UAV flight time, restricted areas and weather conditions.

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8040>

© 2024 Ilmars Apeinans, Valdis Tārauds, Lienīte Litavniece, Sergejs Kodors, Imants Zarembo.

Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

Therefore artificial intelligence must be trained to detect ants, which will be integrated into autonomous monitoring systems.

Artificial intelligence usage in the domain of ants, at this point of time, mainly targets ant tracking in the terms of studying ant cluster behavior. In the article “A dataset of ant colonies’ motion trajectories in indoor and outdoor scenes were tracked to study clustering behavior” [2], Wu et. al. (2022) developed the ground monitoring tool for ant tracking. Each ant was labeled with an ID to monitor its motion track.

In broader scope, in the article “Tracking Different Ant Species: An Unsupervised Domain Adaptation Framework and a Dataset for Multi-object Tracking“ written by Abeyasinghe et al. (2023) [3], the framework was created for object tracking tasks, which was tested on ant colonies.

The aim of our study is to train CNN for ant detection. There is an existing image dataset, which can be applied for CNN training. The dataset was collected by Wu et al. (2022) [2] for analysis of ant colonies’ motion trajectories in indoor and outdoor scenes (hereinafter ANTS). However, ANTS was collected for specific tasks and can be characterized by laboratory conditions. Therefore, we decided to collect a small dataset with natural images to experimentally test dataset transfer impact on CNN accuracy. We called our dataset “WildAnts”.

The experiment was completed using the popular and modern architecture YOLOv8. The YOLOv8n and YOLOv8m models trained on ANTS showed accuracy 98% and 99% mAP@0.5. Meanwhile, their accuracy was only 6% and 5% mAP@0.5 respectively testing on WildAnts. The mirror experiment design showed better results. The YOLOv8n and YOLOv8m models trained on WildAnts showed accuracy 75% and 78% mAP@0.5. Meanwhile, their accuracy was 23% and 29% mAP@0.5 respectively testing on ANTS.

The experiment results shows that it is strongly important to collect domain-specific dataset with natural images for ant detection to train robust CNN for orchard monitoring using UAV.

II. MATERIALS AND METHODS

ANTS dataset:

The dataset “ANTS” was prepared under laboratory and near laboratory conditions for ant path tracking tasks [2]. The dataset consists of 5334 annotated images, which included 712 ants and 114,112 bounding boxes. The image sizes are 1280x720 and 1920x1080. The dataset is available in Mendeley repository under CC-BY4.0 [4]. The ANTS dataset consists of two subdatasets: one contains images collected by imaging ants in a jar (see Fig. 1), another - near anthills (see Fig. 2).

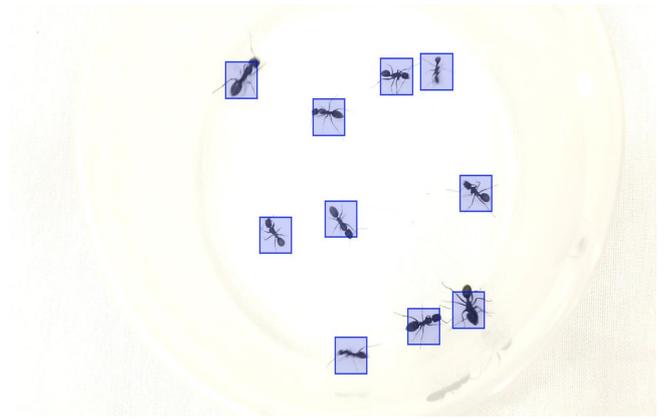


Fig. 1. ANTS dataset: in laboratory conditions [2]



Fig. 2. ANTS dataset: in near laboratory conditions [2]

WildAnts dataset:

The dataset “WildAnts” was created from different videos of ants in natural conditions. Every 12 frames were cut from the collected videos. And then pictures were manually selected. Different sizes and resolutions of images were selected. In result, 253 images were prepared. The images were annotated and saved in YOLO format (see Fig. 3). The image sizes in the dataset vary in a wide range, with the smallest images 640x368 to the largest with dimensions of 3840x2178.

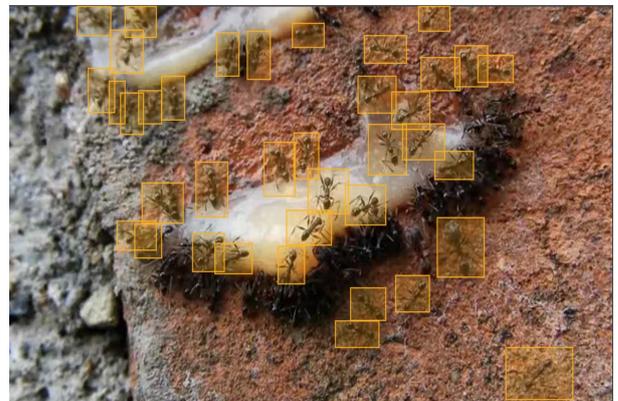


Fig. 3. WildAnts dataset



Fig. 4. WildAnts dataset

YOLOv8 training:

In this experiment, we applied the following YOLOv8 [5] models: YOLOv8n and YOLOv8m. The experiment was conducted on an NVIDIA RTX 2070 GPU.

The obtained datasets, ANTS and WildAnts, were used to train and test the models. Each dataset was randomly divided into training and testing subdatasets using the random shuffle method in Python using proportion 80% and 20%. Each dataset was divided five times and then used for training the models, giving us a total of 10 trained models. The training parameters were the same for both YOLO architectures. The training was performed for 200 epochs with a patience of 50 independently on each dataset. The images were of various sizes and were resized to 640x640 pixels using YOLOv8's built-in function. The experiment was designed similarly to Kodors et al. (2023) to get comparable results [6]. When the training was completed the trained models were tested on another dataset to identify the dataset transfer impact on the accuracy (see Fig. 5).

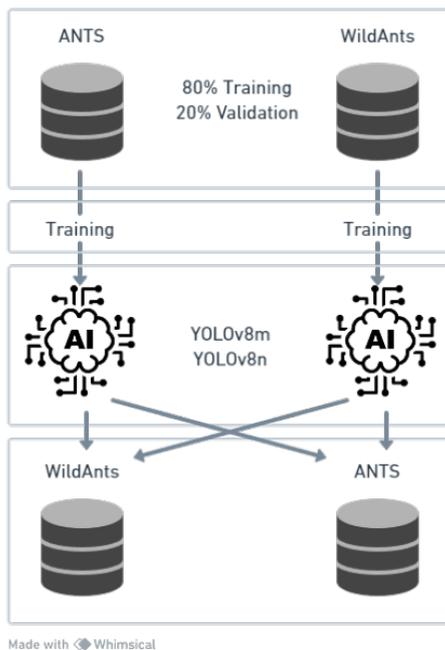


Fig. 5. Experiment design

III. RESULTS AND DISCUSSIONS

Analyzing the results obtained when testing the models on the datasets on which they were trained on, the best result was shown by YOLOv8m equal to 99.0% mAP@0.5 in the case of ANTS dataset (see Tab. 1, median). But for the models trained on the WildAnts dataset, the best result was shown by YOLOv8m equal to 77.4% mAP@0.5 (see Tab. 1, median). Such a difference can be explained by the fact that in the case of ANTS dataset, images were collected under laboratory (see Fig. 1) and near laboratory conditions (see Fig. 2) providing a monotonic background and a good contrast with ants, meanwhile, the dataset WildAnts included images with different scenes and the images are more colorful (see Fig. 3 and 4). The size of objects can not be strongly impactful, because the YOLOv8 architecture was specially enhanced for small object detection [7], meanwhile, the automatic search of optimal bounding box sizes was presented in the YOLOv4 framework [8].

Khalid et al. (2023) compared different YOLO architectures on the natural image dataset of small pests: thistle caterpillars (*Vanessa cardui*), red beetles (*Aulacophora foveicollis*), and citrus psylla (*Diaphorina citri*) [9]. Their experiment showed that YOLOv8n is the most suitable, it depicted the best accuracy equal to 84.7% mAP@0.5 [9]. In our case (see Fig. 6 and 7), the YOLOv8n model trained on ANTS showed better results (max YOLOv8n was 99% mAP@0.5), but the model trained on WildAnts - little smaller accuracy (max YOLOv8n was 81% mAP@0.5).

If we analyze the results obtained by testing the models with swapped datasets (see Fig. 6 and 7), the best result is obtained by the YOLOv8 model trained on the WildAnts dataset with 28.7% mAP@0.5 (see Tab. 2, median). But for a model trained on the ANTS dataset, the best result is shown by YOLOv8n with only 5.5% mAP@0.5 (see Tab. 2, median). Therefore, the models trained on WildAnts are more robust for the dataset transfer.

Analyzing the results in general, it can be seen that the models trained on the dataset ANTS show much worse results when tested on another dataset. But the models trained on dataset WildAnts show much better results compared to ANTS models. That underlines the importance of the natural images collected in the different scenes. The best result was achieved with the YOLOv8m model trained on the WildAnts dataset, it showed relatively good accuracy on own dataset (82% mAP@0.5) and it showed the best accuracy results (32% mAP@0.5) after the dataset change on ANTS.

Our other experiments showed that mosaic and combination of the related datasets can improve accuracy and create more robust models [10]. Therefore, speaking about the best dataset for training, it will be a combination of ANTS and WildAnts. Meantime, the dataset transfer impact shows the importance to continue to collect more natural datasets and tune CNNs for a working environment obtaining user feedback after object detection.

TABLE 1. TRAINING RESULTS (mAP@0.5)

YOLO	Test ANTS model on ANTS dataset		Test WildAnts model on WildAnts dataset	
	v8n	v8m	v8n	v8m
min	0.97307	0.98936	0.68455	0.73213
mean	0.98452	0.99045	0.74711	0.77623
median	0.98848	0.99048	0.76266	0.77475
max	0.98905	0.99109	0.80857	0.82354

TABLE 2. CROSS TESTING (mAP@0.5)

YOLO	Test ANTS model on WildAnts dataset		Test WildAnts model on ANTS dataset	
	v8n	v8m	v8n	v8m
min	0.04252	0.03342	0.18506	0.26863
mean	0.05529	0.04594	0.23334	0.29006
median	0.05540	0.03854	0.23511	0.28765
max	0.07458	0.06638	0.26664	0.31265

IV. CONCLUSIONS

We have experimentally shown the importance of natural images for robust CNN training and need to collect the ant dataset with natural images for orchard monitoring.

The best accuracy results showed the YOLOv8m model trained on ANTS dataset, which achieved the maximal accuracy 99% mAP@0.5, but it was possible only to get accuracy 7.5%, when the testing dataset was changed on WildAnts. Meanwhile, the YOLOv8m trained on WildAnts showed 82% mAP@0.5 on itself, but it was more robust for the dataset changing - 31% mAP@0.5 on ANTS dataset.

It is an excellent demonstration of accuracy decrease on the other datasets [51%; 92%], which were unknown for CNN in the training time. Therefore, it is important to continue to collect more natural datasets and tune CNNs for a working environment obtaining user feedback after object detection.

ACKNOWLEDGEMENT

This research is funded by the Latvian Council of Science, project “Development of autonomous unmanned aerial vehicles based decision-making system for smart fruit growing”, project No. lzp-2021/1-0134.

REFERENCES

- [1] G. Benckiser, “Ants and sustainable agriculture. A review,” *Agronomy for Sustainable Development*, vol. 30, no. 2, pp. 191–199, Apr. 2010, doi: <https://doi.org/10.1051/agro/2009026>.
- [2] M. Wu, X. Cao, M. Yang, X. Cao, and S. Guo, “A dataset of ant colonies’ motion trajectories in indoor and outdoor scenes to study clustering behavior,” *GigaScience*, vol. 11, Jan. 2022, doi: <https://doi.org/10.1093/gigascience/giac096>.
- [3] C. Abeyasinghe, C. Reid, H. Rezatofghi, and B. Meyer, “Tracking Different Ant Species: An Unsupervised Domain Adaptation Framework and a Dataset for Multi-object Tracking.” [Online] Available: <https://www.ijcai.org/proceedings/2023/0061.pdf> [Accessed: Jan. 25, 2024]
- [4] X. Cao, “ANTS--ant detection and tracking,” *data.mendeley.com*, vol. 3, Oct. 2021, doi: <https://doi.org/10.17632/9ws98g4npw.3>.
- [5] Ultralytics, YOLOv8 GitHub repository. [Online] Available: <https://github.com/ultralytics/ultralytics> [Accessed: Jan. 15, 2024]
- [6] S. Kodors, M. Sondors, G. Lācis, E. Rubauskis, I. Apeināns, and I. Zaremba, “RAPID PROTOTYPING OF PEAR DETECTION NEURAL NETWORK WITH YOLO ARCHITECTURE IN PHOTOGRAPHS,” *ENVIRONMENT. TECHNOLOGIES. RESOURCES. Proceedings of the International Scientific and Practical Conference*, vol. 1, pp. 81–85, Jun. 2023, doi: <https://doi.org/10.17770/etr2023vol1.7293>.
- [7] R. Bai, F. Shen, M. Wang, J. Lu, and Z. Zhang, “Improving Detection Capabilities of YOLOv8-n for Small Objects in Remote Sensing Imagery: Towards Better Precision with Simplified Model Complexity” Jun. 2023, doi: <https://doi.org/10.21203/rs.3.rs-3085871/v1>.
- [8] A. Bochkovskiy, C.-Y. Wang, and H.-Y. Liao, “YOLOv4: Optimal Speed and Accuracy of Object Detection,” Apr. 2020. Available: <https://arxiv.org/pdf/2004.10934.pdf> [Accessed: Jan. 12, 2024]
- [9] S. Khalid, H. M. Oqaibi, M. Aqib, and Y. Hafeez, “Small Pests Detection in Field Crops Using Deep Learning Object Detection,” *Sustainability*, vol. 15, no. 8, p. 6815, Jan. 2023, doi: <https://doi.org/10.3390/su15086815>.
- [10] S. Kodors, M. Sondors, I. Apeināns, I. Zaremba, G. Lācis, E. Rubauskis and K. Karklina, “Importance of mosaic augmentation for agricultural image dataset”, 2024.

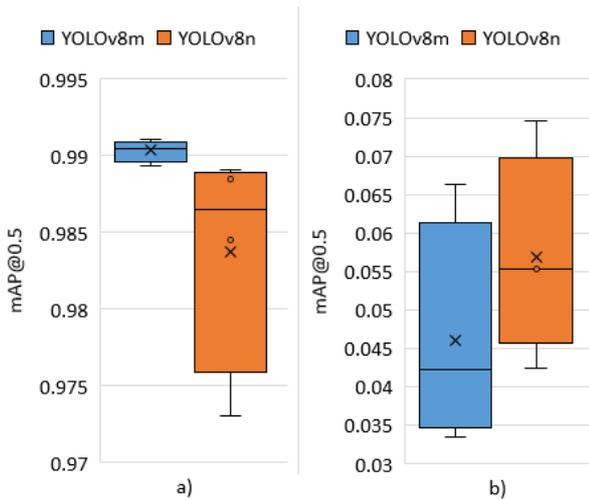


Fig. 6. CNN trained on ANTS dataset [4]: a) tested on ANTS dataset; b) tested on WildAnts dataset

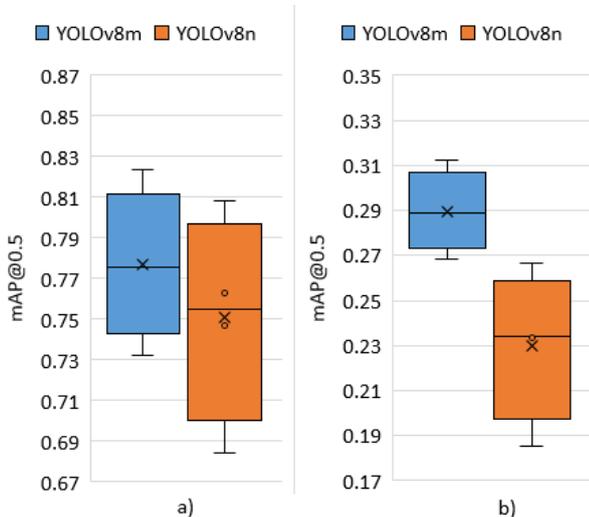


Fig. 7. CNN trained on WildAnts dataset: a) tested on WildAnts dataset; b) tested on ANTS dataset

Optimal Size of Agricultural Dataset for YOLOv8 Training

Ilmārs Apeināns
Institute of Engineering
Rezekne Academy of Technologies
Rezekne, Latvia
ilmars.apeinans@rta.lv

Abstract. The smart farming solutions are mainly based on the application of convolutional neural networks for object detection tasks. The number of open datasets is restricted in the agricultural domain. Therefore, it is required to find the answer to the question: how big a dataset must be collected to train a convolutional neural network for object detection tasks? To solve this task, the YOLOv8 framework was selected for the experiment. Three datasets were prepared: MinneApples, PFruitlets640 and mosaic dataset using both previously named datasets. 100 images were selected for testing. Other images were used to create training datasets, which had the size from 100 until 1000 images with step 100 images. Training was repeated 10 times with each size of dataset. The experiment showed that the increase of dataset from 100 to 500 images provides an accuracy growth up to 15.48% mAP@0.5, but from 600 to 1000 images - only 2.98% mAP@0.5. This study experimentally proves that the dataset size equal to 500 images is the most efficient. Meanwhile, the experiment with the mosaic dataset shows constant accuracy improvement. Therefore, it is more advisable to collect different classes with 500 images than one large dataset. This study will be interesting not only for smart farming experts as well as for all machine learning experts.

Keywords: artificial intelligence, deep learning, precision farming, YOLOv8.

I. INTRODUCTION

Precision farming is a management strategy with the goal to improve productivity, resource usage efficiency, quality and profitability of the food industry and sustainability in the agricultural sector [1]. To achieve the goal of precision farming, a wide range of tools can be applied starting from sensors to acquire information in real time until artificial intelligence (AI), which can be used to make assessments of data and automatic decisions based on aquired data. If the sensors and IoT are applied to collect data, then AI can be used to generalize them, find correlations and automatically analyze acquired data. The accuracy of the artificial neuron networks highly depends on the amount of data, which was used during the training process. In the scope of this article, experiments were made

with the goal to find the optimal size of agricultural dataset for object detection using YOLOv8 architecture.

YOLOv8 [2] (You Only Look Once version 8) is an object detection architecture, which is a continuation of the YOLO family models, which are known for their speed and accuracy. One of improvements in YOLOv8 architecture is its enhancement for small object detection [3], which are quite often use-case in agricultural datasets. The detectable objects may be quite small, such as flowers, pests, small fruits like cherries [4]. The authors of the article "Small pests detection in field crops using deep learning object detection" [5] compared several versions of YOLO architectures. Their experiment showed that YOLOv8 provided the best results of 84.7% mAP.

The property of YOLOv8 is its ability to perform object detection in real time. As well as, YOLOv8 can work with several classes of objects at the same time and mark placement of detected objects. That is essential for smart agrobot development, because manual imagining is a cost-ineffective approach.

As stated before, in many cases the variation of cultivars may affect training results. For example, apples have more than 7500 different cultivars [6]. Same applies if we look at the regional scale as well. Each global region will have different fruits and vegetables cultivars compared to another region in the world. Considering the seasonal limits, when a dataset can be collected, the resulting amount of available datasets that can be used for training is highly limited.

Currently a large number of challenges still exist in the way of implementing AI solutions in agriculture such as insufficient research or security from cyber-attacks, or dependency on technology in general [7]. One of mentioned challenges relevant to this article is stakeholders' and owners' requirements for the high precision of AI and solution suitability to their farm ecosystems. To overcome this challenge it is important to study more about the rapid development of artificial intelligence. The big part of preparing an AI model for

Print ISSN 1691-5402
Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8041>

© 2024 Ilmars Apeināns. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

usage in real-life situations is related to a dataset collection and its preprocessing. Based on that, the task to find out the optimal size of dataset for the agriculture domain is a good starting point to solve the defined challenge.

If the situation with general object detection in agriculture is salvageable with an increased number of specialists for collecting general images for datasets, then the situation with more specific objects is much more complex due to limited expert number or sample availability. E.g. there is a lack of datasets in the field of plant diseases [8]. The disease has several stages of maturing, and for the different types of fruits and vegetables, the disease will be visually different.

Precision farming and artificial intelligence usage in farming is hindered by real life elements, mainly, by the low number of datasets which can be used for training. Fruits and vegetables are usually harvested once per year, therefore the time frame to collect images for the dataset is limited. If by any chance a time period is missed or errors are made during data collection, the next opportunity is only the next period of maturity of the studied fruits or vegetables. After images are collected, then a dataset is prepared for training. The annotation of images is done together with an image discarding, which are damaged, blur or contain other visual distortions. In summary, the preparation of an agricultural dataset is a monotonic and time-consuming process. As a result of that the question appeared “How many images in the dataset is enough to train an efficient object detection prototype?”.

Summarizing the previously stated, the collection and annotation of a large training dataset is time consuming process, which is limited by time frame, when it is possible to photo the flowering, maturing or any other phase of growth of fruits or vegetables, that may be only a week or even less. If time to collect data is missed, the next chance may be only provided in the next season. Considering these factors, the study questions are “Is it more efficient to collect more, but smaller datasets for training is better?” or “What is the optimal size of dataset for the agricultural domain?”.

The aim of the study is to identify the optimal size of agricultural dataset for the CNN training using the YOLOv8 framework.

The experiment was performed using three datasets: two datasets were publicly available datasets and the third was generated using vertical mosaic augmentation. The mosaic augmentation represents the merging of 2 or more images into a single image. The importance of mosaic augmentation was mentioned in an article about YOLOv4 architecture [9], where it was proven that mosaic augmentation improves average accuracy of trained CNN. The additional influence of mosaic augmentation is an artificial increase of training dataset. And mosaic augmentation was added to all later YOLO family architectures.

II. MATERIALS AND METHODS

Datasets: in the experiment three datasets were used for training, validation and testing. Two public datasets were applied: MinneApple [10] and PFruitlets640 [11]. The third dataset was generated from two mentioned datasets.

The first dataset which was selected for the experiment is MinneApple. It consists of 1308 images and over 41000 annotations. The dataset contains images of apples (see Fig. 1). The images were cropped into size of 640x640 without any alterations to bounding boxes to preserve the dataset compatibility with other experiments.

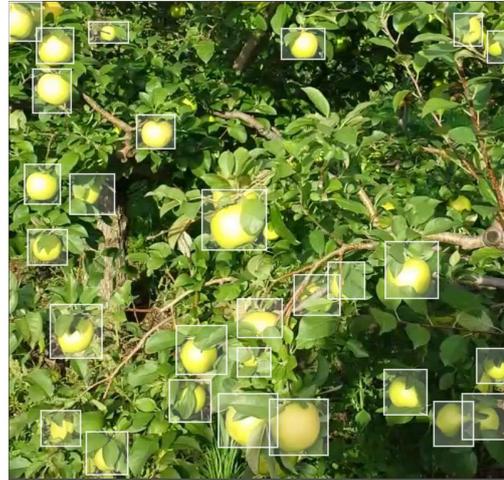


Fig. 1 MinneApples [10]

PFruitlets640 consists of 1455 annotated images of pear fruitlets (see Fig. 2). The images are already prepared for training using YOLOv8, therefore the images have size equal to 640x640. The object of annotation in this dataset is pear fruitlet, which visually looks similarly to apples from MinneApple dataset.

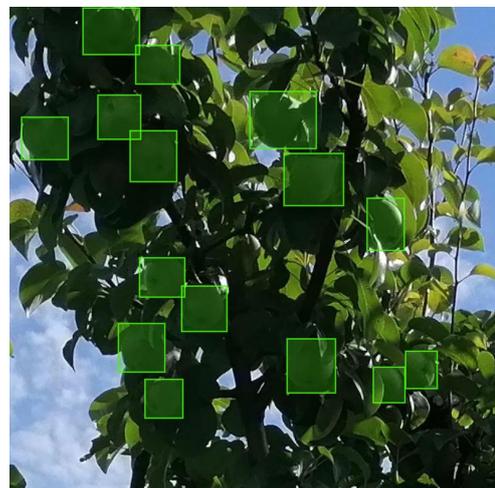


Fig. 2 PFruitlets640 [11]

The mosaic dataset was created using MinneApples and PFruitlets640 datasets. It consists of 4544 images with bounding boxes. To create this dataset, original datasets, MinneApples and PFruitlets640, were automatically cut and merged by vertical axis in the middle of the images (see Fig. 3). The labels consist of two classes: apples and pear fruitlets.



Fig. 3. Mosaic dataset

CNN training: YOLOv8n model [2] was applied in this experiment. The experiment was conducted on a GPU NVIDIA RTX 4070Ti.

Training was done using three datasets:

- PFruitlets640 - 1455 images;
- MinneApples - 1308 images;
- Mosaic dataset was created from two previous datasets - 4544 images.

100 images of each dataset were selected for the testing datasets for later usage after training, the rest of images was left for training and validation. In the experiment, it was important to test the precision on similar images changing the size of the training dataset.

The starting size of training and validation datasets were 100 training images and 30 validation images, which were selected using a random shuffle method in Python script. The YOLOv8n was trained 5 times. After finishing training, a new dataset was created with an increased number of images in the training dataset and validation set. Increases of datasets were +100 images in the training dataset and +30 images in the validation dataset. It was continued until the size of the training dataset and validation dataset reached 1000 training and 300 validation images. Same steps were repeated for all 3 used datasets, if that was possible. MinneApples dataset was not big enough to facilitate training steps with 1000 training and 300 validation images.

After finishing the training phase of the experiment, the testing phase was done by selecting the best trained model for each datasets, which were used to test training results on separated datasets with 100 images. The separate datasets were not used in the training or validation stages, they provided the most accurate testing results. The achieved results were used in discussion.

III. RESULTS AND DISCUSSION

Three datasets were used to determine the optimal size of agricultural dataset for CNN training, validation and testing. If we look at achieved training results (see Tab. 1.),

it can be seen that the larger size of dataset provides the better accuracy results. E.g. MinneApples dataset provided accuracy $mAP@0.5$ of 66.41% in the case of 100 training images. Trained models using PFruitlets640 dataset achieved the worst result at $mAP@0.5$ of 61.49% and trained models on Mosaic dataset created by combining both previously named datasets achieved $mAP@0.5$ of 69.78% at the same size of dataset.

The largest size of the dataset was selected to be 1000 images in the training dataset. Due to the limitations of MinneApples dataset, which contained only 1208 images, the accuracy results for 1000 images are not provided in Table 1. The maximal training size of MinneApples was 900 images, which provided $mAP@0.5$ of 83.05%. Models trained on PFruitlets640 achieved $mAP@0.5$ of 83.29% with a dataset size of 1000 images. At the same size of dataset (1000), Mosaic dataset's models achieved the best result of $mAP@0.5$ equal to 86.76%, which is the highest precision among 3 datasets used in the experiment (see Fig. 1).

If we look at the experiment results in Fig. 4, then on Mosaic dataset provided the best trained models in general, with the highest $mAP@0.5$ of 69.78% for training datasets size of 100 images and $mAP@0.5$ of 86.76% for training dataset size of 1000 images.

TABLE 1. EXPERIMENT RESULTS ($mAP@0.5$)

Dataset size	MinneApples	Mosaic	PFruitlets640
100	0.66414	0.69786	0.61492
200	0.71610	0.75534	0.67192
300	0.74449	0.80103	0.73231
400	0.75954	0.81256	0.78092
500	0.79957	0.83565	0.80640
600	0.80833	0.84265	0.82048
700	0.81587	0.85096	0.82126
800	0.81807	0.85503	0.82440
900	0.83060	0.86304	0.82760
1000	-	0.86763	0.83294
1000-500	0.03103	0.03198	0.02655
500-100	0.13542	0.13780	0.19148

The main goal of this study was to find out the optimal size of a dataset for agricultural model training. As such it is important to look at the difference of precision of models with different training dataset sizes. In Tab. 1, the rows "1000-500" and "500-100" depict the accuracy improvements, which were achieved increasing the datasets from 100 to 500 and from 500 to 1000. Based on the experiment results, it can be calculated that the increase in $mAP@0.5$ for dataset MinneApples from 100 to 500 images was 13.54%, while $mAP@0.5$ increased only by 3.1% in the range of dataset size from 500 to 1000 images. The similar results were achieved in the case of PFruitlets640 dataset, where the precision improvement, from 100 to 500 images, was 19.14% at $mAP@0.5$. Meanwhile, from 500 to 1000 images, the increase of $mAP@0.5$ for PFruitlets640 was only 2.65%. In the case of Mosaic

dataset, the increase of precision from 100 to 500 images was 13.77% at mAP@0.5, while the increase was 3.19% in the range from 500 to 1000 images.

Based on previously looked data, it was shown that the models trained on Mosaic dataset provided the best results among all sizes of datasets that were used. Taking in consideration that, Mosaic dataset provided the best training results in general, it will be applied to calculate the mean increase of precision to compare it with the training results of MinneApples and PFruitlets640 datasets (see Tab. 2).

TABLE 2. ACCURACY IMPROVEMENT PROVIDED BY MOSAIC AUGMENTATION

Dataset size	Mosaic-MinneApples	Mosaic-PFruitlets640	Mean
100	0.03372	0.08294	0.05833
200	0.03923	0.08342	0.06133
300	0.05655	0.06872	0.06263
400	0.05301	0.03164	0.04233
500	0.03609	0.02925	0.03267
600	0.03432	0.02217	0.02824
700	0.03509	0.02970	0.03239
800	0.03696	0.03063	0.03380
900	0.03245	0.03544	0.03394
1000	-	0.03468	0.03468

Data shown in Tab. 2 are calculated considering the fact that the Mosaic dataset provided the best training results. In the case of column “Mosaic minus MinneApples” of Tab. 2, where the accuracy improvements by mosaic augmentation are provided in comparison with MinneApples dataset, data shows an increase in the range from 3.24 % until 5.65%. Next column (Tab. 2, Mosaic minus PFruitlets640) shows comparison of Mosaic dataset and PFruitlets640 dataset results. Increase of accuracy in the case of Mosaic dataset provides a wider range from 2.21% to 8.34%. Using the acquired data, the mean accuracy improvement was calculated (Tab. 2, Mean). The highest increase in accuracy is seen at the dataset sizes: 200 images (6.13% of mAP@0.5) and 300 images (6.26% of mAP@0.5). The improvement of accuracy is increasing up to 300 images and from this point the accuracy starts to decline (Fig. 5) until it reaches the lowest point of 2.82% mAP@0.5 at a dataset size of 600 images. After this point, accuracy increase per dataset size is stable around 3%.

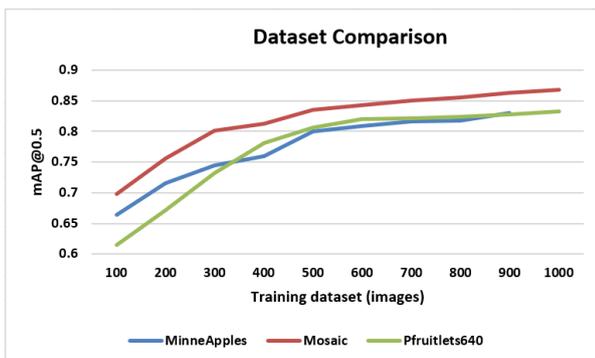


Fig. 4. Dataset accuracy comparison

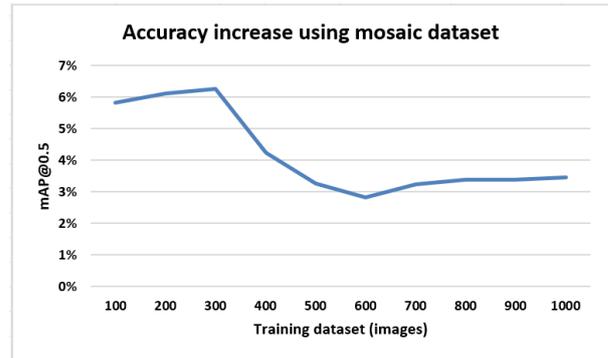


Fig. 5. Increase in accuracy using the mosaic augmentation

IV. CONCLUSIONS

In this article, the optimal size for agricultural dataset was experimentally identified for training object detection CNN. The experiment was completed by using the YOLOv8n model and several public datasets.

The objective of this experiment conducted during the writing of this article was to determine the optimal size of agricultural dataset for YOLOv8n architecture training. To achieve this goal two public datasets, Pear640 and MinneApples, and Mosaic dataset, created by using both public datasets, were used in experiments. To determine the optimal dataset size, CNN models were trained using YOLOv8n on randomly selected images from starting datasets. Dataset size was in the range from 100 images until 1000 images in the dataset with step of size 100 images. Experiment results showed that the biggest increase in accuracy was achieved with dataset size of 500 images, for MinneApple dataset: 13.52% mAP@0.5, for PFruitlets640 dataset: 19.14% mAP@0.5 and for Mosaic dataset: 13.78% mAP@0.5. In comparison with dataset increase from 500 images to 1000 images accuracy increase was smaller, for MinneApple dataset: 3.1% mAP@0.5, for PFruitlets640 dataset: 2.65% mAP@0.5 and for Mosaic dataset: 3.19% mAP@0.5.

ACKNOWLEDGEMENT

This research is funded by the Latvian Council of Science, project “Development of autonomous unmanned aerial vehicles based decision-making system for smart fruit growing”, project No. lzp-2021/1-0134.

REFERENCES

- [1] E. S. Ramil Brick, J. Holland, D. E. Anagnostou, K. Brown, and M. P. Y. Desmulliez, “A review of agroforestry, precision agriculture, and precision livestock farming—The case for a data-driven agroforestry strategy,” *Frontiers in Sensors*, vol. 3, Sep. 2022, doi: <https://doi.org/10.3389/fsens.2022.998928>.
- [2] Ultralytics, YOLOv8 GitHub repository. [Online] Available: <https://github.com/ultralytics/ultralytics> [Accessed: Jan15, 2024]
- [3] R. Bai, F. Shen, M. Wang, J. Lu, and Z. Zhang, “Improving Detection Capabilities of YOLOv8-n for Small Objects in Remote Sensing Imagery: Towards Better Precision with Simplified Model Complexity,” *Jun. 2023*, doi: <https://doi.org/10.21203/rs.3.rs-3085871/v1>.
- [4] Y. Bai, J. Yu, S. Yang, and J. Ning, “An improved YOLO algorithm for detecting flowers and fruits on strawberry seedlings,” *Biosystems Engineering*, vol. 237, pp. 1–12, Jan. 2024, doi: <https://doi.org/10.1016/j.biosystemseng.2023.11.008>.

- [5] S. Khalid, H. M. Oqaibi, M. Aqib, and Y. Hafeez, "Small Pests Detection in Field Crops Using Deep Learning Object Detection," *Sustainability*, vol. 15, no. 8, p. 6815, Jan. 2023, doi: <https://doi.org/10.3390/su15086815>.
- [6] A. Elzebroek and K. Wind, Eds., "Guide to Cultivated Plants," Jul. 2008, doi: <https://doi.org/10.1079/9781845933562.0000>.
- [7] I. Apeinans, L. Litavniece, S. Kodors, I. Zarembo, G. Lacis, and J. Deksne, "Smart Fruit Growing Through Digital Twin Paradigm: Systematic Review and Technology Gap Analysis," *Engineering Management in Production and Services*, vol. 15, no. 4, pp. 128–143, Dec. 2023, doi: <https://doi.org/10.2478/emj-2023-0033>.
- [8] M. Arsenovic, M. Karanovic, S. Sladojevic, A. Anderla, and D. Stefanovic, "Solving Current Limitations of Deep Learning Based Approaches for Plant Disease Detection," *Symmetry*, vol. 11, no. 7, p. 939, Jul. 2019, doi: <https://doi.org/10.3390/sym11070939>.
- [9] A. Bochkovskiy, C.-Y. Wang, and H.-Y. Liao, "YOLOv4: Optimal Speed and Accuracy of Object Detection," Apr. 2020. Available: <https://arxiv.org/pdf/2004.10934.pdf>
- [10] Nicolaihaeni. (n.d.). GitHub - nicolaihaeni/MinneApple: A Benchmark Dataset for Apple Detection and Segmentation. [Online]. Available: <https://github.com/nicolaihaeni/MinneApple> [Accessed Jan. 3, 2024].
- [11] S. Kodors, M. Sondors, I. Apeinans, I. Zarembo, G. Lacis, E. Rubauskis and K. Karklina, "Importance of mosaic augmentation for agricultural image dataset", 2024.

INCOLAB information system for better management of ecosystems in the transboundary region of the Danube River

Milka Asenova

Regional Inspectorate of Environment and

Water – Veliko Tarnovo

Veliko Tarnovo, Bulgaria

milka_as@yahoo.com

Abstract. The article presents the INCOLAB information system for the management of four protected areas for the protection of wild birds included in the European ecological network Natura 2000 in the cross-border region of the Danube River - ROSPA0102 Suhaia and ROSPA0024 Confluence of Olt Danube - Romania, BG0002018 Ostrov Vardim and BG0002070 Ribarnitsi Hadzhi Dimitrovo - Bulgaria. The main purpose of its establishment is to support the control institutions in the decision-making processes and take measures to protect the protected areas and the protected species.

The process of creating the system, part of the Joint Bulgarian-Romanian Plan for the Management of the Four Protected Areas for the Protection of Key Bird Species, has been traced, as an innovative model for monitoring and reporting, a new approach for collecting, using and sharing technical, scientific and environmental data. The main functionalities of the information system and the available applications, both for the control authorities and the public, are presented.

The visualization of the components of the physical architecture of the information system allows a meaningful structured presentation of the process of building a database with information from different sources.

The main benefits of the common information system for the joint management of protected areas and cross-border cooperation are analysed.

Keywords: *database, incidents, inspections, key species, model, monitoring, Natura 2000, reporting*

I. INTRODUCTION

The development of information systems to support the processes of management, control and monitoring, and decision-making is a current trend in all areas of activity - educational and scientific research, early warning and notification of disasters and accidents, environmental monitoring, process management in branch and business organizations, the production

process, human resource management, etc. The “digital acceleration” [1] in recent years has been provoked by the aspiration to develop society, to achieve a stable and greener economy, to achieve sustainable growth.

The existing national information systems in the field of environmental protection in Bulgaria provide the necessary data for the analysis and assessment of the status of environmental components and factors. Available on the website of the Executive Environment Agency - <https://eea.government.bg/bg/dokladi/inf-systems>, they provide public access to information on the state of the environment and serve as a basis for the preparation of documents for the implementation of policies in this area both nationally and internationally.

For the specific needs of the control institutions (as exemplified by the Regional Inspectorate for Environment and Water - Veliko Tarnovo (RIEW) - a specialized territorial administration of the Ministry of Environment and Water - Bulgaria), systems are developed to support the effective performance of the main functions of the institutions in terms of “monitoring, analysis and communication” [2] in the ever-changing natural conditions. Moreover, “the multi-component, multi-factor nature of the management process raises the issue of appropriate data structures”, the use of which plays an essential role in management activity [3].

On the one hand, information systems and technologies give the opportunity to present and track the trends in basic indicators of the state of the environment, and on the other - support the analysis of processes that lead to impacts on ecosystems [4]. The fact is that modern man is increasingly required to make full use of them, both in the professional sphere and in everyday life [5].

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8019>

© 2024 Milka Asenova. Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

V. Kraeva et al. [6] note that the implementation of new technologies requires know-how that incorporates information about new technologies, economic effects and costs and best practices in their implementation.

According to Troshani et al. [7], „information systems are not standalone entities but contribute to environmental sustainability as part of the social and material relations that form the infrastructure underpinning environmental management practice“.

The aim of this study is to present, characterize and analyze the INCOLAB information system as an innovative model for transboundary environmental management. The relevance of the topic is related to the processes of digitization on a global scale, the transboundary and transnational movement of information and data exchange, which appear as an opportunity and resource for better ecosystem management, to support management decision-making and the provision of technologies to people.

Information system INCOLAB, the subject of this research, is one of the results of the project “Innovative and collaborative management of Natura 2000 sites in the Danube border region” (INCOLAB) ROBG-10 (<https://www.riosvt.org/project-interreg/>), financed by INTERREG V-A Romania-Bulgaria Programme and realized by two environmental partners, the National Environmental Guard, Romania - General Commissariat and the Regional Inspectorate for Environment and Water - Veliko Tarnovo, Bulgaria [8].

II. MATERIALS AND METHODS

Scientific publications in the field of implementation and development of information systems in different thematic areas and spheres of activity were studied for the purpose of the research. The theoretical analysis proves information systems’ relevance and significance for societal development.

The basis of the article is the material on the establishment and development of the information system INCOLAB, as part of the implementation of a Bulgarian-Romanian project for cross-border cooperation in the field of biodiversity conservation. The summaries and conclusions drawn are based on the author's personal experience as a direct participant in its implementation in the period 2016-2018 and in the process of subsequent reporting on its sustainability to date.

The information has been systematized, analysed and interpreted based on project documentation and empirical data obtained during work in a real environment. Problems and prospects for development are outlined.

III. RESULTS AND DISCUSSION

Development of INCOLAB information system

The protected areas included in the European ecological network Natura 2000 are designed to protect or restore the favourable condition of the natural habitats included in them, as well as of the species in their natural range. They are designated in accordance with two key European Union Directives - Directive 2009/147/EC on the conservation of wild birds (the Birds Directive) and Directive 92/43/EEC on the conservation of natural

habitats and of wild fauna and flora (the Habitats Directive).

The idea, set in Natura 2000, is that people are an integral part of nature and that it is best for them to interact. Economic activities are not prohibited, but should be limited in order to conserve valuable species and habitats.

Biodiversity is important in its own right, but it also provides a never-ending flow of goods such as food, fuel and medicines, and provides essential services such as climate regulation, flood prevention, water purification, pollination and soil formation. All of these things are necessary for economic prosperity, security, health and quality of life.

Economic pressures and inefficient management of natural resources are the cause of many activities in protected areas and zones, such as illegal exploitation, tourism, construction, poaching, industrial development, etc. These activities cause irreversible damage to the natural environment.

Within the framework of their power to implement and enforce the European environmental legislation, the employees of the National Environmental Guard and the Regional Inspectorate for Environment and Water - Veliko Tarnovo carry out preventive and control activities with regard to the conservation of biodiversity, of species of interest to the community, of the preservation of their integrity in the areas under protection. They carry out on-site inspections, according to an annual plan and on signals and incidents, and they have the right to issue mandatory prescriptions and to impose fines and penalties on violators. A database with information and documents is maintained for each site.

The involvement of the public in monitoring process further contributes to protection and conservation of birds and habitats, of the ecosystems as a whole.

The objectives and resources of the INTERREG V-A Romania-Bulgaria Programme have enabled the development of innovative cooperation measures in the cross-border Danube region, expressed through joint planning, management and the creation of modern, coordinated instruments related to biodiversity conservation, landscape protection and the promotion of protected areas of the European Natura 2000 network.

To understand the philosophy of creating an INCOLAB information system, we provide brief information about the project (Table 1).

The selection of the four sites has been made on the basis of their similarity as habitats for important bird species and because BG0002018 Ostrov Vardim and ROSPA0024 Confluence of Olt Danube are close to the Danube border area and have the same characteristics, BG0002070 Ribarnitsi Hadzhi Dimitrovo and ROSPA0102 Suhaia are used for fish farming. In addition, anthropogenic activities with potential negative impacts on populations are common - poaching, change of land categories used near water bodies, influence of external factors such as avian influenza, etc.

TABLE 1 BRIEF INFORMATION FOR THE PROJECT "INNOVATIVE AND COLLABORATIVE MANAGEMENT OF NATURA 2000 SITES IN THE DANUBE BORDER REGION", ROBG-10

Overall project objective	Sustainable management of ecosystems in European Natura 2000 protected areas by establishing a joint model for their better planning, conservation and use in the transboundary Danube region, introducing a common approach to biodiversity conservation and supporting transboundary investments in Natura 2000 sites.
Outcomes of the project	<ul style="list-style-type: none"> ➤ better administration of Natura 2000 sites and their surroundings; ➤ support for common management through an established information system; ➤ achieving a better conservation status of 27,046 ha of protected areas for the conservation of wild birds - BG0002018 Ostrov Vardim (1,167 ha) and BG0002070 Ribarnitsi Hadzhi Dimitrovo (446 ha) in Bulgaria and ROSPA0024 Confluence of Olt Danube (20,960 ha) and ROSPA0102 Suhaia (4,473 ha) in Romania; ➤ raising public awareness of Natura 2000 sites.



Map 1. Protected sites along the Danube river, included in the project (in Bulgarian)

And here is the place of information system INCOLAB – it is constructed in a way to allow the structured management of all information about the four protected areas - building a database with information from different sources, recording information about events/ incidents with environmental impact in the protected areas and which may require the intervention of the two institutions, within their competences.

The process of development the system went through the following phases:

- provision of data by conducting preliminary and field surveys, mapping and preparation of an assessment of the conservation status/security status of the bird species subject to conservation in protected areas BG0002018 Ostrov Vardim, BG0002070 Ribarnitsi Hadzhi Dimitrovo, ROSPA0024 Confluence of Olt Danube and ROSPA0102 Suhaia;
- preparation of an Action Plan with measures to maintain and restore the favourable conservation

status of the habitats and populations of bird species. Preparation of a Monitoring Plan with a timetable for the implementation of the proposed measures and monitoring route maps to serve the two monitoring institutions;

- preparation of a Joint Management Plan for the four ecosystems in the transboundary Danube region;
- development of an information system to support the implementation of the Joint Management Plan.

The information system is intended for use by the following categories of users:

- employees of the territorial structures of the National Environmental Guard and of the Regional Inspectorate for Environment and Water - Veliko Tarnovo;
- operators of protected areas in Romania;
- citizens who report violations/ incidents through the public portal or the smartphone app in Bulgaria and Romania.

The information system is customized for the National Environmental Guard and the RIEW - Veliko Tarnovo - it has a dual administration and interface. P. Milev mentioned that “the implementation of web-based user interfaces implies the application of appropriate logical software architecture” [9]. In our case, it covers and manages the following types of information: about protected areas and protected species in them, users of the system, register of permits in force in the protected area, database of reported violations/incidents, register of sanctions imposed by the experts, reports and protocols with findings issued by control institutions as a result of planned and unplanned inspections. That information can also be visualised in a geographical context. The possibility to produce reports based on the information entered in the system is available.

Architecture of the information system INCOLAB

The physical architecture of the system is presented in Fig. 1:

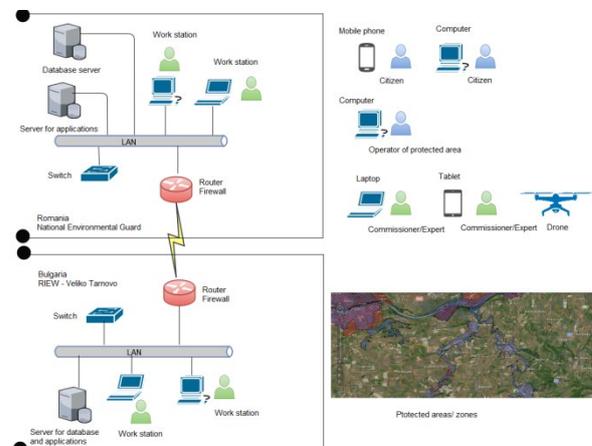


Fig. 1. The physical architecture of the INCOLAB information system

The main components of the system, required by the two administrations, are physical servers (server for applications and database management server), stationary work stations, the existing local LAN, existing switch, laptops, tablets, drones, routers with firewall.

The main components of the system required for citizens' use are:

- tablet, mobile phone - any person interested in finding information regarding protected areas or in reporting incidents noted in the field can download the INCOLAB client application on his mobile phone from the Google Play Store. The Android app is free.
- work station - citizens can use the public web interface of the software application through the external portal of the application server of the control institutions. The public portal can be accessed from any citizen's personal workstation, respectively in Romania and Bulgaria at the following addresses - <https://incolab.gnm.ro/> and <https://incolab.vt.riew.gov.bg/>

It is important to note that public participation, as a source of preliminary data for the common information system, is a new innovative and psychological approach that can make significant changes in the way these areas can be preserved in the future - in the transboundary Danube region that needs common protection. Despite the existence of the system, its use by users is still limited.

We should underline, that the public web interface and the mobile application have an easy to understand and use menu in Bulgarian, Romanian and English languages, and short instructions for the interface have been prepared and published to help the user.

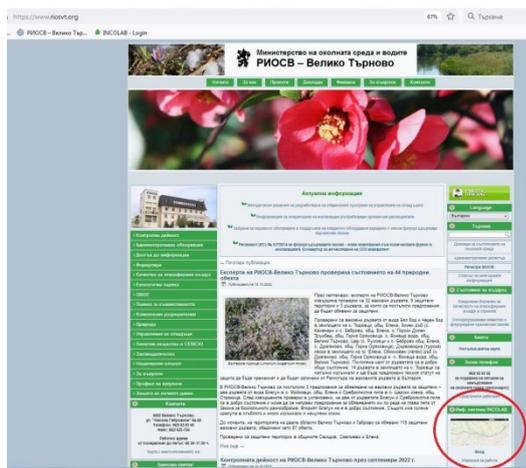


Fig. 2. View of the INCOLAB public web interface on the RIEW-Veliko Tamovo website - <https://incolab.vt.riew.gov.bg/>

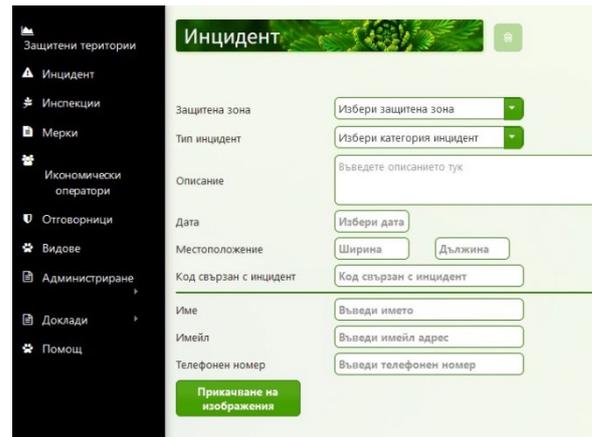


Fig. 3. View of the menu for reporting incidents in INCOLAB public web interface (in Bulgarian)

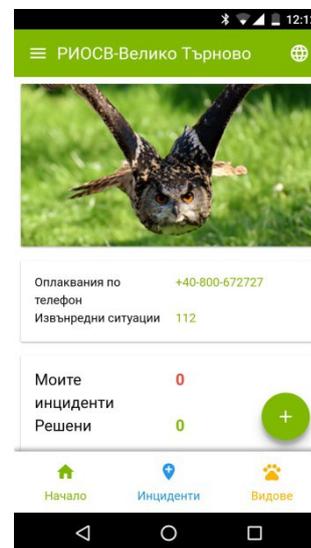


Fig. 4. View of the INCOLAB mobile application in Google Play Store (in Bulgarian)

There are seven main conceptual modules of the INCOLAB system:

1. *System Infrastructure Module* - supplies the central hardware platform, the underlying software platform and the communication platform to allow the implementation of the specific functionalities of the system; supplies the individual equipment for users to allow them to access the functionalities of the system (laptops, tablets);
2. *INCOLAB platform administration and access Module* - implements the administration functions of the software platform, including the defined parameters; manages the management of user authentication and the granting of usage rights; allows access to the different functional modules of the platform; implements the management of the application logs;
3. *Protected areas Module* - allows the definition and updating of their types and characteristics, including the attachment of photographs; allows the definition of areas, including their perimeter in the form of GIS

(Geographic Information System) coordinates using map mode;

4. *Incident Module* - allows the registration of incidents within the platform, both through the public web interface of the portal and the use of the smartphone application; allows the management of the process of tracking and dealing with incidents;

5. *Inspections/verifications Module* - allows the recording of the results of inspections carried out by the environmental commissioners/experts through inspection reports and findings; allows the recording of information relating to the inspections carried out, including penalties imposed;

6. *Map Module* - includes the GIS technology elements that allow the import of the outlines of the protected areas, the display of vector features and the base map, and the localization on the map using GPS coordinates of incident information;

7. *Reports Module* - includes functionality to search for information by alphanumeric or spatial criteria, allows query results to be displayed both in alphanumeric format and on a map background.

As the information system is accessible via the Internet, functionalities have been implemented to collect and analyse potential security incidents, including the identification of malicious behaviour or attempts to use the system inappropriately.

System operation in a real environment

In general, no reports of violations in the two protected areas BG0002018 Ostrov Vardim and BG0002070 Ribarnitsi Hadzhi Dimitrovo, such as fire, destruction of nests, littering, pollution, dead animals/birds, poaching, destruction of vegetation, trees and shrubs, unauthorized picnicking, etc., have been received by the RIEW through any communication channel - telephone, e-mail, information system. The areas have limited access as they are island and fishponds, which does not imply frequent violations of the regimes in their use and management.

The staff of both environmental institutions records data in the system on planned annual spot checks carried out.

The situation is similar on the Romanian side, for protected areas ROSPA0024 Confluence of Olt Danube and ROSPA0102 Suhaia.

The lack of administrative capacity to manage the INCOLAB information system and financial resources to maintain it is proving problematic for its long-term use. Direct access to the internal architecture of the system is needed from each control institution - user of the system for continuous updating of software applications, for changes in the structure of the database, for ensuring the security of shared information.

Perspectives for the INCOLAB information system development

With regard to the multiplication of the system, the following ideas are embedded:

1. Application to other sites in the European Natura 2000 network

The model for developing a common management strategy and information system for the four sites could be applied to all other sites in the Bulgarian-Romanian border region. To scale up, investments related to technical upgrades of equipment, training of users, and technical updating of the system to allow inclusion of new sites are needed.

2. Benefits of common management and cross-border cooperation

The common management and cross-border cooperation approach in an innovative way creates a real basis for new common projects to the benefit of all participants. The expectation is to increase the speed of solving cases that involve common competences on both sides.

3. Setting reporting standards and monitoring tools for the territory

The information system sets a model standard for cross-border data exchange, reports, templates and represents a new type of monitoring tool.

IV. CONCLUSIONS

The INCOLAB information system has been developed as an innovative model for monitoring and reporting on the status of protected areas of the Natura 2000 network for the conservation of wild birds. The recording of facts, data and information from different sources in the Bulgarian-Romanian part of the Danube River aims to implement a new approach in the management of these areas, to allow the exchange of information and data between the control institutions of both countries to serve for interpretation, analysis and preparation of joint reports.

The work in real conditions has shown that the system needs to be promoted, expanded, continuously maintained and serviced for the real exercise of transboundary cooperation with common management and sharing of technical and scientific data.

“Faced with the challenge of the global information society” [10], administrations continue their efforts to digitize and automate processes, data and services, including the search for financial instruments to improve the INCOLAB information system for its effective use for monitoring and reporting purposes.

REFERENCES

- [1] T. Draganova, Application of the electronic platform Wordwall in the teaching of geography and economics in the lower secondary stage (on the example of the hidden text): Scientific conference “Knowledge, science, innovation, technology”, April 28, 2023, Veliko Tarnovo. 2023
- [2] G. Ilieva, Management Information Systems, Plovdiv: Paisii Hilendarski University Press, 2016
- [3] R. Tsankova and S. Georgieva, Information technologies in environmental management, Sofia: BULAVARK, 1998
- [4] R. Petkova and V. Kamburova, “Drinking Water Information System in Bulgaria - Need, Opportunities and Applications”, Available: https://www.researchgate.net/publication/305445478_Info_rmacionna_sistema_za_pitejnite_vodi_v_Blgaria_-

- [_neobhodimost_vzmoznosti_i_prilozenia](#) [Accessed February 22, 2024]
- [5] T. Draganova, Model for rules in preparing a presentation on the educational content of geography and economics in IX grade and its presentation: Second International Scientific Conference "Geographical Sciences and Education", 1-2 November 2013, Shumen, 2013
- [6] V. Kraeva, P. Emilova, N. Marinova and A. Lalev. Adaptation of the information system of the tourist company to the modern economic conditions: Dialog Magazine, INI, Extra thematic issue, 2010
- [7] Indrit Troshani, Bill Doolin, Karl Fradley Giselle Rampersad, Information systems, sociomaterial practices and the emergence of environmental management infrastructures. Available from: https://www.researchgate.net/publication/364320229_Information_systems_sociomaterial_practices_and_the_emergence_of_environmental_management_infrastructures [accessed Apr 09 2024]
- [8] M. Asenova, N. Petkova, Sv. Stanchev and V. Yordanova/ RIEW-Veliko Tranovo, Better management and monitoring of ecosystems in the Danube border area – joint approach, joint actions, Veliko Tarnovo: Faber Ltd., 2017
- [9] P. Milev, Technological features of an information system for reporting and reviewing scientific projects: Economic and social alternatives, number 1, 2022, DOI: <https://doi.org/10.37075/ISA.2022.1.06>
- [10] T. Draganova, The application of information and communication technologies in the teaching of geography and economics in IX grade and a misconception about their preparation and presentation: XIV National Pedagogical Forum with international participation "Education for the future, future for education", 20.06.2013, Stara Zagora, E-Journal "Pedagogical Forum"

Extended User Profiling Approaches for Recommendation Systems

Fayzi Bekkamov

Library Information Systems

Tashkent University of Information Technologies named after
Muhammad al-Khwarizmi

Tashkent, Uzbekistan

bfayzi93@gmail.com

Yashin Sharifov

Optical Communications Systems and Network Security

Karshi branch of the Tashkent University of Information
Technologies named after Muhammad al-Khorezmi

Tashkent, Uzbekistan

sharifovyashin@gmail.com

Abstract. Currently, the volume of data in information systems and the information needs of users are increasing. This causes information overload and a number of difficulties in finding the necessary information. Therefore, individual approaches, including personalization of user profiles, are important in solving this problem. Creating a user profile is relevant for obtaining information from systems in accordance with the needs of the user and for personalizing the services provided by the system. The lack of direct user profiling in information systems creates a number of problems in providing personalized services to users. Around the world, recent research has focused on developing systems that personalize user profiles based on their data sets. The work done so far on a global scale to create and model user profiles is analyzed. In this article, mathematical algorithms such as TF-IDF, Cosine similarity, Word2Vec are used to model and personalize user data. It also provides a classification scheme for user profiling, modeling and personalization. This classification scheme is based on three components. These are user data collection, user profiling, modeling and personalization components. Additionally, the article also mentions the benefits of user identification.

Keywords: user profile, user profile modeling, personalization, information need, semantic connection, similarity, ontology.

I. INTRODUCTION

Currently, as a result of the increase in the volume of data in information systems, users experience information overload. This forces users to spend a lot of time searching for information that matches their information needs and creates demands for personalization approaches that match the user's information search profile. Personalization requires first creating and modeling user profiles. Typically used for user profiles, user data modeling, and personalization. User profiles reflect an individual's personal information, demographics (name, age, country, gender, language, profession, academic background, etc.), as well as their interests and preferences.

User profiling is widely used in various search engines, user identification, personalization, recommendations, intelligent learning systems, data filtering. User profile information varies depending on the information content in the information systems field. That is, the user's profile information is updated dynamically depending on his interests. When communicating with users, information systems should include the study of their behavior (topics of interest, social relationships, user evaluations, and goals) [1, 3].

As a result of taking into account the interests of users, user modeling becomes possible. User modeling is the process of collecting user browsing history data from open systems, creating user profiles, storing and testing systems. For example, recommendation-oriented information systems capture the characteristics of registered users, find similar users based on input data, and offer personalized information and services that ultimately satisfy users' information needs. There are two main approaches to user modeling [5, 12]:

- create an initial profile for a new user;
- keep profile information up to date in accordance with the constantly changing interests, preferences and information needs of users.

These two approaches must be fully implemented since user modeling is done based on profile data (based on the above approaches).

Based on user data, personalization is carried out as a result of creating a profile and modeling the user. Personalization mainly relies on two types of user profiles: static and dynamic profiles. Static personalization does not take into account the initial registration of users from information systems and the creation of a profile, and then the needs and interests of users. As a result, systems recommend irrelevant information and services to users. Because the information needs and interests of users change over time.

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8052>

© 2024 Fayzi Bekkamov, Yashin Sharifov. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

Dynamic personalization overcomes the shortcomings of static personalization, that is, it constantly learns the interests and information needs of users and provides services to users based on their characteristics. Dynamic personalization uses clustering and classification algorithms to create user profiles.

II. MATERIALS AND METHODS

For profiling, modeling and personalization of users, a generalized classification scheme is created (Figure 1). This classification scheme is based on three components:

- Data collection;
- Creating and modeling user profiles;
- Personalization.

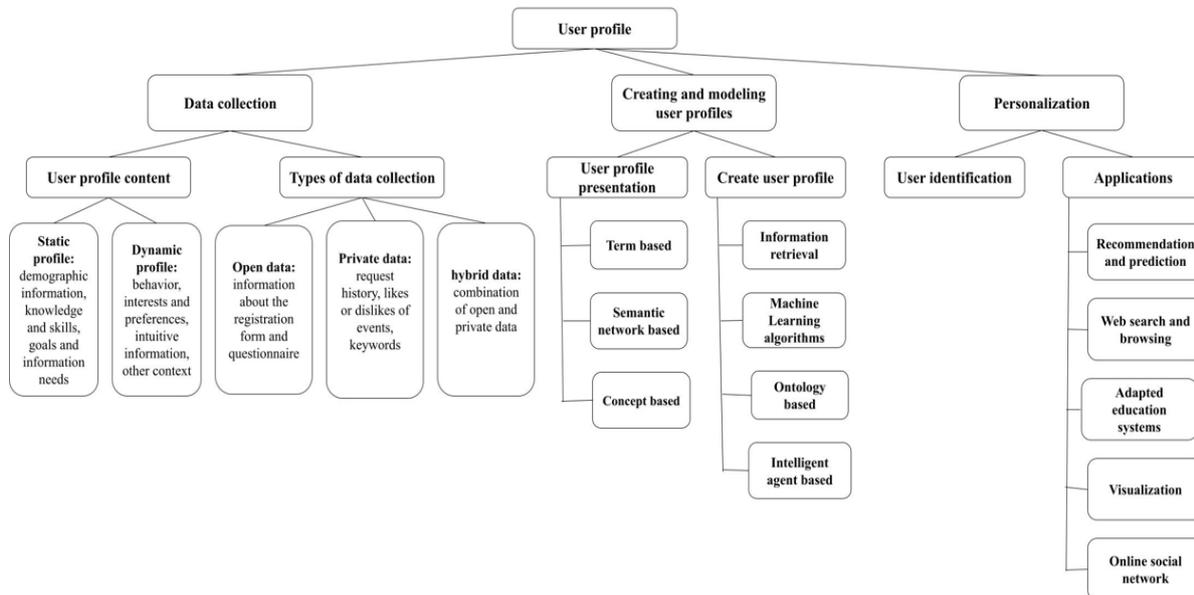


Figure 1. Classification scheme for user profiling, modeling and personalization

III. DATA COLLECTION

The main step in creating a user profile is collecting information about the user. Collecting information from users of information systems, studying their characteristics, information needs, and knowing their interests is an important task in creating personalized systems. Depending on the nature of the data, personalization is carried out. User profile data and data properties must be mutually exclusive [1, 4].

User profile content

A user profile contains various information, including the user's personal information, knowledge and skills, information needs, user goals, behavior, interests, preferences, etc. The following are several types of information for a user profile:

Demographic information. User demographic information includes first name, last name, middle name, country, language, age, gender, education, family members, social background. Demographic information is very important when creating a user profile.

Knowledge and skills. User knowledge and skills are important for student modeling in online learning systems. Students' knowledge is the main feature that determines the appropriate teaching system, and it is important to support them in the subject being taught, give appropriate instructions and adapt the lesson content. Today, some organizational systems take into account the knowledge and skills possessed by users and determine whether a suitable vacancy is available [2, 5].

Goals and information needs. User intent can be determined by their search history in the information systems and applications they use. Information needs are a situation when a user makes a request to search for information in systems (issues a request for an advanced search), with the goal of obtaining the necessary information from systems. Keywords are entered into the search by users, and ratings are recorded by the systems on the server. This is important to provide information and recommendations that match the user's profile and exactly what is needed.

Behavior. Behavior is one of the important pieces of information when creating a user profile. Because many artificial intelligence systems use three types of behavior to determine user behavior: reviews (opinions), ratings and psychological studies (tests, questions, questionnaires). Feedback (opinions) left by the user is one of the main indicators that determines his behavior. Popular social networking systems develop personalized recommendation content based on user feedback.

Interests and preferences. People's interests and preferences are important data when personalizing user profiles. Users' interests may be related to social connections, site names, page topics, sections of information systems, topics in social networks, groups. Also, people's preferences can be obtained from the history of e-commerce systems and from the history of viewing video content. Users' preferences for profile data are modeled based on their short-term and long-term activities. Modeling of long-term activity is mainly carried out in relation to the Google system, that is, created using Google feed themes. Short-term activity

models are created using the history of caches that users have clicked on in information systems.

Intuition data. Intuition plays a key role in user profiling, and data management is carried out without mathematical algorithms. Users' intuitions often shape initial perceptions of resources and services. When creating a user profile, their intuitive characteristics are determined. These signs are the choice of language, a history of continuous visions, the type of mental activity and the ability to think logically. Intuition helps users decide whether to trust a website or brand. It's like an internal compass that helps users navigate cyberspace. Intuition allows users to quickly make decisions, reason, and quickly sort and process information. Gut feelings help users connect emotionally with a resource and service. User profiling is not just about data, but also about understanding the person behind the profile.

Other contexts. It is important to describe the content of resources in information systems. The general and summary content of the resource is considered user profile information. Also, the location of users is important as contextual information in social networks. Because the location information of users can be accurately provided. In this case, source addresses and user locations are compared, and relatively similar information is presented in the form of a user profile feed. Social networks collect information about the psychological state of users, what they like or dislike (like/dislike), as well as emotional data. Some social networks have found that users' emotions directly influence how they use the system. All of this is important information for modeling the user profile in the context of the type. This type of information is then used to provide users with the information they need [6, 8].

Types of data collection

Data collection is carried out in normal, automatic and semi-automatic modes, respectively. The accuracy of user profile data depends on the amount of data generated as a result of user interaction with the system. In addition, the personalization stage reflects how, where and when to use the collected data. There are three types of data collection methods [4, 6]:

- open data;
- private data;
- hybrid data.

Open data. Data collection using open data is carried out directly in connection with the user himself. Registration of users from the information system, requests entering the system, pages divided into categories, assessments of system resources, storage of request history - data collection using an open method. For example, Amazon's system asks users to leave reviews and ratings for resources and services. Amazon then uses the information collected in this open manner to provide personalized recommendations to users. Open collected data is also used to determine user preferences in recommender systems. Some information systems use query keyword extraction, user reviews, and messages saved on social networking pages to express user interests. Data collected in an open manner is also static in that it remains valid until the user explicitly changes

his or her interests and preferences. Additionally, this method is limited to asking users to indicate their interests using keywords.

Private data. Regarding private data, information about the user's interests is usually learned automatically. Online information systems automatically collect user data. Automatic data collection differs from static mode, in which system usage history is collected from system to system on a regular basis. By creating a user profile based on the information collected in private data, personalized search and recommendations are successfully implemented. Information is generated from personal data by tracking the user's profile browsing history, time spent on each page, and user history. Private data collection is currently supported by internet browsers and collects all user actions on the system server.

Hybrid data. Hybrid data is collected semi-automatically with limited user intervention. Information systems collect information from users based on a hybrid approach, using open and hidden methods. This approach is necessary for effective user profiling and timely and accurate data collection. A user profile is created by combining users' personal information, opinions, interests, history of queries entered into systems, and users' history in the system log. Data collection based on this method is carried out by combining open and private methods.

IV. CREATING AND MODELING USER PROFILES

User profile presentation. The second stage of the user profile is the creation and modeling of the user profile based on the collected data. The collected data is processed using mathematical algorithms and plays an important role in modeling the user profile. A user profile view is a collection of pre-collected data that reflects a user's interests. Modeling the user profile representation is carried out in three ways: term-based modeling, semantic network based and concept based modeling methods [8].

Term based. A user model based on keywords and terms generates digital vectors using the TF-IDF algorithm for texts in information systems. User input and saved query data is converted into a vector representation (Word2Vec) and then similarity algorithms (Cosinus, Jacquard, etc.) are discovered. Texts in information systems based on the user's request, that is, keywords, can be sorted by user profile information using TF-IDF algorithms. In this case, the TF-IDF algorithm evaluates to the value range [0,1].

$$TF_{td} = \frac{n_{td}}{\sum_k n_{td}} \quad (1)$$

Here, TF – number of frequencies of the word in the document, t – text, d – document.

$$IDF(w) = \log\left(\frac{N}{DF_t}\right) \quad (2)$$

Here, $IDF(w)$ – number of documents containing words.

$$W_{t,d} = TF_{t,d} * \log\left(\frac{N}{DF_t}\right) \quad (3)$$

After the query data entered by the user is converted to Word2Vec, the user profile is modeled using similarity algorithms. Cosine similarity is expressed in the following order.

$$Sim(u, v) = \frac{\sum_{i \in I(R_{u,i})(R_{v,i})}}{\sqrt{\sum_{i \in I(R_{u,i})}^2} \sqrt{\sum_{i \in I(R_{v,i})}^2}} \quad (4)$$

The similarity of Jaccard is expressed in the following:

$$Sim(u, v) = \frac{|R_u \cap R_v|}{|R_u \cup R_v|} \quad (5)$$

Similarities are measured using these similarity algorithms. The TF-IDF algorithm analyzes requests to information system user profiles and provides customized data sequences.

Semantic network based. Users face problems of polysemy and synonyms when entering queries using keywords in information systems. To overcome these problems, user profiles are linked to the semantic web and each node in the network is weighted. An ontology must be built between the semantic web, user interests, and query history. For example, the WordNet system created an ontology-based user profile model based on user interests and queries. An ontology-based knowledge base of user profiles greatly simplifies working with the semantic web model.

Concept based. Concept-based user profile models are similar to the semantic web model, in which no ontology is built. In this model, semantic network nodes and relationships between nodes are important to the user's profile. Conceptual models are used to determine the user's level of interest in a topic. This model can also use TF-IDF algorithms to weight user profile queries.

Create user profile

There are two important concepts to consider when creating a user profile: first, what data sources users use for what purposes, and second, how to create a user profile using the selected data sources. Research shows that four concepts are important when creating user profiles today. These are data search, approaches based on machine learning algorithms, creation of ontologies, approaches based on intelligent agents. User profiles are created based on interests and preferences. Additionally, the four concepts above may not be fully utilized when creating user profiles. Profile information must be updated to ensure that the chosen construction method accurately reflects users' preferences.

Information retrieval. Information retrieval plays an important role in user profiling as it allows information systems to collect relevant information about user preferences, behavior, interests and demographics. Information retrieval helps collect information about user interactions, such as search queries, browsing history, and content preferences. By analyzing user interaction data, information systems can build a database of their goals and interests. This database allows for more specific recommendations and suggestions, tailored to users' preferences and goals after creating a profile. With user profiles, information systems can operate more efficiently by consistently providing relevant notifications, updates, and alerts based on users' interests and past interactions. In addition, information retrieval

allows you to match resources based on user profiles. This improves the recommendations of relevant resources for individual users, which improves user satisfaction.

Machine Learning algorithms. Machine learning algorithms are widely used to classify documents in information systems into topics to create user profiles. The resulting topics are used as keywords and concepts to create user profiles. In information systems, decision trees, Bayesian classifiers, and K-nearest neighbors (KNN) machine learning algorithms are used to identify document topics by learning classifications from a set of documents matching a user's query. Machine learning algorithms KNN and Bayesian classifier play an important role in creating user profiles through efficient analysis and classification of data. KNN is a simple algorithm used for classification task. This algorithm is useful for creating user profiles and is based on the similarity of data points. When creating user profiles, KNN can be used to find similar users based on various characteristics and attributes. For example, given a dataset of user goals and behavior, KNN identifies users with similar preferences by measuring the distance between their feature vectors. When creating user profiles, a Bayesian classifier is used to classify users into different categories and segments based on their information and behavior. For example, in e-commerce platforms, Bayesian classifiers are used to segment users based on their purchasing history, browsing behavior, such as frequent shoppers, occasional shoppers, and non-buyers.

Ontology based. In user profiling, an ontology is a formal representation of knowledge in a specific domain of data representation. Ontologies provide a common framework for describing concepts and relationships that facilitate interaction between different systems and applications. Creating an ontology is useful in situations where user profiles need to be shared and integrated across multiple information systems. Creating an ontology to represent user preferences, interests, and behavior is essential for personalized user profiling recommendations. Ontology-based user profiles enable information systems to understand the context of user actions and provide tailored recommendations and services. Ontology creation is also useful for tasks such as identifying inconsistencies in user profiles, identifying latent user preferences, and predicting future behavior based on historical data. Ontology-based approaches play an important role in creating user profiles by providing a structural and semantic representation of user data, facilitating interaction, enabling personalization, supporting data integration, and enhancing reasoning and inference capabilities [8, 13, 15].

Intelligent agent based. In the context of user profiling, agent-based approaches play an important role. Intelligent agents collect information about users and create user profiles. These profiles capture users' preferences, behavior, and context. Using data mining and ontologies, profiles can be created with context updates. These updated profiles provide a personalized experience and a better understanding of user needs. By learning relevant contexts based on user behavior, intelligent agents dynamically adapt. Ontology segments represent these relevant contexts. The integration of intelligent agents, data mining and ontologies improves

overall user profiling performance. Intelligent agent approaches enable users to create more informed and context-sensitive user profiles, leading to more personalized services and interactions.

V. PERSONALIZATION

The third step will be to use the information in the user's profile to provide personalized services. Once a user profile is created, personalized recommendation systems are used to provide personalized services in search, social media, and various service delivery processes [10].

User identification. Accurate user identification is critical to any information system that creates profiles representing individual users. With personalization, usernames, email addresses, and passwords form the basis of user identification. This information provides access to personalized services and content. Age, gender, location, nationality and preferences help identify the user. Demographic data helps create initial user profiles. A user identification allows you to personalize behavior by associating behavior with specific people. Personalization, when information systems recognize a returning user, can tailor content and recommendations. For example, an e-commerce system greets the user by name when he logs in, suggests products based on past purchase history, meaning the system remembers the user's preferences. This process is performed using the user identification. User identification is the foundation of effective personalization.

Applications

Recommendation and prediction. Recommender systems and predictions are essential for personalization. Recommender systems provide users with personalized resources and services based on their preferences, behavior, and historical data. Users feel understood (observed) when information systems offer relevant resources (movies, books, products). For example, the Netflix system suggests shows and movies based on viewing history and user profile ratings. And Amazon recommends resources based on your browsing and purchase history. Predictive systems allow information systems to adapt to user profiles in real time. For example, predicting share prices based on stock market trends [7].

Web search and browsing. Searching and browsing play an important role in personalizing and shaping users' online experiences. When you enter a query into a search engine, it returns results tailored to the users' profile rather than generic results. However, remembering previous searches and visited websites helps the user understand your interests. It takes into account social interactions to better understand user preferences. In addition to search, website personalization customizes the entire site experience for each user. Personalized search is the process of searching a collection of documents and web pages based on the user's interests and preferences. User interest is generated by analyzing the websites that users search for.

Adapted education systems. Adapted education systems play an important role in improving personalized

learning experiences. Adapted education systems organize individual lessons for students, taking into account their different levels of knowledge. They dynamically adjust the learning period based on each student's mastery of concepts. Adapted education systems do not follow a curriculum, these systems determine areas of learning based on individual needs, abilities and preferences [9, 14].

Visualization. In modern information systems, decision making is often based on data. Visualization allows us to understand complex information by representing it visually. Effective user profiling requires the creation of accurate user models. Visualization helps to visualize these patterns. Graphs and charts can display user attributes, preferences, and interactions with other people. The user profile reports personalization activities. And visualization helps to understand which features are important to users. Real-time visualization enables dynamic adaptation. As user behavior changes, customizing profiles and personalizing experiences becomes important. Visualization allows users to create meaningful user profiles, improve personalization, and deliver personalized experiences.

Online social network. Online social networks generate large amounts of data through user interactions, messages and connections. This information provides relevant information about the user's behavior, preferences and interests. Online social networks allow you to create complete user profiles. These profiles include individual characteristics such as demographic information, interests, and social connections. Analysis of social connections (friends, groups) helps improve user profiles [11].

VI. CONCLUSION

This article provides some information on the creation, modeling and personalization of the advertiser profile. A classification scheme for the user profile is given. Classification scheme organizers, data collection, user profiling, and personalization steps were analyzed. The first step of the classification scheme includes user profile content and data collection approaches. Information about static and dynamic profile views of user profile content has been provided. Including static profile data, demographic data, knowledge and skills, goals and information needs were analyzed. Dynamic profile data is divided into behavioral data, interests and goals, and other types of contextual data. Data collection approaches are divided into open data, closed data, and hybrid data. Registration form and survey data are open data, query history, event likes and dislikes, keywords are private data and the combination of open data and private data is hybrid data.

The second stage of the classification scheme involves presenting the user profile and creating a user profile. The user profile presentation included information about Term Based Models, TF-IDF Algorithm, Word2Vec Algorithm, Cosine and Jaccard Similarity Algorithms, Semantic Network Based Models, and Concept Based Models. While creating the user profile, detailed information was provided on data mining, machine learning algorithms, KNN algorithm,

Bayesian classifier, ontology based models, intelligent agent based models.

The third level of the classification scheme includes user identification, applications, recommendation and prediction systems, web search and browsing, personalized learning systems, visualization, and personalized private network.

REFERENCES

- [1] Jianqiao Hu, Feng Jin, Guigang Zhang, Jian Wang, and Yi Yang. 2017. A User Profile Modeling Method Based on Word2Vec. *IEEE International Conference on. IEEE*, 410-414
- [2] Jyoti Shokeen, Chhavi Rana, A study on features of social recommender systems. © Springer Nature B.V. 2019
- [3] Madadipouya K., Chelliah S., A Literature Review on Recommender Systems Algorithms, Techniques and Evaluations. *BRAIN: Broad Research in Artificial Intelligence and Neuroscience*, ročník 8, č. 2, July 2017
- [4] Rustamov A, Bekkamov F, Recommender systems: an overview, *Scientific reports of Bukhara State University*, 2021/3(85)
- [5] Marat Rakhmatullaev, Sherbek Normatov, Fayzi Bekkamov, Fuzzy model for determining the information needs of library users, *Environment. Technology. Resources*. 14th international scientific and practical conference. June 15-16, 2023, Rezekne Academy Of Technologies, Rezekne, Latvia
- [6] Elahi, Mehdi; Ricci, Francesco; Rubens, Neil. A survey of active learning in collaborative filtering recommender systems. *Computer Science Review – via Elsevier* 2016
- [7] Marat Rakhmatullaev, Sherbek Normatov, Fayzi Bekkamov, Tavsia etish tizimlarining umumiy tahlili, *Raqamli Transformatsiya va Sun'iy Intellekt ilmiy jurnali*, VOLUME 1, ISSUE 4, DECEMBER 2023.
- [8] Susan Gauch, Mirco Speretta, Aravind Chandramouli, Alessandro Micarelli, User profiles for personalized information access. In *The adaptive web*. Springer, 2007
- [9] Deborah L. Taylor, Michelle Yeung, A. Z. Bashed, Personalized and Adaptive Learning, *Innovative Learning Environments in STEM Higher Education* (pp.17-34), 2021
- [10] Matthew Montebello, *User profiling and Personalisation*, Springer 2017
- [11] Justin Gilbert, Suraya Hamid, Ibrahim Abaker Targio Hashem, Norjihan Abdul Ghani, Fatokun Faith Boluwatife, The rise of user profiling in social media: review, challenges and future direction, *Social Network Analysis and Mining Springer* (2023)
- [12] Sara Ouafitoh, Ahmed Zellou, Ali Idri, User profile model: a user dimension based classification, 2015 10th International Conference on Intelligent Systems: Theories and Applications (SITA), 10.1109/SITA.2015.7358378
- [13] Y. Elalloui and O. El Beqqali, User profile Ontology for the Personalization approach, *International Journal of Computer Applications*, Volume 41, 2012
- [14] Soulef Benhamdi, Abdesselam Babouri, Raja Chiky, Personalized recommender system for e-Learning environment, © Springer Science+Business Media New York 2016
- [15] John K. Tarus, Zhendong Niu, Ghulam Mustafa, Knowledge-based recommendation: a review of ontology-based recommender systems for e-learning, © Springer Science+Business Media Dordrecht 2017

Network attack recognition using fuzzy logic

Angela R. Borisova

Computer Systems and Technologies Department
National Military University
"Vasil Levski", Faculty "Artillery, Air Defense and CIS"
Shumen, Bulgaria
arborisova@nvu.bg

Abstract. The following research paper presents a fuzzy logic system model related to classifying network traffic as malicious or normal. The relevance of the problem stems from the increasingly widespread worldwide problem, namely cyber threats against various companies, organizations, individuals, etc. and at the same time the use of artificial intelligence systems as a means of detecting and preventing various types of cybercrime. To accomplish the task, several basic work methods are followed: first, the development goal is defined - building a fuzzy logic system that supports and automates decision-making about the type of network traffic (malicious or normal traffic), second, appropriate software is selected to perform the task, in this case MATLAB and specifically the Fuzzy Logic Designer toolbox, third, the actual system is built consisting of pre-obtained network traffic inputs that are taken from a pre-collected and compiled .pcap file (the data in it are captured and modified to contain only some network information fields from the set of packets necessary for the experiment to run successfully), the system itself consists of nine input linguistic variables, one output linguistic variable and a knowledge base (the core of the project, namely if-then rules). The studied system is compared with other similar fuzzy output systems of other researchers. Based on this, it is concluded that the approach proposed in the present work to categorize network traffic, based on pre-selected network information fields, in collaboration with other means of cyber protection gives very good results in the context of cyber security.

The present project proposes a fuzzy inference system to classify network packet types and detect TCP-SYN attack. The fully built fuzzy source system provides a different perspective to solve the present problem by defining the abstract solution and facilitating the work of specialized personnel charged with such tasks by automating the process of providing an adequate solution regarding the legitimacy of network traffic.

Keywords: artificial intelligence, fuzzy logic system, network traffic analysis, TCP-SYN flood

I. INTRODUCTION

The urgency of the problem lies in the ever-growing cyberthreats, both with regard to large Internet giants and

commercial, non-profit and governmental organizations, as well as with regard to the average user. The need for a quick and adequate response to protect their data from bad actors forces the systems used to provide protection to rely on the increasing power of artificial intelligence [9].

Security comes with additional question, stressing out cybersecurity as Internet and other media is on the infrastructure core. Attacks by hackers against various organizations and individuals in general are becoming more massive and widespread, and potential attackers can be both organized criminals and amateurs who have decided to play a prank on someone [2]. A few examples can be given in this regard: Continuously sending the same messages to multiple email addresses at random (this action is known as social engineering [3]), with the first goal being to determine whether a real email address exists among the selected, and secondly, whether its owner is susceptible to fraud (most often the message sent contains a malicious attachment, with the help of which, when clicked, users' devices are infected, and information such as personal data, passwords, etc. becomes available to ill-wishers). Another example is direct attempts to hack accounts in various social networks, as well as sending messages of the type: "You need to change your password at bank X", suggesting to customers that this is a preventive measure as part of a bank to protect clients' data and finances, and more. To deal with these and other similar problems, software protection tools such as anti-virus systems, firewalls and, for some time, artificial intelligence systems are used. Working together, protection tools seem successful in a decent manner. But to determine what data arrives over the network to users, the data must be separated into good data and bad labels.

It is appropriate to use software that makes such an assessment of the continuous flow of network packets. There are many possible ways to analyse, evaluate and predict the relevant network traffic, but in this research scenario, one particular system is considered - a fuzzy logic system (FLS - doubtful logic [10]), based on a fuzzy source system, which is designed to classify different types of

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8054>

© 2024 Angela Rumenova Borisova. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

attacks in good and bad (this system uses a ready-made data set called KDD CUP 99) [7], and the current project aims to create a fuzzy logic system that supports the automation process of classifying a given traffic as normal or malicious traffic, as the data set used for logging is taken from pre-recorded network traffic in a .pcap file and pre-processed using an artificial intelligence algorithm. In this line of thought, fuzzy logic systems are used to develop various systems that aim to provide precise estimation of real-time signal processing [1]. Artificial neural networks and fuzzy systems for cybersecurity are used to gather information and enrich data about new threats and vulnerabilities, which is of utmost importance for cyber systems to adapt to ever-changing conditions.

II. MATERIALS AND METHODS

For the needs of the present research project, a system called "NETWORK TRAFFIC_sample" was created in MATLAB using the Fuzzy Logic Designer tool, consisting of 9 input linguistic variables, one output and 10 Mamdani-type rules at the beginning of the experiment. (subsequently the rules were increased to 51) to support the aims of the experiment. The input linguistic variables are: IP source port, IP destination port, IP destination port buffer, TCP source port, TCP destination port, TCP sequence number, TCP synchronize flag, TCP counter, Timestamp. The output linguistic variable label is "Malicious traffic". The system works with weight coefficients ranging from 0 to 1, similar to neural networks, where, depending on the activation function, the output is most often in the same range. Rule is defined: 1 meaning the given network traffic is certainly malicious and 0 meaning that the given network traffic is certainly normal (in the particular case, the membership functions for the output linguistic variable "Malicious traffic" are low risk and high risk). If the weight coefficients have values from 0 to 0.4, they will again belong to the set of normal traffic, i.e. low risk, otherwise if values exceed 0.4, i.e. become 0.5 and greater up to and including 1, they will be categorized in the malicious traffic set i.e. high risk.

Each input linguistic variable in turn consists of a different number of membership functions that satisfy the needs of the system. What they have in common is that they are of the same type called the Generalized Bell-shaped MF (MF - Membership Function), also called the Cauchy MF. This model was chosen because of its many advantages, allowing for more accurate final results and as few similarities as possible between the elements in the individual membership functions. Thus, allowing them to be classified into the correct "group", i.e. their falling into the exact belonging function amongst the predefined ones. Cauchy MF allows changing the shape of the function and the size of the function thanks to the three main parameters that make it up - a and b , responsible for the width and c , responsible for the center point of the membership function. Generalized bell MF is a combination of Gaussian and trapezoidal function. On fig. 1 a graph composed of the membership functions of the linguistic variable *IP source port* is shown, and on Fig. 1.1 the automatically generated MATLAB source code of the same variable is shown.

Based on these two databases, it can be summarized that the membership functions are named using four

example IP addresses, concrete "192.168.6.2", "192.168.6.3", 192.168.6.4, "192.168.6.5". As the membership function of the first IP address "192.168.6.2" is located in the range from 0 to 1, the membership function of the second IP address "192.168.6.3" is located in the range from 1 to 2, the membership function of the third IP packet "192.168.6.4" is located in the range 2 to 3, ... and the membership function of the fourth IP address "192.168.6.5" is located in the range 3 to 4.

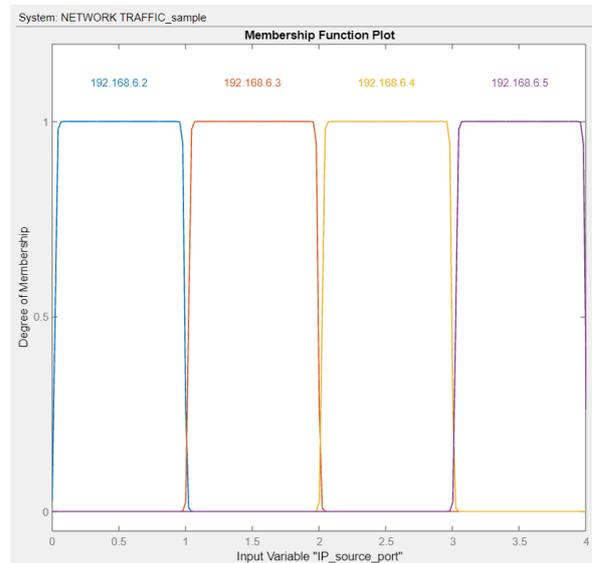


Fig. 1. IP source port Membership function.

```
[Input1
Name='IP_source_port'
Range=[0 4]
NumMFs=4
MF1='192.168.6.2': 'gbellmf', [0.485899 41.4327 0.50796]
MF2='192.168.6.3': 'gbellmf', [0.485899 41.4327 1.50796]
MF3='192.168.6.4': 'gbellmf', [0.485899 41.4327 2.50796]
MF4='192.168.6.5': 'gbellmf', [0.485899 41.4327 3.50796]
```

Fig. 1.1. Listing of IP source port Membership - source code in MATLAB.

IP source port is only one component of the selected total of 9 elements of a single packet involved in network traffic.

Like *IP_source_port*, *IP_dest_port* membership functions (since they are again 4 IP addresses) are in range from 0 to 4. MFs are: "192.168.6.254", "192.168.10.10", "192.168.10.11", "192.168.10.12". *IP_dest_port_buffer* accordingly has two MFs: "Unknown_IP" - occupying the range from 0 to 1 and "Known_IP" - from 1 to 2. *TCP_source_port* consists of 5 membership function: "1024", "1025", "1026", "1060", "2000", similarly from 0 to 5. *TCP_dest_port* consists of 4 MFs and they are: "10", "80", "1023", "8080" ranging from 0 to 4. The next *TCP_Sequence_number* consists of 10 MFs - "1", "2"..., "10", in a range from 0 to 10. Then comes *TCP_syn_flag* with 2 MFs - "0" (it means false, the flag is down), "1" (it means true, the flag is raised) in a range from 0 to 2. The next *TCP_counter* with 2 MFs - "under_10", "10_and_more" from 0 to 2 again. And the last one is *TIME* (timestamp) with 3 MFs - "under_1_second", "1_second", "over_1_second", from 0 to 3 similarly.

The designed system considers these 9 packet information fields as basic control data. What is monitored

is how many times the TCP-SYN flag (TCP synchronize flag) is raised, i.e. how many times the IP source port (user X) communicated (a session had been created) with the IP destination port (legitimate server Y). Rules are built in that if the number of sessions (TCP_counter) reaches 10 or more from a specific client to a specific monitored server within a 1.00 second time-range (TIME), then malicious intent is present (a network attack called TCP syn flood), i.e. user X purposefully sends the same request to server Y in order to achieve Denial of Service (DoS) for example. In such case, the role of IP destination port buffer is to save the recipient's IP address if the TCP syn flag has been detected (the flag is raised, it is 1) and being sent to server from the same actor least twice in less than 1.00 second time-range. TCP sequence number reports the sequence number of the session, and TCP counter counts the total number of packets passed through the system when establishing a connection between the client-server model users. To determine whether a packet is safe or harmful, sample data for the above-mentioned information is provided. To demystify the FLS idea, 10 if-then rules are indicated on fig. 2 and fig. 2.1.

	Rule	Weight	Name
1	If IP_source_port is 192.168.6.2 and IP_dest_port is 192....	1	rule1
2	If IP_source_port is 192.168.6.2 and IP_dest_port is 192....	0.9	rule2
3	If IP_source_port is 192.168.6.2 and IP_dest_port is 192....	0.8	rule3
4	If IP_source_port is 192.168.6.2 and IP_dest_port is 192....	0.7	rule4
5	If IP_source_port is 192.168.6.2 and IP_dest_port is 192....	0.6	rule5
6	If IP_source_port is 192.168.6.2 and IP_dest_port is 192....	0.5	rule6
7	If IP_source_port is 192.168.6.2 and IP_dest_port is 192....	0.5	rule7
8	If IP_source_port is 192.168.6.2 and IP_dest_port is 192....	0.6	rule8
9	If IP_source_port is 192.168.6.2 and IP_dest_port is 192....	0.7	rule9
10	If IP_source_port is 192.168.6.2 and IP_dest_port is 192....	1	rule10

Fig.2. Network traffic rules.

If IP_source_port is 192.168.6.2 and IP_dest_port is 192.168.6.254 and IP_dest_port_buffer is Known_IP and TCP_source_port is 1060 and TCP_dest_port is 80 and TCP_Sequence_number is 10 and TCP_syn_flag is 1 and TCP_counter is 10 and more and TIME is 1_second then MALICIOUS_traffic is high_risk

Fig.2.1. Rule classifying a high risk with a weight of 1, generated by MATLAB.

It can be seen from fig. 2. that all rules are set with weight factors between 0.5 and 1, ensuring that the selected set of rules belongs to the desired output. And fig. 2.1. demonstrates what a rule should look like such as certainly presenting the traffic to be malicious. Obvious point is having a severity factor of 1, the TCP-SYN flag is raised 10 times according to the TCP sequence number, and the IP address of the recipient and sender respectively are the same.

These 10 rules are far from providing all the possibilities for the state of the system, but they are a basic example of how it should work. For example, a rule like:

If (IP_source_port is 192.168.6.3) and (IP_dest_port is 192.168.10.10) and (IP_dest_port_buffer is Known_IP) and (TCP_source_port is 1024) and (TCP_dest_port is 8080) and (TCP_sequence_number is 10) and (TCP_syn_flag is 1) and (TCP_counter is 10 and more)

and (TIME is 1_second) then (Malicious_traffic is high_risk) (1),

will also work correctly with a weight factor of 1, since the above requirement of malicious traffic - high risk, is met and the weight factor is in the correct range from 0.5 to 1 inclusive.

A similar rule, now with a weighting factor of 0, i.e. guaranteeing that the given set of rules certainly does not belong to the desired output, looks like this:

If (IP_source_port is 192.168.6.5) and (IP_dest_port is 192.168.10.10) and (IP_dest_port_buffer is Unknown_IP) and (TCP_source_port is 1025) and (TCP_dest_port is 1023) and (TCP_sequence_number is 1) and (TCP_syn_flag is 1) and (TCP_counter is 1 and more) and (TIME is over_1_second) then (Malicious_traffic is high_risk) (0)

Here, the role of the weighting factor in the construction of these rules is extremely important. In the particular case, a weight set to 0 ensures the situation that the probability of the traffic being malicious is low. The same result can be achieved if the membership function is changed from high risk to low risk and the weight factor becomes 1.

In order to obtain more accurate results, a few more experimental setups are made, and the number of rules in the knowledge base becomes 51.

Fuzzy output systems are abstract, unorthodox [5] and can be modified according to the understandings and needs of artificial intelligence through fuzzy reasoning [8].

On fig. 3 the constructed output is presented, consisting of two membership functions, with the help of which the traffic is classified as good or bad, respectively. Fig. 3.1. presents the automatically generated source code of the output linguistic variable from the MATLAB software.

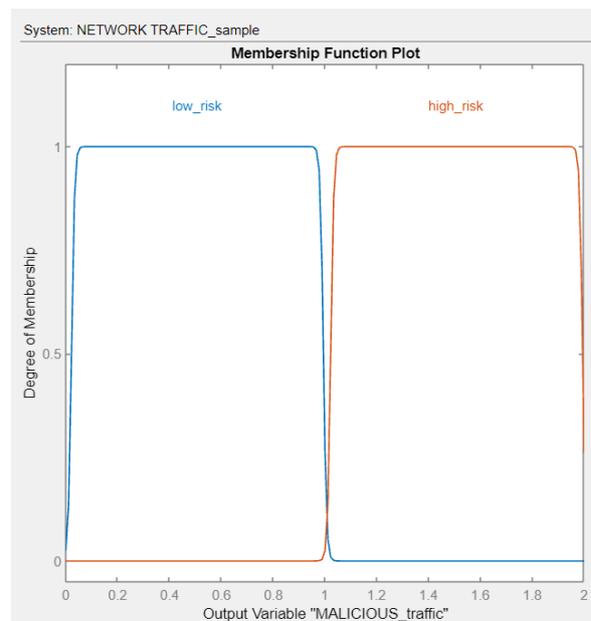


Fig. 3. Degree of membership for 1 linguistic output variable.

```
[Output1]
Name='MALICIOUS_traffic'
Range=[0 2]
NumMFs=2
MF1='low_risk':'gbellmf',[0.485899 41.4327 0.50796]
MF2='high_risk':'gbellmf',[0.485899 41.4327 1.50796]
```

Fig. 3.1. Output - source code in MATLAB.

Judging by fig. 3. and fig. 3.1. it can be summarized that the output of the system can be only two options low risk - harmless traffic or high risk - bad traffic, with the membership function "no risk" extending in the range from 0 to 0.99, and the membership function "high risk" covers the range from 1.0 to 2.

III. RESULTS AND DISCUSSION

As a result of the conducted experiment (with 10 if-then rules), a simulation of a system with fuzzy output was built, giving information about the type of specifically

selected packets of network traffic (whether there is cause for alarm in them, i.e. the presence of a malicious action or not). When testing the already built fuzzy logic system, sample values were selected for the inputs which are defined in the following data array: [0.2321;0.5893;1.903;3.606;1.646;9.69;1.673;1.743;1.606]. This array represents the membership functions of each of the 9 pre-selected network packet information data for monitoring, with the resulting score having a value of 1.51 and indicating that the traffic in this case is malicious, as the membership function of this point is ' high risk' (because MF 'high risk' ranges from 1 to 2). The result of this can be seen on fig. 4.

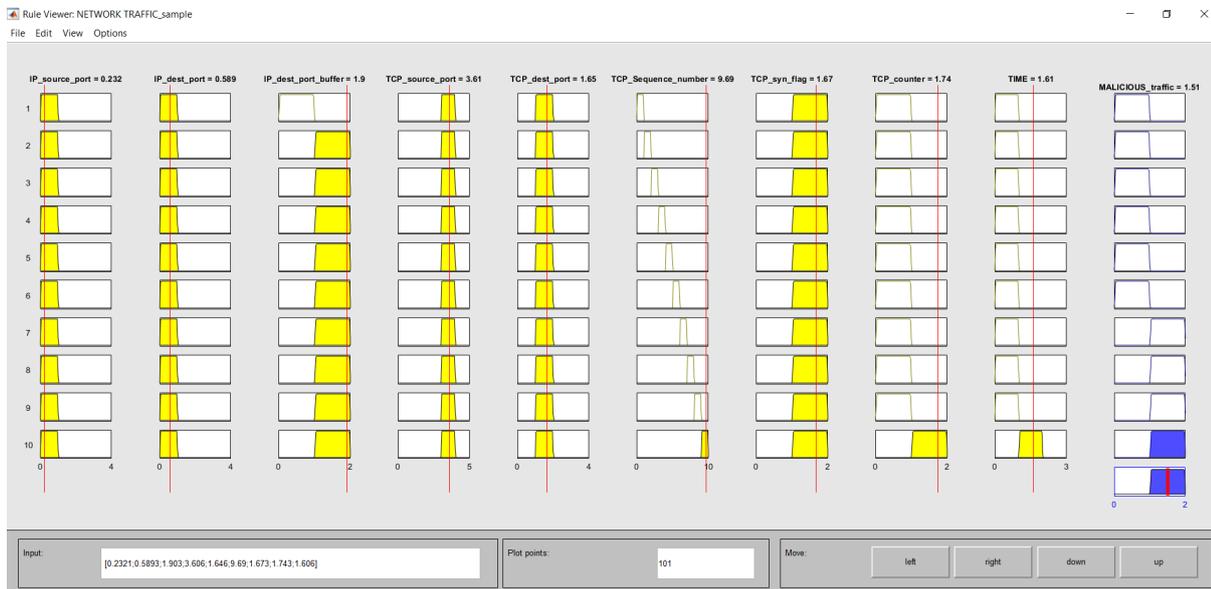


Fig. 4. The result, from the built 10 rules, showing the outcome desired by the expert - with weight coefficients between 0.5 and 1.

In order for the reach to be more comprehensive, 7 more attempts were made, and the if-then rules were supplemented to 51. The results of the experiment can be

seen in table 1 and table 2. As table 2 presents the interpreted results of table 1.

TABLE 1 MULTIPLE TESTING OF FUZZY OUTPUT – WITH 51 IF-THEN RULES

IP_source_port	IP_dest_port	IP_dest_port_buffer	TCP_source_port	TCP_dest_port	TCP_Sequence_number	TCP_syn_flag	TCP_counter	Time amp	Malicious_traffic
1.482	1.661	0.5575	3.695	3.699	0.04425	1.584	0.00885	2.456	0.662
2.696	2.544	0.5575	0.1096	0.4696	1.36	1.296	1.798	1.396	0.903
3.391	3.526	1.904	0.2851	0.9913	10	2	2	1.213	1.24
1.617	3	1.765	0.943	1.861	9.079	1.661	1.833	0.7696	1.07
2.591	1.105	0.7217	0.4167	0.01739	3.904	1.365	1.061	2.596	0.961
2.522	2.93	1.452	3.311	2.417	7.412	1.435	1.325	0.326	1.04
2.625	2.589	1.779	0.5973	3.133	7.478	2	1.336	0.1726	1.05

TABLE 2 INTERPRETATION OF TABLE 1

IP source port	IP dest port	IP dest port buffer	TCP source port	TCP dest port	TCP Sequence number	TCP syn flag	TCP counter	TIME (Timestamp)	Malicious traffic
192.168.6 .3	192.168.10.1 0	Uknown_ IP	1060	8080	1	1	under_10	over_1_ second	low_risk
192.168.6 .4	192.168.10.11	Uknown_ IP	1024	10	2	1	10_and_ more	1_second	low_risk
192.168.6 .5	192.168.10.1 2	Known_I P	1024	10	10	1	10_and_ more	1_second	high_risk
192.168.6 .3	192.168.10.1 2	Known_I P	1024	80	10	1	10_and_ more	under_1_ second	high_risk
192.168.6 .4	192.168.10.1 0	Uknown_ IP	1024	10	4	1	10_and_ more	over_1_ second	low_risk
192.168.6 .4	192.168.10.11	Known_I P	1060	1023	8	1	10_and_ more	under_1_ second	high_risk
192.168.6 .4	192.168.10.11	Uknown_ IP	1024	8080	8	1	10_and_ more	under_1_ second	high_risk

The "Materials and Methods" section describes the ranges in which the respective membership functions of each input linguistic variable and the output linguistic variable lie, and table 2 is constructed based on them. Between the first column and the first row of table 1, the numeric value 1.482 for IP_source_address is presented, which means that the second IP address is specified (since it is in the range 1 to 2), which is "192.168.6.3". Between the second column and the first row of table 1 is the numeric value 1.661 for IP_dest_address, which again shows the second IP address, but this time to the recipient and it is "192.168.10.10". Between the third column and the first row of table 1 is the value 0.5575 for IP_dest_buffer, which means that the value falls in the range 0-1 and the membership function is "Uknown_IP". The intersection of the fourth column and the first row of table 1 expresses the value 3.695 of the input linguistic variable TCP_source_port, i.e. the membership function is "1060" (since it is in the range 3-4). The intersection of the fifth column and the first row of table 1 represents the value 3.699 of TCP_dest_port, so the MF is "8080" (falls in range 3-4). Between the sixth column and the sixth row of table 1, the resulting value 0.04425 is presented, which refers to the TCP_Sequence_number and falls in the range 0-1, which means that the membership function in this situation is "1". The value between the seventh column and the first row of table 1 of the linguistic variable TCP_syn_flag is "1.584" respectively, the resulting value falls in the range 1-2, i.e. MF is "1", i.e. the session is complete. The value between the eighth column and the first row of table 1 of TCP_counter is 0.00885, i.e. MF is "under_10". Between column number 9 and row 1 of table 1 is represented the value 2.456 for TIME (timestamp) - with a total of three membership functions, this value falls in the range 2-3, i.e. "over_1_second". Between the last 10 column and the first row of table 1, the result of the search is concluded, namely whether the traffic is malicious or not. At a value of 0.662 MF is "low_traffic". The interpretation of the remaining 6 lines is analogous.

A detailed examination of Tables 1 and 2 shows that the results obtained are quite good, i.e. the created system works correctly.

A brief comparison between the problem at hand and two other similar problems follows.

Shanmugavadivu's [7] fuzzy system uses 34 input linguistic variables representing a part of the KDD CUP 99 data set, based on which multiple if-then rules are built, of which a part of them determined by a filter is finally used in forming the final exit. Overall, the system is reliable, but from the point of view of having some unused input linguistic variables and ultimately unused if-rules, this can lead to not so good efficiency and not so good speed. On the other hand, Slavyanov's [1] fuzzy system has the required number of rules and the required number of inputs to function properly. In general, the proposed system in this paper uses pre-collected and pre-processed input data that are as accurate as necessary to properly build the algorithm. The rules are properly defined, initially the system was tested with only 10 rules, but subsequently with 51 rules. As the number of rules increases, the accuracy of the algorithm increases.

Striving to take the best of the two systems with which the current one is being compared, and accordingly to avoid approaches that are not well suited to the current problem, an optimal system was created.

Analysing the obtained results from fig. 4, table 1, table 2 and in view of the comparison made with other two similar systems, it can be concluded that the proposed system is efficient, stable [6] and accurate.

IV. CONCLUSIONS

The project that is built in this paper answers the question of how a fuzzy inference system, can be built to successfully classify output as malicious or non-malicious by using weighting factors.

In the context of cybersecurity discussed up to this point, it can be summarized that FLS are a powerful tool for building systems showing the principle of separating data passing through the network into good content and bad content i.e. fuzzy systems are an essential element in an overall system supporting the cyber defense of various organizations and individuals.

The future development of artificial intelligence algorithms is inevitable to continue the evolution in cybersecurity. The introduction of fuzzy output algorithms in the context of network security has demonstrated an

increase in its accuracy and its effectiveness over time [4] and the improvement of security measures in various systems.

The end result is automating the process of deciding on the type of network traffic, analysing and correctly classifying network data by creating a set of rules.

The proposed system can be used in various areas of network security, including optimization of network resources, detection of malicious actions and protection against cyberattacks, and it can be integrated with other systems for even more reliable protection and improvement of response time by specialists in this field.

ACKNOWLEDGEMENTS

This paper is created in favor of Bulgarian National Scientific program "Security and Defense", Ministry Council decision No 731/21.10.2021, Agreement No Д01-74/19.05.2022.

REFERENCES

- [1] K. O. Slavyanov, "Fuzzy logic procedure for drawing up a psychological profile of learners for better perception in courses," in Proceedings of the 12th International Scientific and Practical Conference, July 20-26, 2019, Rezekne, Latvia: Rezekne Academy of technologies, 2019. Available: <http://dx.doi.org/10.17770/etr2019vol2.4073>, [Accessed: January, 5, 2024]
- [2] L. G. Nikolov and K. O. Slavyanov, "On the contemporary cybersecurity threats", International scientific journal "Security & future", vol. 1, pp. 111-113, 2017. Available: <https://stumejournals.com/journals/confsec/2017/3/111.full.pdf>, [Accessed: January, 10, 2024]
- [3] L. G. Nikolov, "Social engineering as a high cybersecurity threat", International scientific journal "Security & future", vol. 3, pp. 106-108, 2019. Available: <https://stumejournals.com/journals/confsec/2019/3/106.full.pdf>, [Accessed: January, 11, 2024].
- [4] M. I. Mihailescu, S. L. Nita, M. Rogobete and V. Marascu, "Unveiling Threats: Leveraging User Behavior Analysis for Enhanced Cybersecurity," in Proceedings of 15th International Conference on Electronics, Computers and Artificial Intelligence (ECAI), June 29-30, 2023, Bucharest, Romania: Institute of Electrical and Electronics Engineers, 2023. Available: <https://doi.org/10.1109/ECAI58194.2023.10194039>. [Accessed: January, 11, 2024].
- [5] B. Singh and A. K. Mishra, "Fuzzy logic control system and its applications", International Research Journal of Engineering and Technology (IRJET), vol. 02, pp. 742-746, 2015. Available: <https://www.irjet.net/archives/V2/i8/IRJET-V2I8104.pdf>. [Accessed: January, 12, 2024].
- [6] G. Sharma, V. Raju, H. Dhall, P. Sudan, B Reddy, I. Alpackaya, "Fuzzy Logic-Based Energy Management in Smart Grids for Renewable Integration," International Conference on "Advanced Materials for Green Chemistry and Sustainable Environment" (AMGSE-2024), vol. 511, pp. 1-14, 2024, Available: https://www.e3s-conferences.org/articles/e3sconf/pdf/2024/41/e3sconf_amgse2024_01013.pdf. [Accessed: January, 12, 2024].
- [7] R. Shanmugavadivu and N. Nagarajan, "Network Intrusion Detection System using Fuzzy Logic", Indian Journal of Computer Science and Engineering (IJCSE), vol.2, no.1, pp. 101-111, 2015, Available: <https://ijcse.com/docs/IJCSE11-02-01-034.pdf>, [Accessed: February, 1, 2024].
- [8] L. C. Barros , R. C. Bassanezi , W. A. Lodwick, A First Course in Fuzzy Logic, Fuzzy Dynamical Systems, and Biomathematics: *Notions of Fuzzy Logic*, Vol. 432. Cham: Springer, 2024, pp. 53-78. https://doi.org/10.1007/978-3-031-50492-1_4.
- [9] P. Vähäkainu, M. Lehto, Artificial Intelligence and Cybersecurity: *Use of Artificial Intelligence in a Cybersecurity Environment*. Cham: Springer, 2022, pp. 3-27. https://doi.org/10.1007/978-3-031-15030-2_1.
- [10] M. Soltanifar, H. Sharafi, F. H. Lotfi, W. Pedrycz, T. Allahviranloo, Preferential Voting and Applications: Approaches Based on Data Envelopment Analysis. Studies in Systems, Decision and Control: *Introduction to Fuzzy Logic.*, vol 471. Cham: Springer, 2023, pp.31-45. https://doi.org/10.1007/978-3-031-30403-3_3.

Investigation and Analysis of Attitudes Towards the Implementation of Artificial Intelligence in Internal Business Processes

Galina Chipriyanova

*Department of Accounting
Tsenov Academy of Economics
Svishtov, Bulgaria*

g.chipriyanova@uni-svishtov.bg

Mihail Chipriyanov

*Department of Strategic Planning
Tsenov Academy of Economics
Svishtov, Bulgaria*

m.chipriyanov@uni-svishtov.bg

Kiril Luchkov

*Department of Economics, Industrial
Engineering and Management
Technical University of Sofia,
Bulgaria*

kiril.luchkov@tu-sofia.bg

Abstract. The research focuses on the attitudes and readiness of organizations to integrate Artificial Intelligence (AI) technology into their internal business processes. The present study aims to determine how organizations perceive technological innovations related to AI. Specific goals include measuring the degree of readiness and acceptance of technological innovations by organizations, as well as identifying factors influencing the success or failure of this process. The main object is AI technology and its potential for enhancing the efficiency of internal business process management. The significance of this analysis is threefold, providing valuable information on current trends and challenges in internal business processes and their transformation under the influence of AI. In the course of the study shall be justified the thesis that AI technology holds significant potential for optimizing internal business processes, that is not yet fully realized and utilized due to various obstacles. Overcoming these obstacles is possible through individualized strategies, the establishment of ethical standards, active training, and other measures that contribute to the successful integration of artificial intelligence into organizational dynamics. The methodology includes a comprehensive literature review combined with the use of questionnaire surveys, Gap analysis and SWOT analysis. The main conclusions are related to the diversity in motivations among surveyed companies, necessitating differentiated strategies. Improving operational efficiency and customer service, and enhancing competitiveness, transpire as driving power for AI implementation. Evaluating attitudes reveals differences in readiness among business organizations, resp. some of them actively taking steps to implement AI, while others are still exploring possibilities or are uncertain about the overall approach to adopt. The recommendations for organizations are multifaceted. Constantly exploring new technologies and

updating approaches are necessary for a sustainable transition to more intelligent business process management.

Keywords: *Artificial Intelligence (AI), internal business processes, operational efficiency, technological innovations*

I. INTRODUCTION

Artificial Intelligence (AI) is a field in computer science focused on creating systems and programs that exhibit intelligent behavior similar to humans. AI utilizes methods and algorithms from various branches of computer science, including machine learning, natural language processing, computer vision, and robotics, to enable systems to perform tasks that typically require human intelligence. Simultaneously, the technical perspective involves researching methods to improve the efficiency, speed and accuracy of AI systems, as well as their adaptability to different scenarios and conditions.

In the modern business world, the rise of AI represents a significant milestone in technological evolution, reshaping the dynamics and efficiency of internal business processes. This transition towards digital transformation requires organizations to rethink their strategies and explore the opportunities that AI offers for optimizing activities.

The implementation of AI holds the promise of substantial advantages, such as increased efficiency, reduced decision-making time and enhancement of overall operational productivity. The combination of machine learning algorithms, big data processing and automation opens new horizons for companies, directing them towards more intelligent and dynamic business models.

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8032>

© 2024 Galina Chipriyanova, Mihail Chipriyanov, Kiril Luchkov. Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

The interest in implementing AI in internal business processes originates not only from the potential for operational optimization but also from improved adaptability to changing market conditions and competition. However, this process requires not only technical but also organizational transformations, taking into account its impact on workplace culture, human resources and ethical aspects.

The research focuses on the trends and challenges associated with the implementation of AI in internal business processes, the attitudes of participants in this process and the factors influencing the acceptance and successful integration of AI. For the purposes of analysis, a detailed review of the current literature is conducted and data collection methods are systematically employed.

The recommendations for organizations are multifaceted. Strategic planning is crucial, requiring the development of specific strategies in compliance with the goals and needs of the company. Ensuring the necessary infrastructure and smooth integration with existing systems are of critical importance. Additionally, companies should pay serious attention to ethical and legal issues related to AI use and develop compliance strategies. Communication and employee participation are key to reducing resistance and ensuring successful adaptation.

II. THEORETICAL FRAMEWORK OF THE RESEARCH

Artificial Intelligence offers a brief overview of the significance of the field, yet it falls short in exploring its nuances comprehensively. While it acknowledges machine learning and deep learning, pivotal components of AI, it could enhance its coverage by delving into additional critical areas such as natural language processing, computer vision and robotics. Expanding on these aspects would provide readers with a more comprehensive understanding of the diverse domains within AI [1].

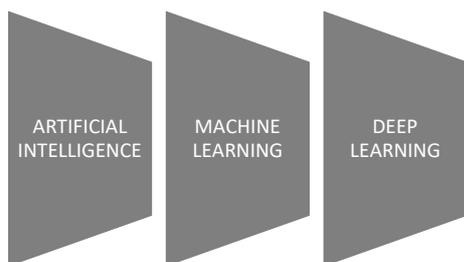


Fig. 1. The concept of Artificial Intelligence.

The literature about the integration of Artificial Intelligence (AI) into internal business processes abounds with insightful analyses and research findings. However, while acknowledging the escalating technological capabilities and the expanding role of AI within enterprise operations, it's imperative to critically assess the challenges and limitations surrounding its successful implementation. Despite the abundance of research, there remains a gap in understanding the nuanced complexities and practical barriers encountered during AI adoption. The academic and business communities should investigate deeper into not just the potentials, but also the risks of integrating AI, considering factors such as organizational readiness, data privacy concerns, ethical implications and the need for

human-AI collaboration [2]. Only through such critical examination can a deeper understanding of AI implementation challenges emerge, promoting more informed decision-making and effective strategies for leveraging AI in organizational contexts.

The literature review emphasizes the potential benefits of automation and process optimization in enhancing operational efficiency and reducing task execution time [3] – [9]. However, while these sources provide valuable insights, a critical analysis reveals a tendency to focus predominantly on the advantages of AI implementation, potentially overlooking associated challenges. For instance, there may be limited exploration of the potential disruptions to existing workflows or the need for significant organizational restructuring to accommodate AI technologies.

Furthermore, while addressing change management and organizational adaptation to innovations including AI [10], there's a notable absence of in-depth discussions on specific strategies or frameworks for effectively managing these transitions. The literature may lack practical guidance on navigating the socio-organizational complexities inherent in adopting AI, potentially leaving organizations unprepared to address these challenges.

Regarding ethical considerations about AI in business [11] – [12], the literature provides valuable insights into security concerns, data protection and trust-related issues. However, a critical analysis reveals a need for more comprehensive discussions on dealing with these ethical risks in practice. This could involve exploring regulatory frameworks, industry standards or ethical guidelines that can help organizations navigate the ethical dimensions of AI implementation more effectively.

Overall, while the reviewed literature offers valuable contributions to understanding the opportunities and challenges of AI adoption in business settings, there is a need for deeper critical analysis and practical guidance to support organizations in navigating these complexities successfully.

The literature review highlights advancements in machine learning for business process management but may overlook practical implementation challenges and prejudices [13] – [15]. While discussing methodologies for big data processing, it may lack depth in addressing limitations and ethical considerations. Additionally, there's limited examination of human-centric aspects, such as user experience and socio-cultural impacts. A more critical analysis is needed to understand the full scope of opportunities and risks associated with leveraging machine learning in organizational settings.

The implementation of AI [16] – [20], especially in internal business processes, represents a key stage in the technological transformation of companies. The analysis of this process reveals a series of crucial aspects and challenges that are of critical importance for the successful integration and adoption of the technology by organizations, as outlined in Table 1.

1) Automation of routine and resource-intensive tasks, the ability for faster decision-making, and processing large volumes of data are considered key

technological advantages, creating opportunities for optimizing work processes and improving operational efficiency. 2) Remarkable a balance between AI and human capacity, i.e. integrating automation while preserving human skills and a creative approach. Challenges include optimal role distribution, staff training, and creating an organizational culture that supports collaboration between technology and people. 3) The implementation of AI necessitates an urgent focus on enhancing security and data protection, including developing effective cybersecurity measures to prevent misuse and ensure compliance with regulatory requirements. 4) The research emphasizes the importance of ethical aspects related to the use of AI in internal business processes. Questions of transparency, fairness and accountability must be precisely addressed to avoid potential ethical issues.

Scientific research in the field of AI focuses on a broad spectrum of ethical issues arising from the rapid development and widespread application of the technology. One key aspect explored in the literature is the transparency of AI algorithms and decisions, as they are often complex and challenging to explain. Particularly within the domain of machine learning (ML), studies underscore the need to understand causal relationships in algorithms to ensure fairness and avoid discrimination.

TABLE 1 THE LEADING CHALLENGES IN IMPLEMENTING AI IN COMPANIES

Guidelines	
1) <i>Technological advantages and opportunities</i> [18];	2) <i>Integration of human capacity and AI</i> [16], [17];
3) <i>Security and Data protection</i> [20];	4) <i>Ethical considerations and responsibility</i> [19], [20];
5) <i>Training and Overcoming Resistance</i> [16].	

Another crucial aspect is the ethical responsibility in implementing autonomous systems and robots. Research concentrates on how technologies can be programmed and managed ethically to minimize potential risks and losses. In the field of personal data, scientific studies pay attention to the challenges of balancing the benefits of AI with the rights to personal privacy. Developing mechanisms for protecting privacy and aligning with regulatory frameworks are identified as key factors.

The ethics of technologies emphasize the need for an ethically oriented approach in the design and implementation of AI, one that combines technological progress with respect for the rights and values of society.

5) The integration of new technologies often faces resistance from personnel. Therefore, the analysis focuses on the importance of staff training and building strategies to overcome resistance, promoting participation and collaboration.

This systematic analysis establishes the foundation for a more detailed examination and the formulation of strategies for successful technological transformation.

III. RESEARCH METHODOLOGY

The research is conducted among 237 small, medium and large business organizations (categories of business) from Central and Eastern Europe to obtain a broad and representative understanding of their perceptions and attitudes towards the implementation of AI in internal business processes. The choice of the survey method is justified by the need to gather a large volume of data while simultaneously preserving the possibility of individual and contextualized responses. The survey questionnaire is diverse, comprising 18 questions that combine open-ended and closed-ended formats. Closed-ended questions provide quantitative data and easy standardization during analysis, while open-ended questions contribute detailed context and allow participants to express their individual opinions. Themes include technological advantages and challenges, social and organizational aspects, data security, ethical issues and opportunities for staff training. Surveys are distributed via email to the pre-selected companies from the sample.

In addition to the survey methodology, we chose to apply Gap Analysis within the AI research. It is a comprehensive and strategically justified approach. Gap Analysis is a powerful tool that reveals the differences between the current state and the desired future in the context of implementing technological innovations. SWOT Analysis was also conducted to identify the distinguishing characteristics of the future-ready company to the highest possible extent.

IV. RESULTS AND DISCUSSION

a. Establishing strategic motives of a company to undertake actions (activities) in implementing AI in business process management

AI is regarded as a business improvement tool to identify specific advantages of using AI and assess their significance. The results have found expression in (Fig. 2).

The data gathered from authors' own research reveal:
 ✓ **Enhancement of operational efficiency (EOE)**. This may involve optimizing production processes, increasing productivity and reducing task execution time.
 ✓ **Improvement of predictions and decision-making (IPD-M)**. The potential for more accurate predictions and intelligent decision-making using AI ignites significant interest. This aspect can contribute to the strategic direction of the business.
 ✓ **Increasing competitiveness (IC)**. This approach may involve innovations in products, a better understanding of the market and quick adaptation to changing conditions.
 ✓ **Improvement of customer service (ICS)**. The focus on enhancing customer service through AI reflects the endeavor for more personalized and efficient customer interactions.
 ✓ **Does not intend to use (DNIU)**. Reasons for not using Artificial Intelligence include a lack of financial resources, insufficient knowledge and training, doubts about the benefits and effectiveness and dependence on traditional methods. This segment can provide valuable insights into barriers to AI implementation and direct attention to areas for improvement.

The data provide a foundation for developing strategies and approaches for the successful implementation of AI in business.

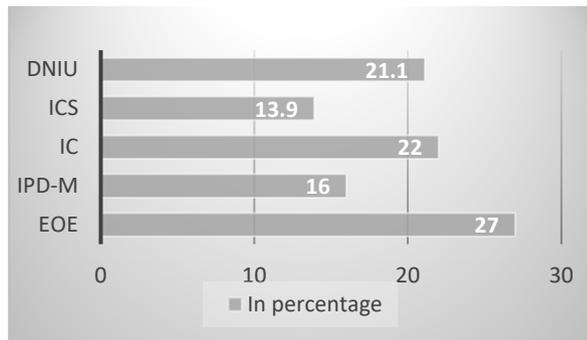


Fig. 2. Assessments of the leading arguments for AI deployment.

b. Identifying potential factors that could obstruct or delay the successful implementation of AI in company's internal business processes

Respondents identified potential obstacles such as a lack of resources, resistance from personnel, legal limitations or other factors that could pose challenges in integrating AI technologies into the company's internal processes. The results have found expression in (Fig. 2).

Based on the above results, the following key aspects can be highlighted: \checkmark **Lack of necessary infrastructure (LNI)** – 13.9% of respondents believe that the need for suitable infrastructure to support AI is evident and creating the necessary technological foundation can become a challenge for companies. This may involve establishing cloud platforms, network integration, etc. \checkmark **Insufficient preparation and training of personnel (IPTP)** – 24.9% of respondents believe that successful AI implementation requires a well-prepared and trained workforce. The need for training and development efforts is critical, focusing on acquiring new skills and adapting to new technologies. \checkmark **Complexities in integration with existing systems (CIES)** – 11.8% of respondents believe that coordination and compatibility between different technologies are required; planning and effective communication are crucial to ensure a smooth integration process. \checkmark **Ethical and legal issues (ELI)** – 10.1% of respondents believe that building compliance and ethical standards are necessary to avoid potential risks and conflicts. \checkmark **Concerns regarding data security (CRDS)** – 13.1% of respondents believe that information protection is essential, especially for sensitive data processed by AI systems. \checkmark **Financial limitations (FL)** – 13.9% of respondents believe that financial limitations can be a real challenge, requiring businesses to balance investments in technology with ensuring financial sustainability.

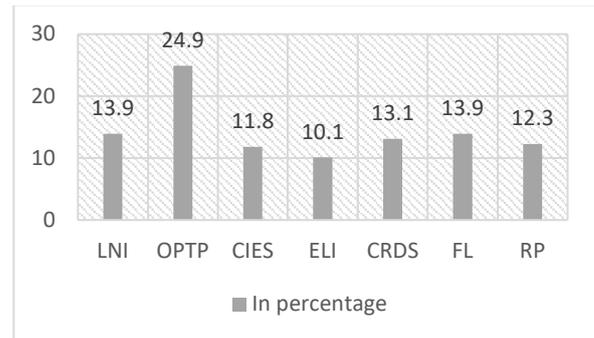


Fig. 3. Assessments of the barriers and nature of potential difficulties to AI implementation.

\checkmark **Resistance from personnel (RP)** – 12,3% of respondents believe that addressing skepticism from personnel requires engagement and communication strategies to reduce resistance and encourage adaptation to new technologies.

Overcoming these obstacles successfully requires a comprehensive and well-planned approach that encompasses technological, educational, ethical and social aspects.

To deepen the analysis through a cross-table (Table 2), we will present the data from the two-dimensional distributions. The percentages are interpreted as a percentage of the *Categories of business* indicator.

TABLE 2 RATINGS OF BARRIERS TO AI IMPLEMENTATION BASED ON CATEGORIES OF BUSINESS

		Categories of business			Total	
		Small	Medium	Large		
Barriers to the Implementation of AI	LNI	Number	8	25	0	33
		In %	25.8	14.4	0.0	13.9
	IPTP	Number	4	53	2	59
		In %	12.9	30.5	6.2	24.9
	CIES	Number	3	14	11	28
		In %	9.7	8.0	34.4	11.8
	ELI	Number	2	12	10	24
		In %	6.4	6.9	31.3	10.1
	CRDS	Number	0	24	7	31
		In %	0,0	13.8	21.9	13.1
	FL	Number	4	29	0	33
		In %	12.9	16.7	0.0	13.9
	RP	Number	10	17	2	29
		In %	32.3	9.7	6.2	12.3
Total	Number	31	174	32	237	
	In %	100.0	100.0	100.0	100.0	

(Source: authors' own research)

The two-dimensional distributions of the data reveal significant differences faced by different categories of business. Regarding small and medium-sized companies (31 and 174 respectively): 1) The main barrier is the lack of infrastructure and qualified personnel with specific competencies in AI. This emphasizes the need for the development of IT infrastructure and intensive training and education in the field of AI. 2) Limited financial resources can slow down the implementation of AI. This requires investments in technology and personnel. 3) Some small

and medium-sized companies express a fundamental resistance to the possibilities of artificial intelligence. This may result from a lack of clear understanding of the benefits or resistance to change.

Regarding large companies (32 in total): 1) The main barrier is associated with the complexity of integrating AI into large corporate structures. This aspect emphasizes the need for strategic planning and coordination to ensure consistency throughout the organization. 2) For large companies, ethical issues related to the protection of personal data, the responsibility of AI systems and the ethical use of technologies are also barriers.

The conducted analysis highlights the need for flexible and individual (customized) strategies for implementing AI depending on the categories of business.

c. *Identifying the specific business processes for which participants believe AI be faced with the greatest economic potential*

The utilization of AI in specific business processes, such as automating routine tasks, predicting trends and personalizing services, can contribute significantly to improving efficiency, reducing costs and increasing revenue. The results have found expression in (Fig. 4).

The analysis of the gathered data reveals the following: ✓ **Manufacturing (M)** – 18.1% of respondents believe that the use of AI in production processes can improve automation, quality control, and optimize the entire production cycle, leading to increased efficiency by reducing costs. ✓ **Marketing and Advertising (MA)** – 24.1% of respondents believe that Artificial Intelligence can contribute to personalizing campaigns, analyzing consumer behavior and optimizing marketing strategies, thereby enhancing efficiency by increasing revenues. ✓ **Customer Relationship Management (CRM)** – 22.8% of respondents believe that AI could provide intelligent solutions for personalizing service, analyzing customer needs and improving customer relationships, consequently increasing customer loyalty and sales revenue. ✓ **Finance and Accounting (FA)** – 16.0% of respondents believe that AI can be used for automating financial processes, predicting financial trends, and reducing risks, thus improving the efficiency of financial management. ✓ **Human Resources (HR)** – 11.8% of respondents believe that AI supports the recruitment process, human resources management and talent development. ✓ **Other functional areas (OFA)** – for 7.2% other potential areas for process optimization and efficiency improvement include logistics, IT infrastructure, etc.

The integration of AI in the researched areas can contribute to achieving greater efficiency, resource optimization and enhancing the competitiveness of the company.

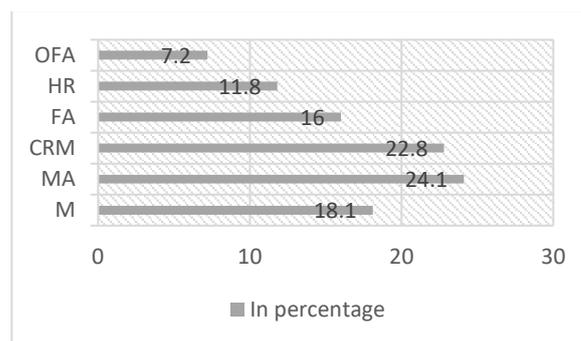


Fig. 4. Assessments of functional areas with the highest potential for AI implementation.

d. *Identification of company overall readiness for the implementation of AI in business processes*

An assessment is made of factors such as the availability of necessary technological resources, the level of staff competence, the presence of strategic plans for AI implementation, as well as support from the leadership. This information can help determine the company's current knowledge and resources in the field of AI and identify potential areas that may require further development. The analysis of the data shows:

- **We are ready and actively implementing** (24.1%) – indicates the business's innovative orientation and commitment to change. These companies likely already have the necessary resources and expertise for the successful implementation of AI technologies.
- **We are considering possibilities** (27.8%). This can be interpreted as a manifestation of heightened interest and awareness of the importance of AI in business.
- **We are not sure** (16.9%). This might result from a lack of clear understanding of the potential benefits and impact of AI in their specific areas of operation.
- **We do not consider it as an option** (11.8%). Some companies still do not consider AI implementation as an option. This response could arise from a lack of information or understanding of the technology's potential in business.
- **I don't know/I can't answer** (19.4%). Uncertainty may be an expression of a lack of a clear vision or circumstances limiting companies' ability to assess the current situation. For successful implementation, companies must continue to explore, train their staff and develop strategies for integrating AI technologies into their internal processes.

e. *Summaries and Recommendations*

The study provided important information and insights regarding company attitudes and readiness for implementing artificial intelligence in their internal business processes.

Fragmentary SWOT analysis of a company randomly selected from the sample, that has successful implementation of AI in internal business processes, indicate an objective picture of its implementation. The results have found expression in assessment of the perspectives of the future-ready company by performing a fragmentary SWOT analysis (Table 3).

Formulating recommendations for organizations aiming at the successful integration of AI into internal

business processes was achieved through a comprehensive approach, combining the analysis of primary data from the authors' empirical research and a Gap analysis of the current and expected developments. Key aspects for the successful implementation of AI include management teams of organizations should develop strategic plans for AI implementation, considering the specific goals and needs of the company. Providing the necessary infrastructure and effortless integration with existing systems are critical for the successful deployment of AI.

TABLE 3 FRAGMENTARY SWOT ANALYSIS

External Factors	
OPPORTUNITIES	THREATS
<ul style="list-style-type: none"> ▪ potential for increased efficiency and optimization of internal processes through AI; ▪ development of new products and services based on AI technologies; ▪ potential for improving the quality and accuracy of internal processes through automation and AI; ▪ better decision-making, both strategically and operationally, through data analysis and trend forecasting. 	<ul style="list-style-type: none"> ▪ risk of cyber-attacks and security breaches during the implementation of digital technologies; ▪ risk of strict regulatory requirements and non-compliance during the implementation of new technologies; ▪ risk of rapidly developing competitors who have already integrated AI into their business processes; ▪ risk of a lack of training systems for employees to work with new Technologies.
Internal Factors	
STRENGTHS	WEAKNESSES
<ul style="list-style-type: none"> √ experts in the field of AI who can guide and manage the implementation of the technology in internal processes; √ existing stable IT infrastructure that supports the successful implementation of digital technologies and AI; √ flexible internal business processes that can be easily adapted to new technologies and innovations; √ committed management supporting the implementation of AI and digitization across all business spheres. 	<ul style="list-style-type: none"> √ limited financial resources that may constrain the scope and speed of implementing new technologies; √ shortage of qualified specialists in the field of AI; √ resistance from the personnel to changes in the workflow associated with the implementation of new technologies

(Source: authors' own research)

Companies need to pay serious attention to ethical and legal issues related to AI usage and build appropriate compliance strategies. Emphasizing the need for open communication and employee involvement throughout the AI implementation process is crucial to reduce resistance and facilitate successful adaptation. Organizations should maintain current exploration into new technologies and update their approaches to AI, as the field continues to evolve.

V. CONCLUSION

Based on the research on the implementation of AI in internal business processes, several key insights can be

summarized: *First*, the diversity of motivations behind AI implementation highlights the need for differentiated strategies that align with the specific needs and goals of each organization. *Second*, the challenges and barriers identified in the empirical study require a systematic approach and strategic planning on the part of companies. *Third*, the variation in the readiness of organizations underscores the need for an individualized approach and personalized training for companies, while emphasizing the importance of continuously monitoring trends in the field of AI. With the perception of AI as a strategic tool for improving business processes, there is a need to expand the knowledge and skills of those working in the field, along with active investments in technologies and resources. Simultaneously, companies must commit to continuous exploration and innovation to remain competitive in a rapidly changing market. To achieve successful implementation of AI in internal business process management, the following guidelines are proposed for future research and development: 1) *Deep analyses of specific sectors* are essential to determine the optimal approach for implementing AI in particular business processes. 2) *Innovations in employee training* – innovative methods for training and developing personnel adapted to the specific requirements of artificial intelligence. 3) *Strategies to overcome ethical and legal challenges* related to data protection and risk management. 4) *Exploring new technologies and trends* to ensure the competitiveness of organizations. 5) *Integration with the strategic goals of organizations*. Confirming AI as an integral part of the strategic goals of organizations, emphasizing not only the technological but also the business aspect of its implementation.

Through the examined guidelines and strategic approaches, organizations can establish a sustainable and successful path for integrating AI into their internal business processes, creating technological development, resilience and innovations in accordance with their specific needs and goals

REFERENCES

- [1] D. Saha, A Brief Introduction to Artificial Intelligence: Ryerson University. [Online]. Available: https://www.torontomu.ca/sciencerezevous/SR2021/A_Brief_Introduction_To_AI.pdf [Accessed January 09, 2024].
- [2] Lichtenhaler, U. An Intelligence-Based View of Firm Performance: Profiting from Artificial Intelligence, *Journal of Innovation Management*, 1, 2019, pp. 7-20.
- [3] Tractica. (2018). Artificial Intelligence Market Forecasts. 315 Consumer, Enterprise, Government, and Defense Use Cases for Machine Learning, Deep Learning, Natural Language Processing, Computer Vision, Machine Reasoning, and Strong AI across 30 Industry Sectors. [Online]. Available: <https://www.tractica.com/research/artificial-intelligence-market-forecasts/> [Accessed January 23, 2024].
- [4] Pwc. (2019). Sizing the prize : Exploiting the AI Revolution, What's the real value of AI for your business and how can you capitalise? PwC's Global Artificial Intelligence Study. [Online]. Available: <https://www.pwc.com/gx/en/issues/data-and-analytics/publications/artificial-intelligence-study.html> [Accessed February 01, 2024].
- [5] M. Rachinger, R. Rauter, C. Müller, W. Vorraber, and E. Schirgi. Digitalization and its influence on business model innovation. *Journal of Manufacturing Technology Management*, 30(8), 2019, pp. 1143-1160.
- [6] D. Petrova. Intelligent, Innovative and Sustainable Industry in Bulgaria – prospects and challenges, *Vide I. Tehnologija. Resursi -*

- Environment, Technology, Resources, Proceeding of the 12th International Scientific and Practical Conference „Environment. Technology. Resources“, June 20-22, 2019, Rezekne, Latvia, Volume I, pp. 210-215, ISSN 1691-5402 – print, ISSN 2256-070X – online. [Online]. Available: <https://doi.org/10.17770/etr2019vol1.4188> [Accessed January 23, 2024].
- [7] D. Petrova. An Alternative Approach to Reducing Aging of Innovative Industrial Products in Terms of Industry 4.0, Environment. Technology. Resources – Proceeding of the 13-th International Scientific and Practical Conference, Rezekne Academy of Technologies, Rezekne, Latvia, 2021, ISSN 1691-5402, Online ISSN 2256-070X, p. 274-280. [Online]. Available: <https://doi.org/10.17770/etr2021vol3.6507> [Accessed January 23, 2024].
- D. Petrova. An Approach to Modeling Innovation Obsolescence, Vide. Tehnologija. Resursi - Environment, Technology, Resources, Proceeding of the 14th International Scientific and Practical Conference, 2023, Volume I, pp. 175–179, Print ISSN 1691-5402, Online ISSN 2256-070X, DOI: <https://doi.org/10.17770/etr2023vol1.7237>, [Online]. Available: <https://www.scopus.com/authid/detail.uri?authorId=56323816400> [Accessed January 23, 2024].
- [8] D. Petrova, B. Vlahova, A. Lengerov, and T. Zlateva-Petkova. Study of the State of Innovation Development and Obsolescence in the Republic of Bulgaria of Companies from the Mechanical Engineering Sector, Vide. Tehnologija. Resursi - Environment, Technology, Resources, 2023, 1, pp. 187–194, DOI: <https://doi.org/10.17770/etr2023vol1.7239>, [Online]. Available: <https://www.scopus.com/authid/detail.uri?authorId=56323816400> [Accessed January 23, 2024].
- [9] C. Crews. What Machine Learning Can Learn from Foresight: A Human-Centered Approach: For machine learning–based forecast efforts to succeed, they must embrace lessons from corporate foresight to address human and organizational challenges. 62(1), 2019, pp. 30-33. [Online]. Available: <https://www.tandfonline.com/doi/pdf/10.1080/08956308.2019.1541725> [Accessed February 05, 2024].
- [10] S. Sikdar. Artificial intelligence, its impact on innovation, and the Google effect. Clean Technologies and Environmental Policy, 20(1), 2018, pp. 1-2.
- [11] J. Hooker and W. Kim Tae. Ethical Implications of the Fourth Industrial Revolution for Business and Society. In Business Ethics, Vol. 3, 2019, pp. 35-63.
- [12] L. Turulja and N. Bajgoric. Information technology, knowledge management and human resource management: Investigating mutual interactions towards better organizational performance. VINE Journal of Information and Knowledge Management Systems, 48(2), 2018, pp. 255-276.
- [13] C. Kuzey, A. Uyar, and D. Delen. The impact of multinationality on firm value: A comparative analysis of machine learning techniques. Decision Support Systems, 2014, pp. 127-142.
- [14] M. Daskalova and D. Ivanova. Interaction between management control systems and big data analytics: A conceptual framework, AIP Conference Proceedings, Volume 2333, 8 March 2021, Article number 030009, 46th International Conference on Applications of Mathematics in Engineering and Economics, AMEE 2020, 7 June 2020 - 13 June 2020. DOI 10.1063/5.0042254. [Online]. Available: https://www.researchgate.net/publication/349910354_Interaction_between_management_control_systems_and_big_data_analytics_A_conceptual_framework [Accessed February 17, 2024].
- [15] Y. Chen, Md. S. Talukder, and M. I. Biswas. The role of artificial intelligence in effective business operations during COVID-19. International Journal of Emerging Markets, June 2022, DOI: 10.1108/IJOEM-11-2021-1666, [Online]. Available: https://www.researchgate.net/publication/361208939_The_role_of_artificial_intelligence_in_effective_business_operations_during_COVID-19 [Accessed February 17, 2024].
- [16] S. Tong, N. Jia, X. Luo, and Z. Fang. The Janus face of artificial intelligence feedback: deployment versus disclosure effects on employee performance, Strategic Management Journal, Vol. 42 No. 9, 2021, pp. 1600-1631.
- [17] W. F. Cascio and R. Montealegre. How technology is changing work and organizations. Annual Review of Organizational Psychology and Organizational Behavior, Vol. 13 No. 2, 2016, pp. 349-375.
- [18] G. Cao, Y. Duan, J. S. Edwards, and Y. K. Dwivedi. Understanding managers' attitudes and behavioral intentions towards using artificial intelligence for organizational decision-making. Technovation, Vol. 106, No. 6, 2021, pp. 101-115.
- D. Mamchur and J. Peksa. An Review of the Effective Energy Consumption within the Green IT and Green Energy Strategies: Environment. Technology. Resources. Proceedings of the 14th International Scientific and Practical Conference, Volume 2, June 15-16, 2023, Rezekne, Latvia. Rezekne: Rezekne Academy of Technologies, 2023, DOI: <https://doi.org/10.17770/etr2023vol2.7295>

Analysis of Virtual Tourism Opportunities in Klaipėda, Lithuania

Akvelina Čuladytė
Klaipėda State University of
Applied Sciences
Klaipėda, Lithuania
a.culadyte@kvk.lt

Aleksandra Batuchina
Center for Social
Geography and Regional
Studies
Klaipėda university
Klaipėda, Lithuania
aleksandra.batuchina@ku.lt

Abstract. In the current article the possibilities of virtual tourism in the city of Klaipėda are analysed. Over the past few decades, digital technology has helped the travel and tourism industry increase its reach. As the world faces the COVID-19 pandemic, virtual tourism has become relevant when the pandemic has made it more difficult to travel in real life. Therefore, it is important to determine whether the prospect of virtual tourism is visible in the city of Klaipėda, and to determine the possibilities of virtual tourism in the city of Klaipėda. The article reviews the concept of virtual tourism and virtual tourism technologies, analyses the idea of virtual tourism products, identifies the classification of virtual tourism products. The trends of virtual tourism in the world and in Lithuania are reviewed. The analysis is based on a detailed analysis of scientific literature, journalistic articles and statistical data. A total of 137 publications were analyzed. Presenting virtual tourism products in Lithuania and the city of Klaipėda. The possibilities of virtual tourism and virtual tourism products of the city of Klaipėda are determined. Such results can be used as a positive role model of the small city virtual tourism attraction and system creation.

Keywords: innovation, thematic analysis, virtual tourism, virtual tourism product.

I. INTRODUCTION

Modern technologies allow us to look at the world around us more and more widely and experience more and more diverse experiences. It is when we face various troubles in life that we look for opportunities to diversify our daily life, broaden our horizons, and experience new experiences, and new technologies help us to do this. Over the past few decades, new technologies have helped the travel and tourism industry increase its reach by allowing tourists to easily access travel booking sites, travel videos, blogs and travel photography. As the world faces the COVID-19 pandemic, virtual tourism becomes relevant. Virtual tourism became relevant when the pandemic made it more difficult to travel in reality. In the period from 10/01/2020 to 03/31/2021, millions of tourists from all over the world visited the websites specialized in virtual tours and

the websites of the world's most popular museums and travelled virtually and viewed the expositions [1]. The effects of this pandemic were especially felt by the tourism sector. The economy declined sharply, tourism business, airlines, hotels, museums, travel agencies and other tourism-related activities suffered negative effects [2]. Due to the coronavirus pandemic in 2020 the number of international tourists decreased by 72 percent, and in 2021 – 71 percent compared to 2019 [2]. In 2021, Global Data's analysis revealed that it was virtual tourism that became especially popular. Virtual tourism was seen by the public as a “pandemic-friendly” alternative, as this form of tourism eased anxiety about various travel restrictions [3]. Virtual tourism emerged as an alternative to physical tourism to safely visit various attractions [4]. Considering the popularity of virtual tourism, it is possible to see the growth of this form of tourism all over the world, including Lithuania.

Klaipėda is the fifth most visited city in Lithuania [5], which can offer tourists many attractive and interesting places of interest that attract not only locals, but also tourists from other countries. Klaipėda - a city that was also called Memel, according to the date of its foundation, is one of the oldest cities in the territory of present-day Lithuania [6]. Therefore, the history of this city is very interesting, deep and wide. It would be interesting for everyone to look back to the past and see how the places of interest looked before. Since the needs, wishes and habits of tourists are rapidly changing, today's expectations to meet the needs of the tourist are significantly higher. In the presence of various unrest or lack of physical opportunities to travel, it is important for the city of Klaipėda to keep up with modern tourism trends, to keep pace with modern technologies, and accordingly to improve its opportunities in the field of virtual tourism. The city must maintain the image of an attractive tourist destination, therefore new measures are constantly being created to shape the image of the city as modern, comfortable and modern [7].

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8038>

© 2024 Akvelina Čuladytė, Aleksandra Batuchina. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

Taking everything into account, the aim of the current research to analyses Klaipėda city example as possible virtual tourism attractions city, in other words, are the prospect of virtual tourism is visible in the city of Klaipėda, and is it possible to determine the possibilities of virtual tourism in the city of Klaipėda. As a result, main research questions are: what is the concept of virtual tourism and virtual tourism technologies? What could be the main virtual tourism products and its classification? Also what are the trends of virtual tourism in the world and in Lithuania? Moreover, in current article we present virtual tourism products in Lithuania and the city of Klaipėda. As result, the possibilities of virtual tourism and virtual tourism products of the city of Klaipėda are determined. Such results can be used as positive examples of small city virtual tourism attraction and system creation.

II. MATERIALS AND METHODS

In order to analyze the possibilities of virtual tourism in the city of Klaipėda, a detailed analysis of scientific literature, journalistic articles and statistical data was carried out. Based on scientific sources, the concept of virtual tourism and the circumstances of its emergence, the idea and classification of the virtual tourism product are examined. In analyzing the trends of virtual tourism in the world and in Lithuania, scientific sources, journalistic articles and statistical data were used. EBSCOhost, Taylor & Francis, Emerald Management, Google Scholar databases were searched for scientific literature, and open access full-text scientific articles published between spring 2023 and 2024 January. A total of 137 publications were analyzed.

A systematic literature review approach was used to analyse the research articles according to the selected inclusion and exclusion criteria. The criteria were: 1) the scientific article is written in English or Lithuania; 2) the publication date of the scientific article was not later than 2019 3) The research article is an open access full-text article; 5) The research article analyses the situation in the context of Covid.

To see the distribution of virtual tourism products in Lithuania, created a map with ArcGIS Pro program, that reveals the distribution of virtual tourism products in Lithuania.

III. RESULTS

Virtual tourism is a form of alternative tourism. This type of tourism is a fairly new area, having become very popular precisely after the COVID-19 pandemic. Scholars Vermaa, Warriar, Bolia, and Meht (2021)[8] state, "It doesn't matter why, where, or how you travel. You can always discover something new and wonderful." Global trends show that alternative tourism, such as health, medical, cultural tourism, ecotourism, spiritual or sports tourism, are new areas of interest for tourists [8]. Namely in 2020 During the period of the COVID-19 pandemic, when there were travel restrictions, tourists had to radically change their travel habits, so a new form of alternative tourism - virtual tourism - gained increasing interest [9]. Virtual tourism became popular because individuals could visit any place in real time, anywhere in the world, using their smartphones [8].

When analysing virtual tourism, we must first clarify the concept of virtual tourism, the concept and the reasons for

its appearance in the scientific literature. Various concepts of virtual tourism can be found in the scientific literature and other sources. Ye, Cho, Liu, Yu Xu, Zhengzhi Jia and Jianyu Chen (2022) [9] claim that Virtual tourism is a new type of tourism, where tourists develop emotional attachment to the real tourist destination through interaction with three-dimensional spaces, seeing scenic areas in virtual space. Muhammad Shoaib Siddiqui, Toqeer Ali Syed, Adnan Nadeem, Waqas Nawaz, Ahmad Alkhodre (2022) [11] states Virtual tourism is a remote application that allows travelers to explore nature, attractions, various off-the-beaten-path sites, ruins, buildings and other travel destinations without the need for physical travel. to visit them.

A. Idea and classification of virtual tourism product

With the help of various modern technologies, it is possible to create various types of virtual tourism products. According to researchers Talafubieke, Mai and Xialifuhan (2021)[12] virtual tourism products enhance the tourism experience of tourists. Virtual tourism products are created and digitized using one or more virtual tourism technologies, which can be seen in

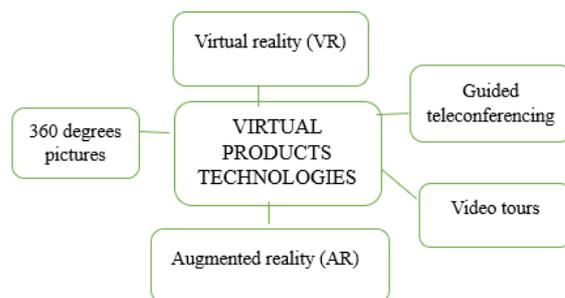


Fig. 1. Technologies of virtual products. [11]

With the help of these digital technologies, various virtual tours can be created products.

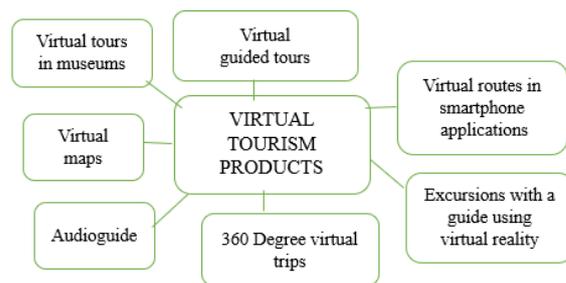


Fig. 2. Virtual tourism products. [19]

Thus, it can be said that virtual tourism products can be created using various virtual reality technologies, such as 360-degree photos, guided teleconferencing, virtual reality, augmented reality, and video tours. With the help of these technologies, unique tourism products can be created that facilitate the nature of tourist travel. You can choose from the following virtual tourism products, such as virtual museum tours, virtual maps, 360-degree virtual tours, guided tours using virtual reality, virtual itineraries in smartphone applications, virtual guided tours.

B. Virtual tourism trends in the world and Lithuania

In 2020 the global COVID-19 pandemic has changed the tourism sector and negatively affected the global travel and tourism industry [2]. The tourism sector had to look for ways to maintain tourists' interest in a tourist destination. It was decided to use various programs. One of them is the Ascape application for smartphones. An app that offers 360-degree videos that offer virtual tours of popular tourist destinations and facilities [13]. The virtual reality provided through this application allows tourists to see the three-dimensional (3D) environment as if they were actually there [14]. One of the most popular destinations in Ascape is Hawaii. Tourists planning to visit the island can use their smartphone to preview the future attraction, take a virtual tour, take a virtual walk, look around, and feel as if they are already in Hawaii [13].

Analysis by GlobalData, a social media analytics (SMA) platform that identifies and tracks emerging trends, has shown that "virtual tourism" is the most popular form of tourism. Because in 2021 it was still the quarantine period, tourists did not travel much for adequate and obvious reasons, and they chose the safest, cheapest, and at that time the easiest way to travel - virtual tourism.

There is a clear trend in the world to use virtual reality technologies to create and implement digital content virtual tourism products. With the help of virtual technology, museums are being digitized so that users can get up close and personal to view the presented exhibits. Various places of interest are also transferred to the virtual space, so that users have the opportunity to visit the attractions virtually.

Virtual tourism is perfectly applied in Lithuania as well. Virtual tourism products are created and implemented on their websites by tourist information centers, museums, visited objects, hotels, etc.[1].

In 2022 the modernization of the Lithuanian Integrated Information System of Museums (LIMIS) was completed, during which new electronic services for museums and visitors were created, the digital collection management subsystem for museums was improved, and the main LIMIS public access was basically updated [15]. More than 110 Lithuanian museums and other institutions provide data in this system. It provides one of the electronic services "Virtual museum tours". This electronic service provides an opportunity to virtually familiarize yourself with the expositions and exhibitions of Lithuanian museums. Users can see the expositions in the museum, images of the spaces, exhibits included in the virtual tours, read information about them or listen to audio and video recordings related to the exposition [16].

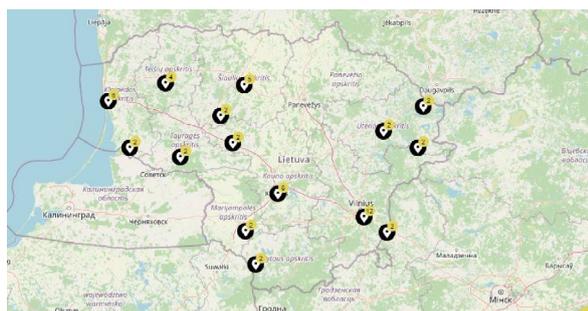


Fig. 3. Virtual tours in museums. [15]

Most municipalities in Lithuania have virtual maps with places of interest located in the city. One of them, the sights of the Akmenė district. It can be seen in the image below:



Fig. 4. Places of interest in Akmenė district. [17]

Many Lithuanian municipalities have installed mobile applications for smartphones. For example, visitAkmenė, a mobile tourist guide, is for smartphones app for devices. The mobile guide with the help of GPS helps to orientate while traveling and provides information about places of interest in the municipality of Akmenė district. The app also provides pedestrian, bicycle and car routes with links that tourists can use to get to know Akmenė region [17]. Anykščiai district municipality also offers to discover Anykščiai using your phone.

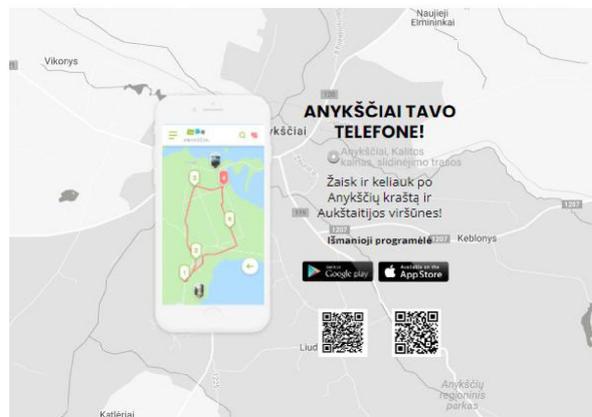


Fig. 5. Anykščiai on your phone. [20]

Below is a map of Lithuania, where you can see the location of virtual tourism products in Lithuanian municipalities.

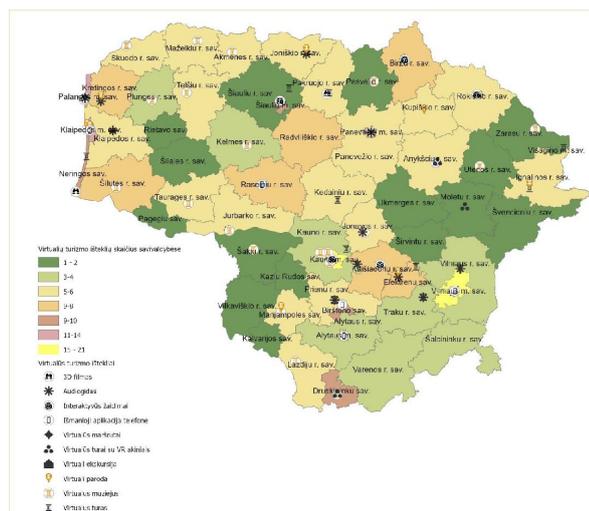


Fig. 6. Virtual tourism products in Lithuania

It can be seen that the largest cities of Lithuania - Vilnius and Kaunas - have the most virtual tourism resources. The big cities of Lithuania are characterized by an abundance of interesting tourist attractions, which have integrated and virtual reality. These are the cities that attract the most tourists. Last year alone, in 2022 1.195 million people visited Vilnius. Kaunas - 586.6 thousand tourists from all over the world [18]. Cities can offer a variety of virtual tourism resources. You can find many virtual tours of museums, virtual routes, smart apps, and audio guides created in museums. Virtual tourism products that can be found in the virtual space may seem attractive to many tourists, so there is a desire to come and see the objects in reality. The municipalities in the east and southwest of Lithuania, marked in dark green on the map, have the fewest virtual tourism products. Most of them are Lithuanian district municipalities located on the border of the Republic of Lithuania, or district municipalities that receive the least amount of tourists. These are municipalities that make less use of their tourism resources, which is why they are not characterized by an abundance of virtual tourism products.

In Lithuania, we see a clear trend of growth of virtual tourism products. Lithuania can offer a wide variety of virtual reality tourism products created by modern technologies, which everyone can discover. In the virtual space, you can virtually travel around various museums in Lithuania, travel along various created virtual routes, and with the help of virtual reality technologies - virtual reality, you can return to the past. Smart mobile applications prevail in Lithuania, which have been installed in most cities, where you can find all the necessary information. Various virtual educational-cognitive programs, interactive games, and flight simulators are also offered.

II. DISCUSSION

Klaipėda is a port city with its deep and rich history and cultural environment that attracts tourists. The city's maritime heritage, various tourist attractions attract tourists from all over the world to experience unique, unforgettable experiences in Klaipėda. The city's maritime past is evident in the old town, historical buildings create a wonderful atmosphere. The Clock Museum, which exhibits a fine collection of clocks, and the Castle Museum, housed in a

restored 13th-century building. in the castle, provides an insight into the city's history and heritage.

In Klaipėda, you can find virtual tours of museums, such tours have been implemented by the Museum of Clocks, the Gallery of Pranas Domšaitis. Virtual exhibitions are offered by the Museum of Little Lithuania, the Lithuanian Maritime Museum. The Klaipėda Audioguide smart app was created by the Klaipėda State Seaport Directorate, and its use is distributed by the Klaipėda Tourism Information Center. A virtual map with places of interest can be found on the Klaipėda TIC website. The city of Klaipėda also offers virtual tours with guides, which are placed on the Internet, and you can walk around the city of Klaipėda using virtual reality technology - 3D format.

The Klaipėda Tourism Information Center offers the route "Talking Sculptures". This is the Klaipėda sculptures dubbing project. Metal plates with the name of the sculpture and a QR code are attached next to each listed sculpture, which you can scan to hear how the sculpture will tell its story (KTIC, 2023)[7]. A map of the talking sculptures can be seen in the image below.

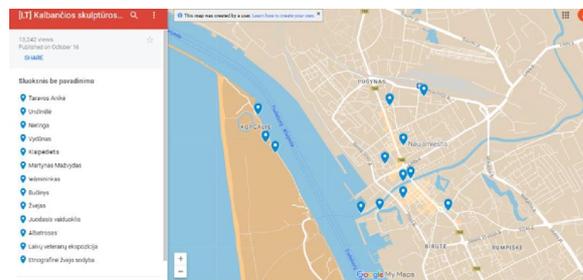


Fig. 7. Map of talking sculptures. [7]

The Klaipėda Tourism Information Center provides a virtual map with places of interest.



Fig. 8. Virtual map with places of interest. [7]

Most virtual tourism products can be found online and used on your smart devices. All described virtual tourism resources of the city of Klaipėda are difficult to represent cartographically, since they do not have their specific physical location. Most of them are found in the virtual space, but seven physical places have been selected, including museums, libraries and the Klaipėda Tourism Information Center, these places are represented on the map that can be seen below.



Fig. 9. Virtual tourism products in Klaipėda

It can be seen that a map of virtual services has been presented, seven objects in Klaipėda have been selected, which are shown on the map of virtual tourism services in Klaipėda. Most of the virtual tourism products in the city of Klaipėda, such as virtual maps, a smart app on the phone, or virtual tours that are placed on the website, all these created products are in the virtual space, they do not have a specific physical location that can be represented cartographically. For this reason, the selected objects that can be seen on the virtual tourism services map of Klaipėda city have a physical location, where virtual tourism products are created, created and installed.

There are 128 attractions in the city of Klaipėda. The city must offer many tourist facilities, educational and entertainment excursions, a variety of educational programs, active leisure entertainment and activities [21]. However, virtual tourism is not yet strongly developed. In order for the city of Klaipėda to become a center of attraction for internal and incoming tourism, there is a lack of advertising, and virtual tourism would help to create it. There are modern museums and exhibition halls in Klaipėda, the city has a unique heritage, and virtual tourism products installed in the virtual space would help popularize all of this. It would become a marketing tool to make the tourist want to come to a certain place. And for people living in other cities, it would be easy to reach the attraction.

Taking into account the empirical part, we can see from the answers of the research participants that a clear reason emerges, due to which virtual tourism products become a challenge for tourism-related companies. This is a lack of funding and expensive equipment. Since these are not cheap products, it would cost a lot of money to create something smart, modern and virtual. Such products should not be developed by individual companies, but by the city as a whole. By receiving funding from the municipality or collaborating with several organizations and implementing various projects, virtual tourism products would be easier to implement. A great example is the virtual tour created in the Watch Museum, it is a joint project with LIMIS, in which they offered to participate, and the creation of this product was not only very useful during the pandemic period, but also brings further benefits - after taking the virtual tour, users come to the museum to see real exhibits.

When users see virtual tourism products in the virtual space, they have the opportunity to plan their route in Klaipėda in order to visit one or another attraction. An interactive virtual map with places of interest and integrated panoramic photos would be very useful for this. Currently, the map created by the Klaipėda Tourism Information

Center only marks the places of attractions, but if an interactive map is integrated with panoramic photos, it would be possible to see a real view of the area and its surroundings.

The attractions in Klaipėda city are not fully utilized in order to increase the tourist potential. The analysis of the conducted research showed that by integrating virtual and augmented reality, attractions would look more innovative, modern, and attract more people. Since Klaipėda has lost many historical buildings during wars and fires, augmented reality would be useful, during which certain historical people living in that period would be restored and revived. We should immerse ourselves in different historical eras, for educational processes, both 360 degrees and augmented reality, virtual reality, all these technologies would attract more people to museums. In general, everything that is created in the city and in the museum could be brought to the virtual world, since the new generation wants less and less contact with a person, they want to be independent, individually interested in tourist objects. An excellent example is in the German city of Lübeck - in the Günter Grass-House Museum. This example could be applied in Klaipėda by taking tourists virtually to the city's past. Viewers would use virtual reality goggles to watch images of the past as the city changed over the years.

In summary, it can be said that three things are needed to develop virtual tourism in the city of Klaipėda. Advertising, financing and new virtual, interactive virtual tourism products, such as an interactive city map with places of interest or virtual tourism products with virtual reality glasses. In order for the city to remain modern and up-to-date, interesting, innovative virtual tourism products must be constantly created, which would provide users with informational and cognitive benefits and create unique experiences.

IV. CONCLUSIONS

1. After examining the concept of virtual tourism and the circumstances of its emergence from a theoretical perspective, it can be concluded that virtual tourism is a new form of tourism, inseparable from digital technologies, virtual and augmented reality technologies, which provide users with unique experiences and the opportunity to browse and travel without leaving home. This new form of tourism emerged as an alternative to the usual traditional tourism and its emergence and popularity was caused by the COVID-19 pandemic situation.

2. After analyzing the idea and classification of a virtual tourism product from a theoretical perspective, it was found that virtual tourism products are created using one or more virtual tourism technologies. The two most popular virtual tourism technologies are distinguished - virtual and augmented reality, which offer interactive images and provide new experiences. With the help of these digital technologies, various virtual tourism products can be created, such as virtual museum tours, virtual maps, 360-degree virtual tours, guided tours using virtual reality, virtual itineraries in smartphone applications, virtual guided tours. The most popular

virtual tourism products are 360-degree virtual tours and virtual museum tours, while less popular are guided tours using virtual reality.

3. After analyzing the trends of virtual tourism in the world and in Lithuania, it was found that the popularity of virtual tourism is growing rapidly both in the world and in Lithuania. With the help of ever-improving digital technologies in 2020. virtual tourism products with digital content are developed and implemented more intensively, museums and other places of interest and objects are digitized so that users can view the exhibition up close and virtually. In Lithuania, it can also be observed since the beginning of the COVID-19 pandemic in 2020. a clear trend in the development of virtual tourism products. The largest concentration of virtual tourism products is in the big cities of Lithuania. The municipalities in the east and southwest of Lithuania have the fewest virtual tourism products. Most of them are Lithuanian district municipalities located on the border of the Republic of Lithuania, or district municipalities that receive the least amount of tourists.

4. After analyzing the virtual tourism resources and services of the city of Klaipėda, it was found that virtual tourism in Klaipėda is an integral part of general tourism. In the virtual space, you can find virtual city walks, virtual tours of museums and galleries, as well as virtual guided tours, which are placed on online platforms, and places of interest can be found on the provided virtual map. Klaipėda city as well must offer a mobile application Klaipėda Audioguide. The largest number of virtual tourism products has been created by one of the most visited museums in Lithuania - the Lithuanian Maritime Museum, which has to offer various virtual tours and exhibitions. The majority of virtual tourism products do not have their specific physical location, they are found only in the virtual space, but the largest tourist objects of Klaipėda city: Lithuanian Maritime Museum, Clock Museum, Pranas Domšaitis Gallery, Imanuelis Kant Public Library, Klaipėda County Public I. Simonaitytė Library, Klaipėda Tourism the information center and the Museum of Little Lithuania have installed one or more virtual tourism products.

5. After determining the possibilities of virtual tourism and virtual tourism products of the city of Klaipėda, it was determined that it would be appropriate for the city of Klaipėda to focus on the presentation of the city's rich past when creating virtual tourism products. It is appropriate to increase the advertising of virtual tourism products by differentiating according to the target audience, and thus create the image of a modern, attractive city with the help of digital technologies. It is also important to implement mobile applications with integrated audio guides for increasing the accessibility of tourist information. In order to reduce the financial burden and when creating digital content products, it is appropriate for museums and other objects to join joint projects.

REFERENCES

- [1] J. Daubarienė, „Virtualaus turizmo vystymo ypatumai“, 2021. Available: https://www.utenoskolegija.lt/upload/file_manager/visuo_menei/jzvalg/2021nr1/3%20j.%20daubariene_%20virtualaus%20urizmo%20vystymo%20ypatumai.pdf
- [2] UNWTO „Impact assessment of the COVID-19 outbreak on international tourism“, 2023 Available: <https://www.unwto.org/>
- [3] N. Atri and N. Atri, (2023, March 15). Virtual tourism is the most popular type of tourism in 2021. Travel and Leisure Asia Available: <https://www.travelandleisureasia.com/in/news/virtual-tourism-popular-type>
- [4] A. Peštek, and M. Sarvan, Virtual reality and modern tourism. Journal of Tourism Futures, 7(2), 2020, pp. 245–250. <https://doi.org/10.1108/jtf-01-2020-0004>
- [5] N. R.-. E. Činga and N. R.-. E. Činga (2019, April 8). Lankomiausi Lietuvos miestai ir rajonai | We love Lithuania. We love Lithuania. <https://welovelithuania.com/lankomiausi-lietuvos-miestai-ir-rajonai/>
- [6] Klaipėdos apskritys Ievos Simonaitytės viešoji biblioteka. (2022). „Raudonų plytų Klaipėda“. Available: <http://www.krastogidas.lt/marsrutai/80-raudonu-plytuklaipeda>
- [7] Klaipėdos turizmo informacijos centras (KTIC). (2020). Available: <https://klaipedatravel.lt>
- [8] Sanjeev Verma, Lekha Warriar, Brajesh Bolia, Shraddha Mehta „Past, present, and future of virtual tourism-a literature review“, 2022 Available: https://www.researchgate.net/publication/36117916_Past_present_and_future_of_virtual_tourism-a_literature_review
- [9] M. Mahdikhani, „Predicting the popularity of tweets by analyzing public opinion and emotions in different stages of COVID-19 pandemic“, 2021. Available: [Predicting the popularity of tweets by analyzing public opinion and emotions in different stages of Covid-19 pandemic | Request PDF](https://www.researchgate.net/publication/36117916_Past_present_and_future_of_virtual_tourism-a_literature_review)
- [10] D. Ye, F. Liu, D. Cho and Z. Jia, Investigating switching intention of e-commerce live streaming users. Heliyon, 8(10), 2022. e11145. <https://doi.org/10.1016/j.heliyon.2022.e11145>
- [11] M. S. Siddiqui, T.A. Syed, A. Nadeem, W. Nawaz, and A. Alkhodre, Virtual Tourism and Digital Heritage: An analysis of VR/AR Technologies and applications. International Journal of Advanced Computer Science and Applications, 13(7), 2022. <https://doi.org/10.14569/ijacsa.2022.0130739>
- [12] M. Talafubieke, S. Mai, and N. Xialifuhan, Evaluation of the virtual Economic Effect of tourism Product Emotional Marketing based on Virtual Reality. Frontiers in Psychology, 2021. <https://doi.org/10.3389/fpsyg.2021.759268>
- [13] J. Kim, T. Shinaprayoon and S.J. Ahn, Virtual tours encourage intentions to travel and willingness to pay via spatial presence, enjoyment, and destination image. Journal of Current Issues and Research in Advertising, 43(1), 2021, pp.90–105. <https://doi.org/10.1080/10641734.2021.1962441>
- [14] F. Biocca, The Cyborg's Dilemma: Progressive Embodiment in Virtual environments [1]. Journal of Computer-Mediated Communication, 2006, 3(2), 0. <https://doi.org/10.1111/j.1083-6101.1997.tb00070.x>
- [15] Lietuvos integrali muziejų informacinė sistema. (2023). Available: <https://www.lndm.lt/struktura/limis/lietuvos-integrali-muziejju-informacine-sistema/>
- [16] National State Enterprise of Lithuania Museum of Art, (2023). <https://www.lndm.lt/en/>
- [17] Akmenės turizmo informacinis centras (2023). Available: <https://www.akmene.lt/sveciui/lankyti-objektai/128>
- [18] The State Data Agency (Statistics Lithuania) (2023) becomes the competent authority for the implementation of the Data Governance Act - Asset Publisher. (n.d.). https://osp.stat.gov.lt/en_GB/web/lsd/home-/asset_publisher/lbrXvLVHX2ln/content/valstybes-duomenu-agentura-tampa-kompetentinga-istaiga-igyvendinant-duomenu-valdymo-akta/
- [19] J. Oškiniš, „Pakvietė keliauti laiku: virtualioje realybėje leido pasižvalgyti po išnykusį Aleksotą“. 2022. Available: <https://www.lrytas.lt/it/ismanyk/2019/11/06/news/pakviete-keliauti-laiku-virtualiojerealybeje-leido-pasizvalgyti-po-isnykusi-aleksota-1245054>
- [20] Tourism information center of Anykščiai (2023). Available: <https://www.visitanyksčiai.lt/anyksčiai-tourism-and-business-information-center/>
- [21] Klaipėdos miesto savivaldybės 2021-2030 metų strateginis plėtros planas (2021). Available: <https://www.klaipeda.lt/data/public/uploads/2021/05/ksp-projektas-20210524-galut.pdf>

The impact of online social communication on the training of social workers and educators (Ukrainian universities)

Maryna Davydiuk

Department of Pedagogy, Vocational
Education and Educational
Institutions' Management
Vinnytsia Mykhailo Kotsiubynskyy
State Pedagogical University
Vinnytsia, Ukraine

Oksana Fushtei

Department of Psychology and Social
Work
Vinnytsia Mykhailo Kotsiubynskyy
State Pedagogical University
Vinnytsia, Ukraine

Anna Khilya

Department of Primary Education
Vinnytsia Mykhailo Kotsiubynskyy
State Pedagogical University
Vinnytsia, Ukraine
anika.line@gmail.com

Irina Sarancha

Department of Psychology and Social
Work
Vinnytsia Mykhailo Kotsiubynskyy
State Pedagogical University
Vinnytsia, Ukraine

Abstract. With the growing need to revise approaches to the educational process, educational institutions are increasingly turning to the digital opportunities and needs of the modern society. By closely monitoring the trends in the use of ICTs, engaging in various pilot projects for Ukraine to ensure digital literacy, develop digital competence, and use of Web 2.0 and VR social media, educational institutions are increasing their presence in the digital space of the Internet. From our point of view, this is a good basis for the declared changes in the educational paradigm at all levels of the educational process, including the training of specialists who will ensure the social, economic and cultural growth of the nation in the future. That is why it was important for us to study the theoretical database of scientific, research and pedagogical literature on the use of social media for education; compare the challenges mentioned in global trends in the use of social media and in Ukrainian practice; compare the *presence* and interaction of universities in social media with their *value* in the market of professional training of specialists, in particular, social and pedagogical profile. Based on the analysis of the above components, we have drawn conclusions about the challenges facing the Ukrainian higher education system, their root causes, and presented a number of tips and solutions that will allow universities to achieve not only a *presence* in the network, but also to be competitive both in the national environment and in the international arena.

Keywords: higher education, social communication, social networks, teacher training, training of social workers.

I. INTRODUCTION

Nation needs information.

Pryamy TV channel

It is impossible to imagine the society of the 20s of the XXI century without technology and its inherent solutions in all sectors of human life. And the more we immerse ourselves in technology, use ICT, virtual and augmented reality, artificial intelligence and improve information search algorithms, the more it affects the individual and his or her professional self-determination. The impact occurs at all levels of social interaction and in all age groups of society. From infants to people of the third age. Of course, the level of well-being in a particular territorial community should be taken into account in this aspect.

However, the main message of our scientific research is that the world is changing and changes lead to new forms of communication, which in turn affects social *media and information migration* and the need for rethinking and professional reset of certain fields of science, training in accordance with the current challenges and needs of both society and the individual who wants to realise his or her potential in social interaction.

Print ISSN 1691-5402
Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8018>

© 2024 Maryna Davydiuk, Oksana Fushtei, Anna Khilya, Irina Sarancha.
Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

This process of professional reset, in our opinion, concerns primarily social workers and educators, in particular the process of their training. After all, the psychology of the modern personality is changing in the process of cognition, which is associated with the free flow of information on the Internet and open, partially or completely anonymous communication in social networks, messengers, etc. Although the question of absolute anonymity may be rather questionable, based on the arguments of Dimans and Kotler that Internet companies *are already in your home, working with artificial intelligence and have long been experts in collecting and analysing your data* [1].

II. MATERIALS AND METHODS

In our opinion, one of the main stages in the training of specialists, as in previous years, is advertising. It means the presentation and dissemination of information that would help attract young people to professions such as teachers or social workers. And in this case, social networks are becoming the most adequate advertising platform in modern conditions. After all, any post goes viral and multiplies and reproduces challenges, comments, emoticons, etc. And this, of course, increases the recognition of the profession, educational institution, individuals and their professional qualities.

That is why the topic of the impact of social communication and the Internet on the training of social and pedagogical staff is important. And in this review, we will turn to data analysis and comparison:

- In particular, at the first stage, we analysed the trends of international and Ukrainian research in the field of social communication and their impact on the educational process.
- Next, based on the analysis of the ranking lists of Ukrainian universities, we identified the top three leaders according to the overall ranking [2] and the ranking of pedagogical universities [3] that train teachers and social workers in Ukraine in 2023. We also added Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University (VSPU) to this list, and thus obtained a list of seven higher education institutions in Ukraine (Table 1), which we tracked and analysed in real time.
- In the third stage, we analysed the presence of the universities we selected in the most popular social networks in Ukraine (Facebook, YouTube, TikTok, Instagram) and analysed the most popular educational institutions based on hashtags, depending on the number of mentions, and then compared these figures with official rankings.

Below we present the results of our research, conclusions and challenges, which, in our opinion, are facing universities in the context of information accessibility and social communication online.

TABLE 1 A SAMPLE OF UNIVERSITY RANKING INDICATORS

№	University	Location	General rating	Pedagogical rating
1	Taras Shevchenko National University of Kyiv	Kyiv, Kyiv region	1	-
2	Ivan Franko National University of Lviv	Lviv, Lviv region	2	-
3	National University Lviv Polytechnic	Lviv, Lviv region	3	-
4	Ternopil Volodymyr Hnatiuk National Pedagogical University	Ternopil, Ternopil region	60	1
5	National Pedagogical Dragomanov University	Kyiv, Kyiv region	66	2
6	Ivan Franko Drohobych State Pedagogical University	Drohobych, Lviv region	67	3
7	Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University	Vinnytsia, Vinnytsia region	79	5

III. RESULTS AND DISCUSSION

Turning to the first point of our study, we have conducted a brief review of freely available materials that present research on social communication and the Internet.

Most of the studies that are currently being covered by scholars focus on positive trends, summarising progress in a particular field due to the expansion of online education opportunities. However, with the global shift to online communications during Covid-19, public communication has included processes that we cannot and should not ignore.

In particular, we should not ignore three main disadvantages: blurring the line between personal and working time; decreased personal productivity; and increased cases of professional burnout (as we have written about in our other works). It is also worth noting that researchers have identified the following negative aspects of social media and the Internet, such as anxiety, stress, depressive disorders and other health problems in case of disproportionate use, setting unrealistic expectations that lead to stressful situations, and also among the disadvantages of use are brainwashing, absorption of fake news, breakdown of marriages, trolling, cyberbullying, violation of privacy, online witch hunts and wasting time; low digital literacy is associated with low motivation to use new ICT-based tools [4], [5]. As a result of this reloading, inclusion in a permanent digital presence, lifestyle and learning changes, skills and competences required in the knowledge society are also undergoing significant changes. After all, in order to cope with the information overload of the digital age, students (should) apply learning strategies that involve searching, sifting, managing, re-combining, verifying and contextualising information based on such cross-cutting skills as reflection, criticism, evaluation on the one hand; collaboration and communication on the other and the third side of the cross-cutting skills is innovation, creativity, and the ability to learn [4].

Of course, these are the theses that a teacher should learn for himself or herself, planning activities taking into account the individual characteristics of the younger generation that has grown up surrounded by digital media, demonstrates significantly different learning styles from previous cohorts, because they are those who are able to

control different sources of digital information simultaneously [5].

In addition, having analysed the scientific literature on this topic as part of our research, we found it interesting that for the European scientific space, for scientific institutions participating in international projects, studies of the impact of social media on processes in both the economy and education are quite common. However, if we look at the Ukrainian experience, it was only after the introduction of quarantine restrictions in 19 that scientists and academic staff began to study the issue of interaction with the audience through messengers. However, there are no significant national studies that would contribute to the development of a comprehensive action plan for PR companies and the dissemination of best practices of educational institutions (practices of innovative teachers, open lectures on television, information about projects involving not only Kyiv universities and state-funded projects, etc.) This, in turn, would help reduce the level of *inferiority* of Ukrainian citizens, raise the status of education, and reduce the outflow of young people from Ukraine (including scientists, researchers, developers, designers, etc.). In addition, the lack of a clear policy of the institutions themselves, as we will discuss below, regarding participation in the information space of social networks, giving priority to platforms used by teachers and avoiding interaction with youth also creates a vacuum of information for analysing the market of applicants and students.

In terms of thesis, eight years ago, researchers noted that teachers do not sufficiently prepare future teachers to use social media, and that despite the potential of social media for collaboration, teachers do not use them enough, thus losing many opportunities [6]. We partially confirmed this by interacting directly with groups of students through discussions of proposed creative works, interviews and questionnaires about their activity on social media. We were able to extract even more information by analysing the most used social networks for information about the universities identified for our study.

Thus, we have already presented in Table 1 the selected universities for the analysis of their presence. The selection algorithm was also described in the previous section. Therefore, we move on to the last question of our work on analysing the presence of these higher education institutions in the network.

For this purpose, we chose a simple algorithm for searching for information using hashtags, as this is a common way to create thematic areas for searching for information on the entire Internet.

The information search algorithm had the following steps:

1. on Facebook pages, we entered the full name of the university into the search feed. For example:
Taras Shevchenko National University of Kyiv.
This step was the first one, because according to the existing proposal, most of the university teaching staff belong to Generation X, some to Baby Boomers and another to Millennials (according to the distribution

by year of birth proposed in the field of social sciences [7]). Therefore, we easily found the official pages of universities, their individual structural units, and unofficial pages of students and alumni. In addition, this step gave us indirect information about the quality of information policy and its comprehensiveness.

2. Based on the results obtained for each institution, we received official and student publications that create a scientific, practical, creative, and research image of the university. That is, publications about the university's scientific achievements, conferences and events organised at the university, etc.

It is worth noting that this step gave us indirect information about the level of computer skills of the university's *representation* on Facebook. This may not be a significant point for our study, but it gives us an idea of why the information policy of the institution lacks comprehensiveness and innovation.

So, to return to the step above, we identified official publications and scanned them for hashtags, which helped us in our further work with other social networks and platforms.

3. Then, based on the *first* hashtag, we *walked* all four previously mentioned networks - Facebook, YouTube, TikTok, Instagram. Additionally, we used the Hashtags that arose in the process of searching for information from the results.

For example, using the example of VDPU, we took the most common hashtag #ВДПУ (corresponding to the abbreviation of the institution) and received the total number of posts on Facebook (12,000 posts), in addition to other variations of the main hashtag. For VDPU, it was #вдпу_ім_м_коцюбинського. The second hashtag was not widely used, so it did not reflect the number of posts, and since it corresponded to the posts included in the posts under the first hashtag according to the preliminary visual analysis, we did not include it in the sample on this platform. While for the next step of our algorithm for analysing the university's presence on the Internet, the second hashtag was more widespread, in particular on TikTok and Instagram.

The same algorithm was used for the other six universities.

4. For the reliability of the results. We repeated all steps 1 to 3 with the search for results in English. For this purpose, the name of each institution was copied from the official web pages. This step allowed us to expand the scope of searching for information by hashtags on social media. It is also worth noting that this step had a root cause. Some of the short hashtags in Ukrainian provided information about Russian-language educational institutions. This was due to the use of abbreviations as hashtags without additional markings that could have corrected the difficulties in the search and database formation.
5. Thus, as a result of processing the information by hashtags, we received a number of repetitive materials and chose quantitative indicators as the basis for our analysis. After all, in the case of a qualitative analysis, taking into account the level of

publication (public relations office, structural unit, teacher, student; scientific, creative, volunteer, etc. event; direct, targeted or indirect advertising); its relevance to the subject of our research; its relevance to the topic of our research, its scientific nature or personal information, we should use appropriate software tools for simultaneous screening to obtain reliable data. Or make a request to the official representatives of social networks and wait for a response in accordance with the protocols of interaction with open/closed data. After all, the data is updated every few minutes, the number of publications increases, and this will affect the analytics of qualitative data more than the statistics of quantity.

The results of the analysis of the number of publications are presented in Table 2. In addition, the results of this study show that most students use social media and its tools themselves, with Facebook being the most popular social network for interacting with educational institutions. While the other three are used for personal purposes and show no signs of strategic communication with the public to expand the university's influence and audience.

TABLE 2 A SAMPLE OF QUANTITATIVE INDICATORS OF POSTS BY SEVEN UNIVERSITIES IN FOUR SOCIAL NETWORKS (FACEBOOK, YOUTUBE, TIKTOK, INSTAGRAM; REQUEST FROM JANUARY 2024)

№	University	TikTok (M)	Instagram (K)	YouTube (video)	Facebook (K)
1	Taras Shevchenko National University of Kyiv	85,7	47,7	215	23
2	Ivan Franko National University of Lviv	66,4	18,9	695	22
3	Lviv Polytechnic National University	37,5	5,2	318	2,6
4	Ternopil Volodymyr Hnatiuk National Pedagogical University	22	2,6	596	2
5	National Pedagogical Dragomanov University	5,2	1,9	35	1,6
6	Drohobych Ivan Franko State Pedagogical University	1,7	0,7	166	1
7	Vinnitsia Mykhailo Kotsiubynskyi State Pedagogical University	2,9	5,1	75	12

Of course, the presented here is only a part of the "iceberg" of social communication and its influence on the choice of a university, its position in official rankings and the OWS-system (one woman said). Of course, the second thesis is a joke, but today personal communication is still a priority for choosing the best educational institution in Ukrainian society - this is the first thing. And secondly, in the modern world, personal communication has migrated to the Internet environment within social networks, platforms and, of course, messengers (we do not touch on

them in our research because this is a completely different topic with its own principles and patterns of functioning).

After comparing the ranking indexes with the indicators of the institutions' presence on social media, we can conclude that TikTok's indexes coincide with the official lists, while other indicators are very different. Of course, we conducted an additional analysis of the number of students according to the licensed volumes according to official data [8], which is presented in Table 3.

And based on a comparison of the number of applicants in the last four years, we can see that when we converted all the indicators into a rating system from 1 to 7, we found the arithmetic mean for each of the identified educational institutions. All the indicators into a rating system from 1 to 7, we found the arithmetic mean for each of the identified educational institutions. Thus, there have been no significant changes among the first five positions in the ranking we have chosen. Although the gap between the third and fourth places is significant (2,3 points), all five institutions remained in their positions in the ranking. While the last two changed positions.

TABLE 3 LICENSED VOLUMES OF HIGHER EDUCATION INSTITUTIONS ACCORDING TO OFFICIAL DATA FROM THE PLATFORM VSTUP.OSVITA.UA

№	University	2020	2021	2022	2023
1	Taras Shevchenko National University of Kyiv	18082	18489	16822	16211
2	Ivan Franko National University of Lviv	18177	17837	18113	19134
3	Lviv Polytechnic National University	32224	30307	37007	38739
4	Ternopil Volodymyr Hnatiuk National Pedagogical University	7941	6275	5795	6510
5	National Pedagogical Dragomanov University	11767	11558	12829	*
6	Drohobych Ivan Franko State Pedagogical University	3985	3574	5052	4660
7	Vinnitsia Mykhailo Kotsiubynskyi State Pedagogical University	6012	6013	4883	4981

* - данні відсутні у зв'язку зі змінами юридичного статусу закладу

Of course, we did not conduct an additional analysis of the number of subscribers, the presence of an official page and side pages, the activity of community members (comments, likes) or the number of views of the institution's videos. This, of course, can be the basis for a deeper analysis and research that will allow educational institutions to look at the problem of a high-quality information policy and a well-thought-out PR campaign. But most importantly, we have drawn attention to the equivalence and impact of the use of the relevant strategy on the visibility of the educational institution, which in the

near future can significantly increase or decrease the number of applicants and the scientific potential in general.

And in this aspect, we agree with the need for flexibility of the education system and its *response* to the demand of the information society, which is *to introduce social computing tools in higher education, such as:*

- *an institutional tool, replacing or extending the virtual learning environment (VLE);*
- *a communication tool among students and between students and teachers, supporting also the exchange of knowledge and material, but mainly creating an environment of understanding and assistance;*
- *a methodological or didactic tool within certain disciplines, courses and classes, with a focus on improving, facilitating and enhancing knowledge acquisition [9].*

This will entail the need to address the issues of integrating Web 2.0 tools into the educational process, making them publicly available or for internal use only; *whether to make activities student or staff led; and, how the use of SC tools will affect learning and teaching [9].*

IV. CONCLUSIONS

To summarise the results of our research, we analysed the impact of social communication on the Internet on the training of social workers and teachers on the example of seven universities in Ukraine. The conclusions drawn are almost identical to those of the official ranking and the data we obtained (in terms of average indicators).

Of course, among the discussion issues, we can single out the issue of relevance of the information that students post on social media with hashtags and in official groups that involve or can be joined by teachers, employers, etc. And the information that future specialists produce in personal communication, which is not subject to publication and dissemination. This is the side that will remain as long as society and social connections exist, like the 25th frame in a film.

It is also debatable that today there is a technological and educational transformation, involving artificial intelligence, materials presented by a *"talking head"* and visualised through various applications.

This change in the concept of education makes it necessary to rethink teaching approaches and provide a qualitative explanation of why it is necessary to know certain subjects, laws, etc. for the teacher or social worker profession. Although, in some cases, young professionals start producing content like this themselves through TikTok: *"Why didn't we learn this?", "We could use it!"*. We will discuss this in our next publications. And this is also part of the influence of social media on the choice of profession or advanced training courses.

But, among the main conclusions we can draw today within the framework of the outlined aspects of the study is the following:

- Social media have a significant impact on the choice of educational institution.

- Publications for social communication have an almost instantaneous reaction of the audience to certain events in the educational institution. Moreover, the lower the university's ranking in the general lists, the less reactions there are at the national level. Also, the number of reactions and the *power of influence* of social communication on the *politics* of an educational institution depends on the location.

It is also worth noting that the location of an educational institution may also gradually lose importance with the transition to the digital world, because today in Ukraine the choice of universities in the capital and cities close to the EU is more related to transport links, opportunities for further employment and the amount of resources that come to the educational institution from various sources, while less significant regions have fewer such resources and *goodies* for a wide audience. This will not matter at all with the transition to cloud technologies and online audiences. Especially if we can use virtual and augmented reality services or at least 3D technologies in preparation for our future professional activities.

In addition, the blurring of borders and globalisation in the educational space can and should lead to the fact that an applicant from anywhere in the world will be able to choose where to study to teach.

Thus, the main message that should be understood and picked up, in our opinion, is that in the digital world, every educational institution, as well as a financial institution or government organisation, must develop a strategy for digital interaction with participants in the educational process.

REFERENCES

- [1] P. Diamandis, S. Koler. Maibutnie blyzhche nizh zdaietsia. Yak tekhnolohii zminiuiut biznes, promyslovist i nashe zhyttia / per. z anhl. D. Kozhedub. Kyiv: Laboratoriia, 2021. 320.
- [2] Konsolidovanyi reitynh vyshiv Ukrainy 2023 roku. Vyshcha osvita v Ukraini. [Online]. Available: <https://osvita.ua/vnz/rating/51741/>. [Accessed: Jan. 18, 2024].
- [3] Naikrashchi pedahohichni zaklady osvity Ukrainy. Vyshcha osvita v Ukraini. [Online]. Available: <https://osvita.ua/vnz/rating/42227/>. [Accessed: Jan. 18, 2024].
- [4] J. Abbas, J. Aman, M. Nurunnabi, S. Bano. The impact of social media on learning behavior for sustainable education: Evidence of students from selected universities in Pakistan. Sustainability, 2019. 11(6). p. 1683.
- [5] C. Redecker, Y. Punie. Learning 2.0 Promoting Innovation in formal Education and Training in Europe. ECTEL' 10 Proceedings of the 5th European conference on Technology enhanced learning conference on Sustaining TEL: from innovation to learning and practice. 2010. pp. 308-325.
- [6] R. Gil-Fernández, D. Calderón. El uso de las redes sociales en educación: una revisión sistemática de la literatura científica. Digital Education Review, 2021, num. 40, p. 82-109.
- [7] A. V. E. D. van Twist, & S. Newcombe. Strauss-Howe generational theory. 2021. [Online]. Available: <https://www.cdamm.org/articles/strauss-howe>. [Accessed: Feb. 13, 2024].
- [8] I. M. Chyrak. Ekonomika sotsialnykh media: navchalnyi posibnyk. ZUNU, 2023. 300.
- [9] Vstup.OSVITA.UA. Dani otrymani z YeDEBO 01.12.2023. [Online]. Available: <https://vstup.osvita.ua/>. [Accessed: Feb. 13, 2024].

Methodological and technical aspects of models for digital management of transport systems

Dimitar Dimitrov
Faculty of Transport Management
University of transport
Sofia, Bulgaria
ddimitrov@vtu.bg

Ivan Manchev
Faculty of Transport Management
University of transport
Sofia, Bulgaria
imanchev@vtu.bg

Abstract. The digital transformation of transport systems is a priority area worldwide and aims to improve the quality of the services offered, as well as the processes of planning and management of work and traffic in transport. Digitization allows in a qualitatively new way to compile basic technological documents, as well as to manage specific transport and business processes. Through such management, the transport of passengers and cargo becomes faster, more efficient and safer. The main problems in the construction of the new digital platforms are related to hardware and software collateral. This article discusses methodological and technical aspects of digital transport management models using new technical and technological solutions of specific business processes and systems management models. The specifics and main directions on which to work to improve the implementation and development of digital systems in transport are outlined.

Keywords: *Building Information Modelling (BIM), Digital management, Digital transformation, ITS – Intelligent Transport Systems, Sustainability*

I. INTRODUCTION

The transportation industry is the bloodline of modern society and the basic industry for the development of the national economy. Transport infrastructure is the key to the formation of transportation capacity and the basis of economic and social development. In last decades economy has grown rapidly, infrastructures have developed vigorously. Accordingly transport infrastructure has also made great achievements under development and construction. Extensive operation and management will accelerate the depreciation and loss transportation infrastructure, the high-quality asset. In order to achieve the sustainable development of transport infrastructure, scientific and effective management techniques are essential. The degree of intellectualization of transport infrastructure plays a key role in transportation safety, efficiency and interaction between

transportation modes. The intelligent transportation system is the future development direction of the transportation system and one of the key measures to solve of problems. Establishing a real-time, accurate and efficient evaluating systems that functions in a large-scale and all-round way is the development direction of intelligent transportation systems. Accumulate rich experience to achieve the ultimate development goal of an informative, intelligent and humanized transportation system [1].

The current situation of transport infrastructure management is explored, data sources and characteristics of basic transportation information are discussed in the article. In order to give full play to the value of transport infrastructure data, three goals for digital management of transportation infrastructure are discussed: network-level, full life cycle and multi-source information fusion management. The new challenges brought by the digital management of transport infrastructure in the era of big data are analysed [2], [3].

II. MATERIALS AND METHODS

A. Overview of transport infrastructure management

Transport infrastructure management requires the management of basic information, usage characteristic, maintenance records and other information of traffic facilities. It's includes static and dynamic data, as well facility attribute data and operational records. Such information covers a long period of time, including engineering, economy, service and other factors. Therefore, has many objects, wide range of types, a long period, high liquidity and all make management difficult.

The rapid development of information technology in recent years, the level of digital management has been improved in the transport infrastructures. The collection, analysis and maintenance of transport infrastructure data are the core of the management system's role [4].

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8049>

© 2024 Dimitar Dimitrov, Ivan Manchev. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

Using GIS, BIM, graphic recognition, Wi-Fi, 4G, 5G and so on sensors and different technologies, the collection of transport infrastructure data is becoming faster and more accurate, maintenance of service more convenient. The development of information network technology, such as development of Web, PC, Cell phone clients, allow managers to conveniently query asset information, perform information maintenance anytime and anywhere. The fuzzy comprehensive evaluation, neural network algorithm etc. provide methods for analysis. So more accurate and reliable transport infrastructure information models can be established. Grey prediction model, decision tree, genetic algorithm etc. provide great solutions for comprehensive maintenance of transportation facilities. Based on development of these technologies and method for analysis, it's particularly important to collect accurate and comprehensive infrastructure data. All obtained data can also play a great role in decision making. Implementation of the digital management is very feasible and necessary [5], [2], [6].

B. BIM background

Building Information Modelling (BIM) is a process developed in the 70s in the USA to create and manage information and digital representations of physical and functional characteristics. The tools used in BIM have different nature and comprehend databases, 3D models and even things like contracts. Further development and refinement across last decades along with technological progress, becoming more popular and recognized worldwide nowadays. It's not just a 3D software, but rather an entire, very different approach. Transportation infrastructure is one of the many applications of BIM, especially in current times and globalized world, characterized by an ever-increasing transportation demand related to economical and demographical changes, along with transport infrastructures complexity. In recent years approach is getting extended to Smart Cities and Intelligent Transport Systems (ITS), which makes sense given the complex and multidisciplinary nature of these infrastructure. This paper will introduce a brief description of the BIM in relation to ITS, moving then to more technical details [7].

C. Information modelling and ITS

ITS comprehend a multitude of technical devices and processes interconnected into network, aimed to control and optimisation the different types of transport and their mechanisms. For example, ITS applied to road transportation is the ensemble of connected sensors designed to optimize traffic flows, in combination with Connected Autonomous Vehicles (CAVs). Other examples of ITS include Intelligent Road Intersections (IRI), Smart Roads and so on. ITS work with large amounts of data stored and exchanged between vehicles, surrounding infrastructure and electronic devices etc. All these aspects can be implemented in models in order to have a well-organized and well-working system, either in a design phase, or in working phase or for maintenance. The interconnection between Geographic Information System (GIS), ITS and BIM can be achieved by modelling data thanks to the use of Unified Modelling

Language (UML) and Model Driven Architecture (MDA). Different system architectures can be developed for structuring and manipulating BIM models, along with 3D geospatial information, collection of points and any data that can be collected by smart sensors in places; one of such systems considers four different layers: data pre-processing, data systematization and storages, system interface, and front-end data manipulation; data integration is achieved thanks to the development of an UML. This method allows reconstructing and geo-referencing 3D BIM models, along with data storage and visualization; the final outcome constitutes what is called a Precinct Information Modelling (PIM). Thematic models considered in this system included: Building, Vegetation, Sensor, City Furniture, Land Use, Transportation, and Terrain [6], [8], [9];

Comprehend a multitude of technical devices and processes interconnected into network, aimed to control and optimisation the different types of transport and their mechanisms. For example, ITS applied to road transportation is the ensemble of connected sensors designed to optimize traffic flows, in combination with Connected Autonomous Vehicles (CAVs). Other examples of ITS include Intelligent Road Intersections (IRI), Smart Roads and so on [10], [11].

D. Main difficulties faced by management of transport infrastructure

At the present the main difficulties faced by the digital management of transport assets are: 1) Insufficient historical data on transport infrastructure management. 2) Transport infra management involves many types of data so processes of integration and application are difficult. 3) Transport infra management is usually based on projects. The different platforms are difficult to exchange and share data. The advancement of comprehensive management of regional route networks is hindered [11], [12].

E. data sources for transport infrastructure management

There are four main sources of basic transport data: design information, facilities collected, manual collected and network collected data [2].

A. Design information data: The basic data mainly include the electronic topographic maps of different proportions, the design and constructions documents etc. The basic geographic information maps are used in general for surveys of water systems, survey control, survey of residential, coast and shelf. A large number of multimedia, exchanges and contract reports are also contained.

B. Facilities collected data: Now there are more various monitoring facilities. For example, widely used sensor systems including Fiber grating, piezoelectric material, shape memory alloys etc. Also have high-definition cameras, weather monitors, radar detectors etc. The camera technology, laser scanning, infrared temperature field photography and geological radar detection technologies are used. The automation of process is efficient and no manual errors.

C. Manual collected data: In some cases, the detection equipment can't directly collect info, so the detection of mechanical equipment and data export

required manual additional operations. Nowadays the automation is high and manual collection is getting down.

D. *Network collected data*: In the Internet age people's lives are increasingly dependent on the Internet. The development of the mobile Internet applications such as precise location positioning, terminal perception, cloud processing and computing. Data fed from user phones by road is also useful information resource.

F. *New systems under the digital management of transport infrastructure*

A. *Network-level management*

Currently commonly used transport infrastructure management systems are mostly project-level. That is the scope of management is only a single specific project. The management cycle is the project operation life cycle. At the different stages of project, the different systems will be used due to different responsibilities, which will lead to the fragmentation of information. For different projects the information is even more fragmented. Even if the geo locations are close or adjacent, organisation rules, languages, data processing methods are different due the different management systems. Project level management can lead to loss information between projects and even the various stages of the same project, which hinders the exploitation of the potential of data in asset management. The network-level transport infra management can solve these problems. The network-level manage and analyses the historical and real-time data. The evaluation and forecast models are used for analysis and decision making. The limited maintenance funds are allocated more effectively and reasonably [13].

The calculation logic structure of the system is shown in the Fig. 1 The system evaluates judges whether the planned investment is satisfied. Finally, the feasible maintenance plans are got and the plans are not unique.

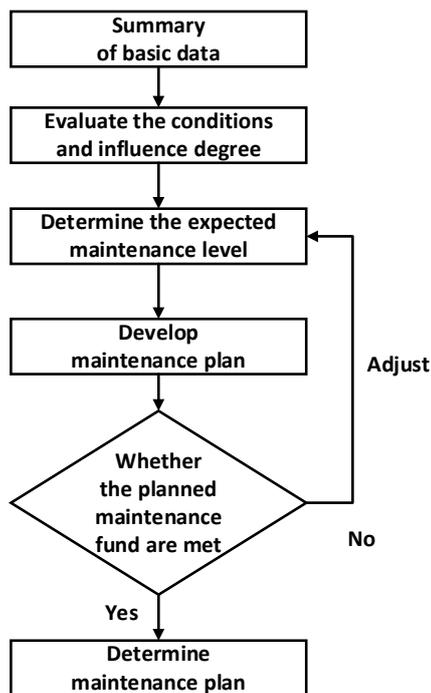


Fig.1 Network-level management procedures for transport infrastructure

B. *Full-lifecycle management*

In the fully-lifecycle transport infrastructure there are many participants. Most only involve part of the process and the type of data generated are complex and diverse. There are problems of poor data communication, data delay and even data islands. To a large extent these lead to low level management and efficiency. Development of informatization in full swing to improve the efficiency and effectiveness of information exchange, it's necessary for transport infrastructure to establish a platform for effective management and sharing of full-lifecycle data.

The full-lifecycle of transport infrastructure can be divided into three stages: design, construction and operation. The information between various stages is still interrelated and ensuring the effectiveness of info communication. The digital management platform of transportation infrastructure should have unified and integrated characteristics as shown in Fig. 2

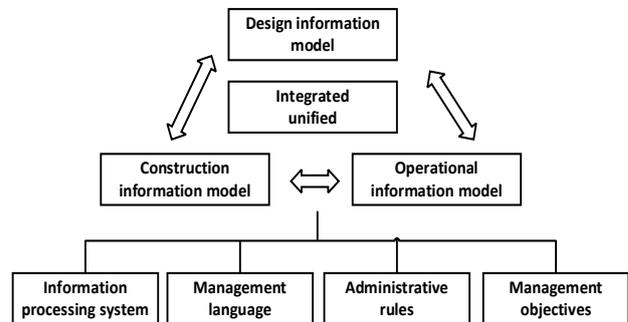


Fig.2 Transport infrastructure management model based on the whole life of the project

Establishing a digital management platform for transport infrastructure and building a database that stores and manages the entire life cycle data that runs through design, construction and operation is an effective way to realize the full life-cycle of management. The overall idea is shown on Fig. 3

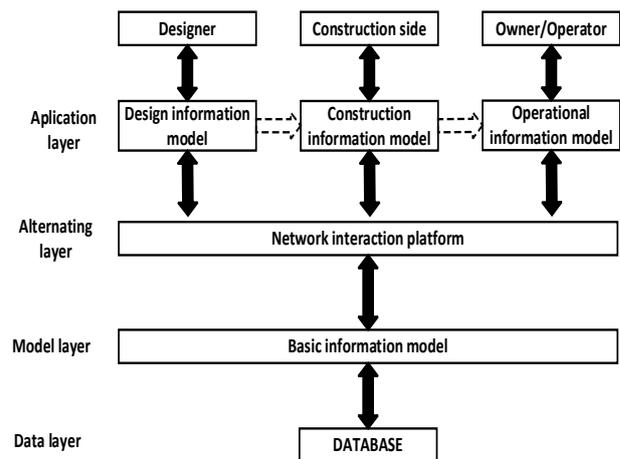


Fig.3 Full life cycle transport infrastructure management platform structure

C. *Multi-Source Information Fusion*

Multi-source information fusion refers to the comprehensive processing of information from different sources, so as to obtain more unified and rich information. With development of Internet and Wi-Fi technologies

there are more channels for information acquisition. It's realized that information integration can improve the accuracy and comprehensiveness of the evaluation and understanding. The multi-source information fusion technology has developed rapidly [5].

In transport infrastructure management, through the integration of information, the geological and hydrological data, historical construction, maintenance data related to facility can be obtained quickly and directly. The application process of multi-source distributed data is shown in Fig. 4. The effect of multi-source information fusion is not a simple accumulation, but $1+1 > 2$, which can fully tap the potential data.

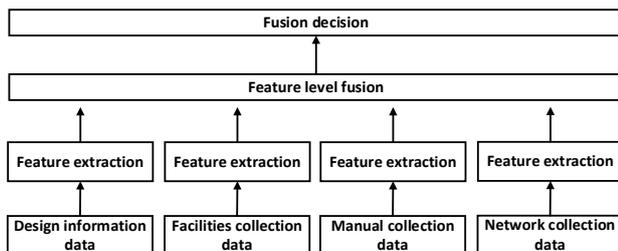


Fig.4 Schematic diagram of multi-source information fusion technology

The transport infrastructure digital management platform assists in scientific maintenance decision-making by reasonably summarizing and storing transport infrastructure information, realizing the sharing of asset information.

III. CONCLUSION

In the last decades, transportation systems have witnessed a demand growth, caused by factors like an increasing local and international mobility, globalized trades and mainly improvement of economic conditions. The complexity of transportation systems has therefore getting more significant than previously, generating high transport volumes and huge amounts of related information. The application of BIM process to transport infrastructure can facilitate their management, as BIM allows the creation of realistic 3D models which can be enriched with technical data; BIM also allows sharing this information among stakeholders of different backgrounds. ITS technology like radars, sensors, and automated devices interconnected within a network, permit much easier management operations and the creation of detailed databases which can be implemented into models. The integration of BIM, GIS and ITS lead to powerful models which can be used for tasks such as monitoring infrastructure's safety, controlling an Intelligent routes and flow. This information can be viewed and analyzed in real time and quickly shared and analyzed, afterward shared among technicians and professionals, and it's relatively easy to consult thanks to the accuracy of 3D models. Future research might be directed towards the implementation aspect of BIM, GIS and ITS, also searching for new applications, methods of data processing and finding solutions to make these technologies more accurate, widespread and cost-effective [14], [15].

IV. ACKNOWLEDGMENTS

This paper was supported by a grant from the Internal Research Projects Program funded by the state budget of the Ministry of Education in the Republic of Bulgaria (Project "Intelligent Transport Systems: Problem Areas and Advanced Solutions").

The grant covered the research work as well as the costs of open access publishing.

V. REFERENCES

- [1] T. Gaponenko and L. Hvoevskaya, "Digital transport platforms: reality and prospects," *Transportation Research Procedia*, vol. 63, pp. 1185-1191, 2022.
- [2] M. Vasilenko, E. Kuzina, N. Drozdov, Y. Tagiltseva and N. Korenyakina, "Modelling As Transport Service Quality And Efficiency Increase," in *European Proceedings of Social and Behavioural Sciences*, 2021.
- [3] Vasilenko, Marina and Kuzina, Elena and Bepalov, Vadim and Drozdov, Nikita and Tagiltseva, Julia and Korenyakina, Natalia and Prokopchuk, Vladimir and Nadolinsky, Pavel, "Digital technologies in quality and efficiency management of transport service," *E3S Web Conf.*, vol. 244, p. 11046, 2021.
- [4] V. Kryukov, K. Shakhgeldyan, E. Kiykova, D. Kiykova and D. Saychuk, "Assessment of transport enterprise readiness for digital transformation," *Transportation Research Procedia*, vol. 63, pp. 2710-2718, 2022.
- [5] M. Deveci, D. Pamucar, I. Gokasar, M. Köppen, B. B. Gupta and T. Daim, "Evaluation of Metaverse traffic safety implementations using fuzzy Einstein based logarithmic methodology of additive weights and TOPSIS method," *Technological Forecasting and Social Change*, vol. 194, p. 122681, 2023.
- [6] I. Petrova, "Design of production systems and processes with erp systems in railway freight transport," *Mechanics Transport Communications*, vol. 21, no. 1, 2024.
- [7] S. Barberi, F. Arena, F. Termine, A. Canale, I. O. Olayode and Y. Zuccalà, "BIM applied to intelligent transport systems," *AIP Conference Proceedings*, vol. 2611, p. 060011, November 2022.
- [8] I. Petrova, "Challenges to improve road safety solved with the help of artificial intelligence," *Proceedings of University of Ruse*, vol. 62, no. 4.1, pp. 34-39, 2023.
- [9] I. Petrova, Models for the phased development of transport infrastructure, PhD thesis, 2022.
- [10] R. Salazar-Cabrera and A. Pachon, "Methodology for Design of an Intelligent Transport System (ITS) Architecture for Intermediate Colombian City," *Ingeniería y Competitividad*, vol. 21, p. 47-60, March 2019.
- [11] E. Duganova, I. Novikov, A. Novikov and N. Zagorodnii, "Problems of introduction of digital technologies in the transport industry," *Transportation Research Procedia*, vol. 63, pp. 1024-1033, 2022.
- [12] I. E. Hajduk and M. Poliak, "Proposal of methodology for customers relationships establishing in terms of transport services," *The Archives of Automotive Engineering – Archiwum Motoryzacji*, vol. 101, p. 5-31, 2023.
- [13] A. Durand, T. Zijlstra, M. Hamersma, A. 't Hoen, N. van Oort, S. Hoogendoorn and S. Hoogendoorn-Lanser, "Fostering an inclusive public transport system in the digital era: An interdisciplinary approach," *Transportation Research Interdisciplinary Perspectives*, vol. 22, p. 100968, 2023.
- [14] G. Abuselidze, O. Mohylevska, N. Kompanets and L. Iushchenko, "Modern concepts and methodological recommendations for teaching economic disciplines: tasks of the course "Digital Management of Transport Infrastructure"," *Transportation Research Procedia*, vol. 63, pp. 2759-2766, 2022.
- [15] P. Kartsan and S. Mavrin, "The Digital Revolution of the Transportation Industry," *Transportation Research Procedia*, vol. 68, pp. 116-119, 2023.

Intelligent Rail Transport Management Systems - Methodological Essence, Goals and Tasks

Dimitar Dimitrov

Faculty of Transport Management
University of transport
Sofia, Bulgaria
ddimitrov@vtu.bg

Krassimir Lalov

Faculty of Transport Management
University of transport
Sofia, Bulgaria
klalov@vtu.bg

Abstract. The use of intelligent systems for the management of railway transport is a current issue related to a number of innovative methods of carrying out freight and passenger transport, traffic management and efficient use of the infrastructure. These systems allow users to be better informed and use them more safely, more coordinated and "smarter". From a methodological point of view, the requirements for these systems are growing, and the technical solutions are developing according to the trends for the development and modernization of the information technologies themselves. In this article, a generalized methodological analysis is made for the requirements, goals and tasks of these systems. The experience of the implemented intelligent systems that are used to manage railway transport is reported, as well as the types of information services that are provided for passengers and cargo.

Keywords: Artificial Intelligence in Railway Transport, Digital management in Railway Transport, Intelligent transportation system, Railway safety,

I. INTRODUCTION

Intelligent transportation system, as a new technology and control system, is a hot topic and challenge in traffic research. The application of intelligent transportation system, in addition to road traffic, water transportation, aviation, in particular, also plays a huge role in railway transportation with "high security, high efficiency, high quality of service". This is the Rail Intelligent Transport System (RTIS). [1]

Europe faces major challenges when it comes to formulating its transportation policy. Information and communication technologies (ICT) are considered a key tool to create the intelligent transportation systems (ITS) that Europe needs. In freight transportation, ICT is seen as playing a crucial role in providing efficiency in freight transportation operation and in integrating it within the

overall ITS that are now being put in place in Europe. The issues and priorities for freight transportation integration with the European ITS are presented, with concentration (as one such priority) on the issue of linking freight transportation management systems with the advanced Traffic-management systems of the European ITS. Also covered are the results so far of the thematic network THEMIS, which concentrates on the relation between freight transportation and ITS. A thematic network is a special type of research project, financed by the European Union's Directorate General of Transport and Energy in order to review and synthesize the results of research in a specific field, in this case freight transportation. The efforts made at the European level toward the formulation of a common, ITS-based freight transportation systems architecture are also reviewed. In this respect, there is a report on work done within project THEMIS. [2] [3] The EU transport system and infrastructure will be made fit to support new sustainable, compatible, secure and interoperable mobility services that can reduce mortality, congestion and pollution. [4]

II. MATERIALS AND METHODS

Intelligent Transport Systems (ITS) in railways represent a transformative approach to modernizing and optimizing railway transportation. These systems leverage advanced technologies to enhance efficiency, safety, and overall management of railway transport. The integration of ITS in railways involves a holistic approach, encompassing various key aspects of the transportation ecosystem.

1. Digital Train Control Systems: [5]
 - Automated systems for train control to manage train movements efficiently,
 - Signalling systems for real-time communication between trains and control centres,

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8050>

© 2024 Dimitar Dimitrov, Krassimir Lalov. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

- Traffic management to optimize train movements and improve safety.

2. Communication Systems - High-speed data communication for real-time monitoring, control, and communication between trains and control centres.

3. Digital Management system of railway freight transportation based on the concept of Industry 4.0. Improving the efficiency of freight wagons monitoring system by using GPS and other sensors with geolocation technology integrated into carriage, they will alert about condition of the freight in real time. Such sensor will be able to integrate to the IoT system through a specialized Internet platform that also supports mobile version program. [6]

4. Digital Passenger Information Systems:

- Real-time information systems for passengers, providing updates on train schedules, delays, and other relevant details.
- Integrated management systems to streamline passenger services, including ticketing and journey planning.

5. Digital Ticketing and Payment Systems - Implementing smart ticketing and payment solutions for a seamless passenger experience. ITS technologies and services for the collection of fees in the field of transport have been developed in the last 20 years starting with toll collection systems, and more recently the pricing of transport, according to certain criteria (e.g. emissions). A separate section of this area is the “smart ticketing” systems i.e. ITS enabled ways to pay the tickets in public transport or other transport services.

There is a long number of policy decisions, standardization and legislative steps that create the current landscape in this area. Electronic Fee Collection (EFC) systems offer the possibility of “smart” charging for the use of transport infrastructure (mainly roads) following the pricing policies established in the different EU Directives as mentioned above. This is also called “smart pricing” as opposed to smart ticketing which refers to the collection of fares in a public transport system. According to the stakeholders’ hearings, held within the STTP exercise, smart pricing will be a market where the infrastructure managers, together with the vehicles industry, and the ITS providers, will co-operate in order to produce a (road or other mode) service and provide it at a certain price to the “consumers” with one given technology or with harmonised technologies.

6. Predictive Maintenance - Using sensors, Smart devices, IoT Systems, and data analytics to predict and prevent equipment failures, reducing downtime and maintenance costs. Implementation of proactive maintenance strategies to minimize downtime and improve overall system reliability.

7. Safety and Security Systems - Deploying surveillance, access control, and emergency response systems to enhance the safety and security of railway operations. Integration of intelligent security solutions to safeguard passengers, staff and railway infrastructure stations railway.

Different multimodal transport systems - Railway, subway, airplane, and other have significant an interest of utilization of wireless communications for critical and noncritical services to improve performance, reliability, and passengers experience. [7]

8. Energy Management and Grid Optimization - Optimizing energy consumption through smart grid technologies, energy-efficient train operations, and regenerative braking. Implementation of energy-saving measures such as regenerative braking and optimizing train operations for reduced environmental impact.

Integrating these intelligent systems can lead to a more efficient, reliable, and safer railway infrastructure. It's an ongoing area of development within the broader field of smart transportation.

The introduction of ITS in railways reflects a commitment to creating a more intelligent, interconnected, and sustainable transportation system. By embracing cutting-edge technologies, railways aim to provide safer, more reliable, and convenient services while optimizing resource utilization and minimizing environmental impact.

Artificial Intelligence (AI) is becoming pervasive in most engineering domains, and railway transport is no exception. However, due to the plethora of different new terms and meanings associated with them, there is a risk that railway practitioners, as several other categories, will get lost in those ambiguities and fuzzy boundaries, and hence fail to catch the real opportunities and potential of machine learning, artificial vision, and big data analytics, just to name a few of the most promising approaches connected to AI. The scope of this paper is to introduce the basic concepts and possible applications of AI to railway academics and practitioners. To that aim, this paper presents a structured taxonomy to guide researchers and practitioners to understand AI techniques, research fields, disciplines, and applications, both in general terms and in close connection with railway applications such as autonomous driving, maintenance, and traffic management. [8] The important aspects of ethics and explain ability of AI in railways are also introduced. The connection between AI concepts and railway subdomains has been supported by relevant research addressing existing and planned applications in order to provide some pointers to promising directions. [9]

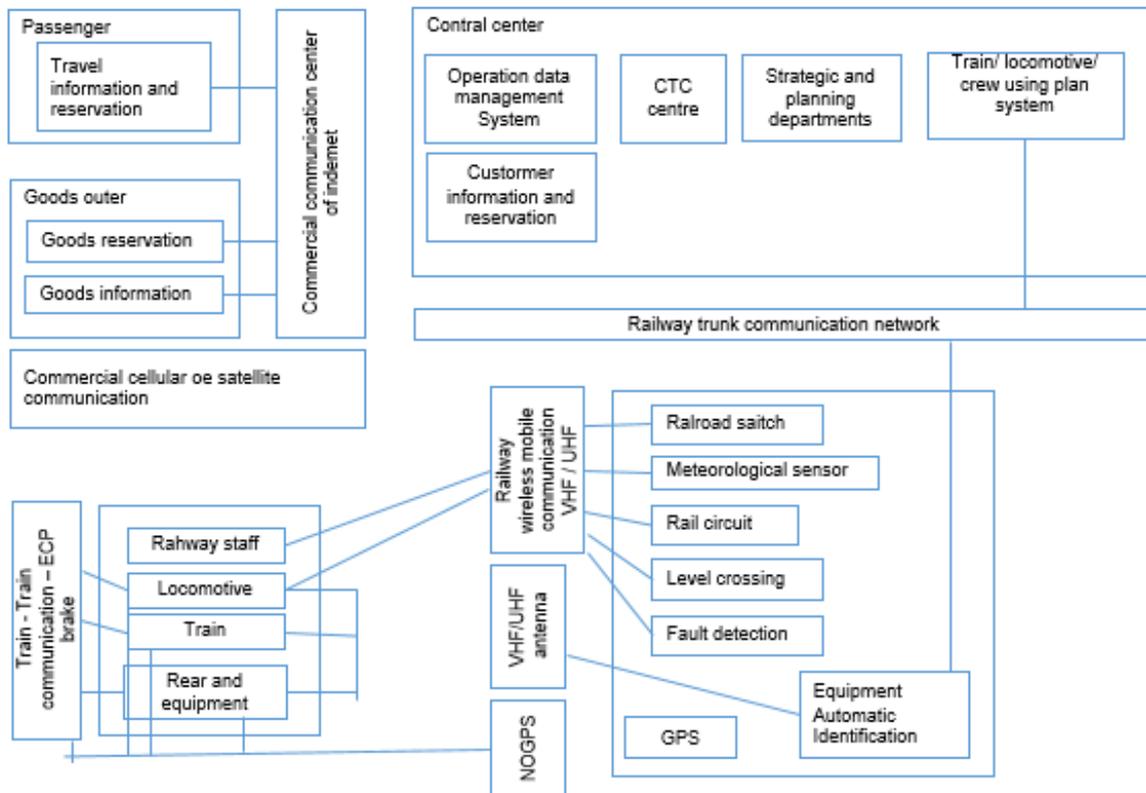


Fig. 1. Intelligent Transport Systems

Implementing Intelligent Transport Systems (ITS) in railways comes with various challenges, reflecting the complexities of integrating advanced technologies into existing transportation infrastructures. Some key challenges include:

1. **Interoperability:** Achieving seamless integration and interoperability among different ITS components, as various systems may come from different vendors or have different standards. [10]
2. **Legacy Infrastructure:** Adapting ITS to existing railway infrastructures, which may have older technologies and limited compatibility with modern systems, poses a significant challenge. [11]
3. **Cybersecurity Concerns:** As ITS involves extensive use of digital technologies and communication networks, ensuring robust cybersecurity measures is crucial to protect against potential cyber threats and attacks.
4. **Cost Implications:** Implementing ITS requires significant financial investments for technology adoption, training, and infrastructure upgrades. Balancing these costs with the potential benefits can be challenging.
5. **Regulatory Compliance:** Adhering to and navigating through diverse regulatory frameworks and standards, both at national and international levels, can be complex and time-consuming.
6. **Data Management:** Managing and analysing vast amounts of data generated by ITS components, including data from sensors and communication systems, poses challenges in terms of storage, processing, and ensuring data privacy.

7. **User Acceptance and Training:** Ensuring that railway staff and passengers adapt to the new technologies seamlessly requires effective training programs and addressing potential resistance to change.

8. **Maintenance and Reliability:** Maintaining the reliability of ITS components and ensuring timely updates and repairs is crucial to prevent disruptions in railway operations.

9. **Scalability:** Designing ITS solutions that are scalable to accommodate future growth in railway traffic and technology advancements without requiring significant overhauls.

10. **Public Perception:** Overcoming potential concerns and scepticism from the public regarding privacy issues, safety, and the overall impact of ITS on their daily commute.

Addressing challenges connected with developing and introduction of ITS requires a collaborative effort involving railway authorities, technology providers, policymakers, and other stakeholders. It also emphasizes the importance of careful planning, continuous monitoring, and a phased approach to the implementation of Intelligent Transport Systems in railways.

Implementing Intelligent Transport Systems (ITS) in railways involves a systematic methodology to ensure successful integration and optimal functionality. Here's a broad overview of the methodology:

1. **Needs Assessment:**
 - Identify specific challenges and requirements within the existing railway system.

- Conduct a thorough analysis of operational inefficiencies, safety concerns, and potential areas for improvement.
2. Define Objectives:
 - Clearly outline the goals and objectives of implementing ITS in railways.
 - Prioritize objectives based on their impact on safety, efficiency, and overall system performance.
 3. Stakeholder Involvement:
 - Engage key stakeholders, including railway authorities, operators, technology vendors, and regulatory bodies.
 - Gather insights and feedback to ensure a comprehensive understanding of the system's needs.
 4. System Architecture Design:
 - Develop a detailed system architecture that addresses the identified challenges and meets the defined objectives.

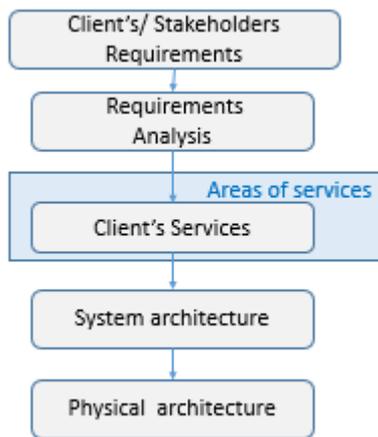


Fig. 2. System Architecture Design

- Consider interoperability, scalability, and compatibility with existing infrastructure.
5. Technology Selection:

Evaluate and select appropriate technologies for different ITS components, such as train control systems, communication networks, and passenger information systems.

 - Consider industry standards and compatibility to ensure a cohesive and integrated system.
 6. Pilot Projects:
 - Implement small-scale pilot projects to test the chosen technologies and assess their feasibility and effectiveness in a real-world environment.
 - Gather feedback from pilot projects to make necessary adjustments before full-scale implementation.
 7. Regulatory Compliance:
 - Ensure compliance with relevant regulatory frameworks and standards governing railway operations and technology use.
 - Collaborate with regulatory authorities to address any concerns and obtain necessary approvals.

8. Data Management Plan:
 - Develop a robust plan for data collection, storage, and analysis.
 - Implement measures to ensure data privacy, security, and effective utilization for decision-making.
9. Training Programs:
 - Design comprehensive training programs for railway staff involved in operating and maintaining the ITS.
 - Educate staff on the benefits of the new system and provide ongoing support.
10. Implementation and Integration:
 - Execute the full-scale implementation of ITS components in a phased manner to minimize disruptions to railway operations.
 - Ensure seamless integration with existing infrastructure and systems.
11. Monitoring and Optimization:
 - Implement continuous monitoring systems to track the performance of ITS components.
 - Regularly assess the system's effectiveness and make adjustments or upgrades as needed.
12. Public Awareness:
 - Communicate changes to the public through effective awareness campaigns.
 - Address concerns and highlight the benefits of ITS for passengers.

By following a structured methodology, the integration of Intelligent Transport Systems in railways can be executed efficiently, ensuring improved safety, efficiency, and overall performance of the railway network.

III. RESULTS AND DISCUSSION,

Intelligent Transport Systems (ITS) are implemented in railways for several compelling reasons, aiming to enhance the overall efficiency, safety, and effectiveness of railway transportation. Here are key reasons why ITS is crucial in the railway sector:

1. Improved Safety:
 - ITS introduces advanced signalling and train control systems, reducing the risk of accidents and collisions.
 - Real-time monitoring and automated safety protocols contribute to a safer railway environment.
2. Enhanced Operational Efficiency:

- Automated train control and traffic management systems optimize train movements, reducing delays and enhancing overall operational efficiency.
- Efficient utilization of infrastructure and resources leads to improved capacity and reduced congestion.

3. Real-time Information for Passengers:

- Passenger information systems provide real-time updates on train schedules, delays, and other relevant information, improving the overall passenger experience.
- ITS enables better communication between railway operators and passengers.

4. Predictive Maintenance:

- ITS incorporates predictive maintenance through sensor data and analytics, helping anticipate equipment failures before they occur.
- This proactive approach minimizes downtime and enhances the reliability of railway systems.

5. Energy Efficiency:

- Energy management systems within ITS optimize train operations for energy efficiency.

Energy shortage is one of the major concerns in today's world. As a consumer of electrical energy, the electric railway system (ERS), due to trains, stations, and commercial users, intakes an enormous amount of electricity. Increasing greenhouse gases (GHG) and CO2 emissions, in addition, have drawn the regard of world leaders as among the most dangerous threats at present; based on research in this field, the transportation sector contributes significantly to this pollution. Railway Energy Management Systems (REMS) are a modern green solution that not only tackle these problems but also, by implementing REMS, electricity can be sold to the grid market. Researchers have been trying to reduce the daily operational costs of smart railway stations, mitigating power quality issues, considering the traction uncertainties and stochastic behaviour of Renewable Energy Resources (RERs) and Energy Storage Systems (ESSs), which has a significant impact on total operational cost. In this context, the first main objective of this article is to take a comprehensive review of the literature on REMS and examine closely all the works that have been carried out in this area, and also the REMS architecture and configurations are clarified as well. The secondary objective of this article is to analyse both traditional and modern methods utilized in REMS and conduct a thorough comparison of them. In order to provide a comprehensive analysis in this field, over 120 publications have been compiled, listed, and categorized. The study highlights the potential of leveraging RERs for cost reduction and sustainability. Evaluating factors including speed, simplicity, efficiency, accuracy, and ability to handle stochastic behaviour and constraints, the strengths and limitations of each optimization method are elucidated. [12]

- Implementing smart technologies, such as regenerative braking, contributes to a more sustainable and environmentally friendly railway system.

6. Reduction in Congestion and Delays:

- Advanced traffic management systems enable better coordination, reducing congestion and minimizing delays.
- Efficient scheduling and real-time adjustments enhance the overall flow of trains on the railway network.

7. Improved Asset Management:

- ITS facilitates better asset management by tracking and monitoring the condition of railway infrastructure and equipment.
- This leads to more informed decision-making regarding maintenance and upgrades.

8. Adaptability to Changing Conditions:

- ITS allows for dynamic adjustments to changing conditions, such as weather, emergencies, or unexpected events.
- Real-time data and communication systems enable agile responses to unforeseen circumstances.

9. Data-Driven Decision-Making:

- The collection, aggregation, store and analysis of data generated by ITS components support data-driven decision-making for railway operations.
- This leads to more informed strategies for system optimization and improvement.

10. Integration with Other Transportation Modes:

- ITS facilitates interoperability and integration with other transportation modes, promoting seamless connectivity between railways and other forms of transport.

The main application areas of ITS in the freight transport and logistics domain are the following:

- Development and implementation of the next generation e-freight transport environment known simply as "e-freight" (inducing individual cargo item intelligence and providing interaction with the "item" throughout the transport chain);
- Freight Transport Management applications (dealing with the management of the transport operation from order capture to payment and invoice control);
- Fleet management applications with the objective of optimising the utilisation and scheduling of a fleet of freight vehicles (or wagons, or vessels);
- Management of special categories of freight such as Dangerous goods
- Terminal management including access control, loading bay and parking zone management, etc. [13]

11. Compliance with Modern Standards:

- Implementing ITS helps railways comply with modern standards and technological advancements in the transportation sector.
- This ensures that railway systems stay competitive and aligned with industry best practices.

In summary, the adoption of Intelligent Transport Systems in railways is driven by the desire to create a safer, more efficient, and technologically advanced transportation network that benefits both operators and passengers.

In this article we have used different libraries of information related with the problem of Intelligent railway transport system and conclude that the transportation systems are already more automated, vehicles have to increase capabilities of the communications and to be equipped with huge wireless communications services, sensors and controllers. Railway communications have to provide various high data rate applications for valuable passengers and for train service. [7] These business applications need to be applicable for five rail scenarios:

- Train-to-infrastructure - video and other information in real time
- Interwagon - wireless network between wagons
- Intrawagon - links between user equipment and access points of a wagon
- Inside station - links between access points and user equipment
- Infrastructure-to-infrastructure - video and other information in real time transmitting among various infrastructures.

IV. CONCLUSIONS,

Intelligent railway transport system is important part for improving transport system – modal transport, trans country, passengers and freights, containerization. ITS has huge energy impact in the transport. ITS support quality, speed, accuracy.

V. ACKNOWLEDGMENTS

This study was supported by a grant from the Internal Research Projects Program funded by the state budget of the Ministry of Education in the Republic of Bulgaria (Project “Intelligent Transport Systems: Problem Areas and Advanced Solutions”).

The grant covered the research work as well as the costs of open access publishing.

VI. REFERENCES

- [1] R. Shi and S. Ni, “Theory and Application Technology of Railway Intelligent Transportation Systems,” 21 9 2015. [Online]. Available: <https://ascelibrary.org/doi/abs/10.1061/9780784479384.081>.
- [2] G. A. Giannopoulos, “Integrating Freight Transportation with Intelligent Transportation Systems: Some European Issues and Priorities,” Sage Journals, 1 1 2002. [Online]. Available: <https://journals.sagepub.com/doi/abs/10.3141/1790-04>. [Accessed 26 2 2024].
- [3] T. Degrande, F. Vannieuwenborg, S. Verbrugge and D. Colle, “Deployment of Cooperative Intelligent Transport System infrastructure along highways: A bottom-up societal benefit analysis for Flanders,” Elsevier, 1 2 2023. [Online]. Available: <https://www.sciencedirect.com/science/article/abs/pii/S0967070X23000380?via%3Dihub>. [Accessed 26 2 2024].
- [4] T. Degrande, F. Vannieuwenborg, S. Verbrugge and D. Colle, “Deployment of Cooperative Intelligent Transport System infrastructure along highways: A bottom-up societal benefit analysis for Flanders,” 1 4 2023. [Online]. Available: <https://www.sciencedirect.com/science/article/abs/pii/S0967070X23000380?via%3Dihub>. [Accessed 26 2 2024].
- [5] W. Zhuo and J. Li-min, “The Theory and Method of Design and Optimization for Railway Intelligent Transportation system,” [Online]. Available: [https://books.google.bg/books?hl=bg&lr=&id=sb0vvVQDdjAC&oi=fnd&pg=PP1&dq=Intelligent+Transport+Systems+\(ITS\)+i+n+railways+represent+a+transformative+approach+to+modernizing+and+optimizing+railway+transportation&ots=xSsD66iAoW&sig=sctjPMRWiReizqII-U5al6CfKW](https://books.google.bg/books?hl=bg&lr=&id=sb0vvVQDdjAC&oi=fnd&pg=PP1&dq=Intelligent+Transport+Systems+(ITS)+i+n+railways+represent+a+transformative+approach+to+modernizing+and+optimizing+railway+transportation&ots=xSsD66iAoW&sig=sctjPMRWiReizqII-U5al6CfKW).
- [6] M. Balog and H. Sokhatska, “Intelligent Systems in the Railway Freight Management,” 23 4 2019. [Online]. Available: https://link.springer.com/chapter/10.1007/978-3-030-18715-6_33. [Accessed 26 2 2024].
- [7] C. Briso-Rodríguez, K. Guan, Y. Xuefeng and T. Kürne, “Wireless Communications in Smart Rail Transportation Systems,” [Online]. Available: <https://www.hindawi.com/journals/wcmc/2017/6802027/>.
- [8] P. I., “Challenges to improve road safety solved with the help of artificial intelligence,” *Proceedings of University of Ruse*, vol. 62, no. 4.1, pp. 34-39, 2023.
- [9] N. Bešinović, L. D. Donato, F. Flammini and R. M. P. Goverde, “Artificial Intelligence in Railway Transport: Taxonomy, Regulations, and Applications,” 15 12 2021. [Online]. Available: <https://ieeexplore.ieee.org/abstract/document/9652066>. [Accessed 26 2 2024].
- [10] P. I., “Design of production systems and processes with erp systems in railway freight transport,” *Mechanics Transport Communications*, vol. 21, no. 1, 2024.
- [11] I. Petrova, Models for the phased development of transport infrastructure, PhD thesis, 2022.
- [12] M. Davoodi, H. J. Kaleybar, M. Brenna and D. Zaninelli, “Energy Management Systems for Smart Electric Railway Networks: A Methodological Review,” *mdpi*, 4 6 2023. [Online]. Available: <https://www.mdpi.com/2071-1050/15/16/12204>. [Accessed 26 2 2024].
- [13] G. A. Giannopoulos, E. Mitsakis and J. M. Salanova, “Overview of Intelligent Transport Systems (ITS) developments in and across transport modes,” 2012. [Online]. Available: https://www.researchgate.net/profile/George-Giannopoulos-2/publication/270571785_Overview_of_Intelligent_Transport_Systems_ITS_developments_in_and_across_transport_modes/link/s/54c129b20cf2d03405c4ec3d/Overview-of-Intelligent-Transport-Systems-ITS-developmn.
- [14] Е. комисия, “ЕК предлага амбициозни нови цели за емисиите на CO2 от тежкотоварни превозни средства от 2030 г. нататък,” [Online]. Available: https://bulgaria.representation.ec.europa.eu/novini-i-sbitiya/novini-0/ek-predlaga-ambiciozni-novi-celi-za-emisiite-na-co2-ot-tezhkotovarni-prevozni-sredstva-ot-2030-g-2023-02-14_bg.

Digitization and intelligent management systems in transport: an overview of problems and solutions

Dimitar Dimitrov

Faculty of Transport Management
University of Transport
Sofia, Bulgaria
ddimitrov@vtu.bg

Abstract. The implementation of intelligent transport systems /ITS - Intelligent Transport/ in the transport sector is one of the first tasks in the development of information and communication technologies /Information and Communication Technologies - ICT/. In essence, it is an actual task and means creating and processing the information flows and data in real time to locate and manage the vehicles, infrastructure and traffic in order to improve the mobility and the quality of the transport services offered. This article aims to give a modern view of digitalization of technological and business processes, as well as the development of ITS in the field of the transport sector. Special emphasis is given to modern problems and solutions in the digitization and implementation of these information systems. with a view to their effective and safe use, traffic and mobility management, improving the efficiency and quality of the service, as well as the impact on the ecology, etc.

Keywords: *Digitalization, Management, Technology, Transport, Intelligent Systems, Information and Communication Technologies.*

I. INTRODUCTION

Transport services occupy an important place in human existence and especially in today's digital era in which the world is changing very dynamically. Transport plays a vital role in transporting various goods, services and people. Moreover, the requirements for it are constantly increasing and are associated with an increase in the speed of delivery, safety, security and comfort of transport. All this requires the use of so-called intelligent transport systems (ITS), which systems use digital technologies to manage the transport system. This aims to tackle the problem of accidents, reduce pollution, traffic congestion and deliver goods in a timely manner. In this regard, transport has always been a leader in integrating the latest technologies.

Building a good ITS involves the use of various areas such as sensor networks, machine learning (ML), transport

area of civil engineering, etc. In this regard, various research areas dealing with these problems focus specifically on the problem of road safety. ITS is designed so that they can overcome problems related to traffic control and management, accident prevention, road charging, parking, noise and pollution control, etc. The present analysis is based on the systematized in [1], [2], [3], [4] and the study is aimed at refactoring the problems and solutions of the use of these systems in transport.

ITS provides intelligent management of the growing number of vehicles on the road in order to reduce congestion and avoid accidents. Various technologies are also used to empower congestion, traffic management and road accident services by informing users about the road scenario in real time [5].

ITS ensures road safety and participants are informed about traffic conditions, climate, etc. All this makes the transport system efficient, and the quality of transport networks is increasing [6], [7].

ITS works using information technology and most often wireless networks. Signals are transmitted between different vehicles, as are infrastructure equipment. On this basis, moving vehicles become familiar with and handle traffic, and ITS helps the transport system to operate in an efficient way [4].

Different technologies are used to implement ITS, nowadays these are the Internet of Things (IoT) and the Internet of Vehicles (IoV) [8]. ITS are a combination of technologies working together to provide the best transport management system. Automotive networks (VANETs) have a variety of intelligent transport applications. These networks help drivers by sending notification and data messages by setting up hazard alarms. VANETs give security and skills to traffic, with the aim of reducing travel

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8048>

© 2024 Dimitar Dimitrov. Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

time, costs and pollution emissions. IoT is a technology that connects the digitalization of the real world [9], [10].

Existing research is based on different approaches to offer the best solution to ensure an efficient transport system. There are many aspects that have not been considered thoroughly enough, and technologies are developing very quickly, which requires constant refactoring of IT solutions for the construction of these systems.

The study aims to consider:

- The need for ITS, importance and requirements, pros and cons, as well as issues related to their implementation.
- The main application areas of ITS.
- The various problems we face in implementing ITS, as well as the solutions to address these problems, along with security issues and challenges.
- Future research areas for ITS implementation are also discussed.

II. MATERIALS AND METHODS

A. Intelligent Transportation Systems

Modern ITS are designed to improve the efficiency and safety of transport systems. They aim to optimize transport costs, energy and fuel consumption, and to preserve the environment. ITS are an integral part of larger projects for building smart cities and regions using modern IT methods and infrastructure for transport management, data processing and analysis, maintenance and automation of logistics, decision-making systems, etc. In this way, modern ITS opens new opportunities for IT services for drivers, passengers and providers of infrastructure and e-services provided in cloud computing, etc. That is, ITS is rather a general term for many models, systems and applications that are developed and implemented, not just strictly IT [4].

From the point of view of the development of transport infrastructure and services, the application of ITS is in the following areas shown in Fig. 1:



Fig. 1. Application areas of ITS.

As road traffic is constantly increasing, it is necessary to implement intelligent transport system management strategies to prevent accidents [11], [12], [13]. There are many strategies on this issue by using different technologies that are implemented in ITS. An important place is also the management of projects in the construction and modernization of transport sites and systems [14], [15], [16].

As early as 2000 year [17] ITS proposed as "VEHIL: a full-scale test methodology for intelligent transport systems, vehicles and subsystems" in the form of hardware, which was implemented on a vehicle and tested and called an Intelligent Vehicle System [18]. The concept of the hardware-based grouping was used, and testing was done for the complete vehicle system, but due to its complex implementation it was not so successful. A traffic simulator tool for ITS performance evaluation was then constructed [19]. This simulation tool combines the characteristics of the vehicle, the driver and the environmental factors, and the ITS efficiency.

In the following years there are also developments, but from 2010 onwards different approaches are proposed to assess ITS using different mechanisms for Machine Learning /ML/ [5], [20]. Several data analysis techniques are proposed to evaluate the best method of ITS data analysis [21]. The development of cooperative ITS (CITS) using IoT and IoV has also been developed by various researchers [10].

As early as the 1990s, the U.S. Department of Transportation adopted a national ITS standard. In this model, the traffic management subsystem maintains monitoring and controlling road traffic by exchanging data with the road infrastructure subsystem. On this basis, the following two criteria for the classification of ITS systems can be considered:

- intelligent infrastructure and
- intelligent vehicles.

Now the Architecture Reference for Cooperative & Intelligent Transportation (ARC-IT) provides a framework for planning, programming, and implementing intelligent transportation systems [22].

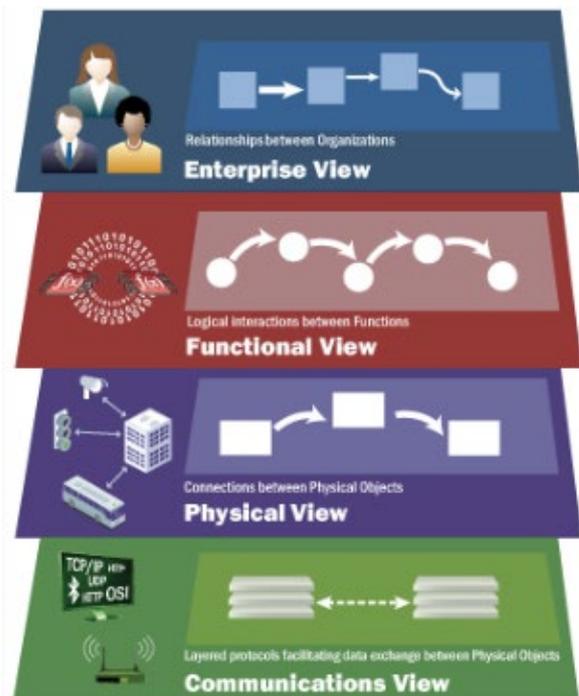


Fig. 2. Architecture Reference for Cooperative & Intelligent Transportation (ARC-IT).

ARC-IT has shown on Fig. 2 is comprised of 4 Views:

- *Enterprise* - Describes the relationships between organizations and the roles these organizations play in the connected vehicle environment.
- *Functional* - Describes abstract functional processes (elements) and their logical interactions (data flows) that meet system requirements.
- *Physical* - Describes physical objects (systems and devices) and their functional objects, as well as the high-level interfaces between these physical objects.
- *Communications* - Describes layers and protocols that are required to support communications between physical objects involved in the connected vehicle environment.

a) *Advantages of ITS*

ITS use information technology as well as other advanced technologies to support the organization of transport work. The benefits are mainly expressed in two areas: *First* - to reduce congestion and the number of accidents, and *Second*, to transform conventional transport systems into intelligent ones in order to improve their efficiency. Below are the advantages of using ITS [5]:

- *Mobility*: Through ITS, road users are informed in advance about road traffic conditions. In this way, ITS plays a vital role in the mobility of people and goods and services worldwide.
- *Congestion*: ITS is commonly used to avoid congestion by providing information on road conditions, climatic conditions and other factors such as traffic lights and many others and directs drivers to the most appropriate route to avoid the problem of congestion and thus smooths out the traffic system.
- *Pollution control*: Road traffic is increasing day by day due to several reasons: the increase in vehicles and the emission of pollutants from vehicles which is also increasing, and this harms the environment. Pollution can be of any kind, such as the emission of harmful smoke from vehicles, which causes air pollution, as well as noise pollution, etc. By implementing ITS, this can guide people in vehicles not to emit pollutants by providing them with timely guidance on vehicle maintenance.
- *Accident prevention*: Increasing traffic on the roads also increases the number of accidents that threaten human life. Implementing ITS can prevent accidents and save people's life by providing them with proper instructions while driving.
- *Improving reliability of travel time*: The application of ITS reduces the time needed to reach the destination by providing the best optimized journey route [23].

b) *Disadvantages of ITS*

ITS also have several disadvantages and negative impacts, which can be formulated as follows:

- *Dependency*: The deployment of ITS depends on the built infrastructure and Internet connectivity. The implementation of ITS requires the use of various latest technologies that may not be familiar to the

people who will use them. Many of the vehicles are not equipped with these latest technologies to allow the deployment of ITS, i.e. the benefit is only for these vehicles, which have the latest technology and components built in.

- *High cost*: Due to the use of a number of components in the implementation of ITS, this system has become very expensive and it is not possible to apply it to everyone. Maintenance costs are also very high.
- *Lack of awareness*: Since ITS are based on emerging technologies, many people are not aware of this, so they are respectively not aware of the benefits of this system, i.e. successful ITS is the one with which people are informed.
- *Lack of resources*: ITS cannot become successful until all the necessary resources for their construction and deployment have been made available. The diversity of resources is necessary to implement ITS, which can be related to both technology and manpower, etc.

B. *IoT and IoV in ITS*

IoT (Internet of Things) is used in every area of the technologically oriented modern world. IoT and IoV (Internet of Vehicles) is widely used in transport as traffic management, controlling traffic lights, implementing an intelligent parking system, providing the best transport routes, and identifying road and weather conditions on the basis of which road traffic can be judged and the person can travel [24], [25].

a) *IoT Applications*

IoT devices are in different regions of an area and are mostly used to prevent road congestion, telematics frameworks in vehicles, security, and surveillance systems. IoT is used in transportation by deploying various components such as sensors, actuators, and other devices. They collect the data and analyze these data using ML approaches to extract useful information for predicting road conditions to provide ITS. The inclusion of IoT in the transport sector completely transforms the transport system scenario in the world. Various IoT applications in transportation include public transport management, real-time vehicle tracking, connecting vehicles using a global positioning system (GPS) and cameras, distance traveled and fuel consumption identification, and much more [26]. IoT applications in different areas are represented by the diagram (Fig. 3).

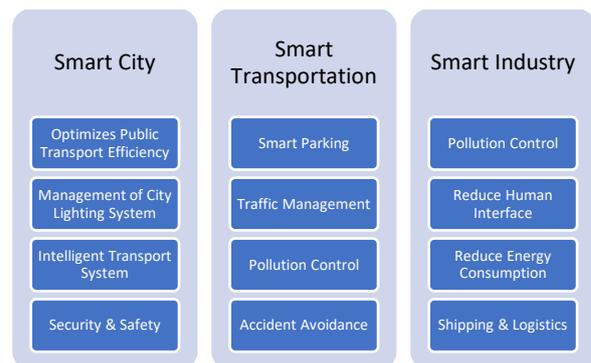


Fig. 3. Applications of IoT in various areas.

b) IoV applications

IoV is widely used these days in the implementation of ITS to optimize the performance of the transport system through integration with IoT [27], [28], [29]. IoV integrates with IoT, and security is the main concern when using IoV. They use the concept of VANETs to provide ITS applications [23]. IoV is a combination of IoT and VANETs, which is an emerging ITS research area. IoV performs five types of communication:

- 1-from vehicles to vehicles (V2V),
- 2-roadside devices,
- 3-personal devices,
- 4-from vehicles to sensors and
- 5-from vehicle to infrastructure of cellular networks, as shown in Fig. 4.



Fig. 4. Communication in Internet of Vehicles.

C. ITS technologies

ITS applications use different technologies. Some of the main technologies used by ITS are discussed below in Table 1 [30], [31], [32].

TABLE 1 DATA COLLECTION TECHNOLOGIES FOR ITS

No	Name of technology	Description
1	Video graphic	Capable to represent large amount of data but not suitable for large distant objects
2	Infrared	Higher accuracy of collected data but less area coverage
3	Triangulation method	Used for estimating the traveling time based on distance between antennas
4	Vehicle re-identification	Used for vehicle detection
5	GPS based	Satellite navigation Detects the speed and location of vehicle, works in every climatic condition even in heavy rainfall

Vehicles communicate with each other to obtain information about the current state of the road, traffic, as well as to avoid traffic jams and accidents. The communication technologies shown in Table 2 are VANETs and are widely used in ITS applications [32].

TABLE 2 COMMUNICATION TECHNOLOGIES FOR ITS

No	Name of technology	Description
1	GSM	Provides two-way communication and provides services like paging, SMS
2	GPRS	Reliable and packet-oriented data transmission service
3	MOBITEX and TETRA	Provides large area coverage

ITS must use data collection techniques so that it can communicate with different moving vehicles on the road. Data collection techniques are very important, as indicated in Table 2, as they collect the information related to the physical location of devices together with various aspects which are very important for ITS operation.

There are two categories: infrastructure-based technologies include video surveillance sensors, and vehicle-based technologies involve the use of GPS systems.

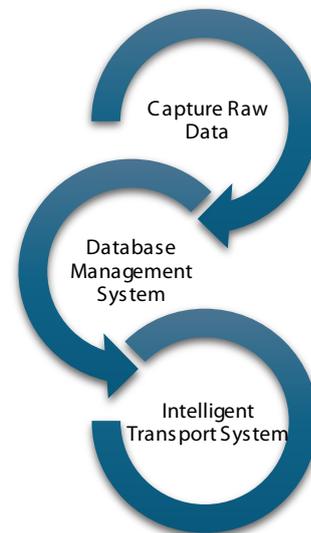


Fig. 5. Data conversion process.

Data collected from different wireless devices must be analyzed and must be stored in an appropriately structured format. Data conversion is displayed in Fig.5 a management system that stores the linked data and helps ITS analyze it. Analysis of traffic-related data helps to extract the necessary information from the technologies used shown on Table 3 [33].

TABLE 3 DATABASE TECHNOLOGIES FOR ITS

No	Name of technology	Description
1	Big Data	Advanced technology that provides various tools to handle huge amount of data based on five Vs of Big Data
2	Cloud Services	Allows to manage and store data without requirement of any infrastructure and allows the movement of data globally across the world
3	Data Fusion	Allows fusion of data from different sources like GPS, phone tracking, moving vehicles and converts them into manageable form

The issue of ITS security is also very important, both for infrastructure and vehicle components. The general attacks on ITS and their consequences are shown in Table 4.

TABLE 4 COMMON ITS ATTACKS AND ITS CONSEQUENCES

№	Name of attack	Consequences
1	DoS attack	Makes the server unavailable to users
2	Vehicular ad hoc network attacks	Misleads the vehicles by providing wrong information
3	Wired network attacks	Jamming of signals
4	Physical attacks	Compromise of services
5	Wireless network attacks	Snooping, eavesdropping, and man-in-the-middle attack

A lot of research is underway to design autonomous vehicles that can also be considered ITS. The need to implement such systems is to themselves avoid traffic jams, yes themselves prevent accidents and accidents. Problems and issues related to autonomous vehicles need to be considered and reliable solutions must be provided [34]. The use of such autonomous vehicles has advantages and disadvantages. The negative impacts of autonomous vehicles are as follows:

-Safety issues: Autonomous vehicles have various security flaws, with sometimes vehicles not being able to be controlled in emergency situations or while driving at very high speeds and they become uncontrollable. In addition, sensors in autonomous vehicles often fail to sense the objects that suddenly come in front of vehicles on the road. Because of these safety issues, autonomous vehicles are causing problems in the field of ITS. Sensors can sometimes not detect obstacles on the road due to low visibility in heavy rain, thunderstorm and other weather conditions.

-ML problems: Most autonomous vehicles use ML techniques such as applying brakes, detecting objects and automatically stopping the car in the event of an emergency, but this can sometimes create problems for them. These ML algorithms cannot guarantee that these vehicles are safe and accident-free. We cannot force companies to use the standardized data set for training, validation and testing.

So, these ML-based autonomous vehicles are still suffering from the problems that need to be solved.

-Congestion and collision of vehicles: These vehicles are included with a number of technologies and these are driverless vehicles, which is why sometimes the components of the vehicle can become damaged. Due to a misunderstanding of the commands issued by the person sitting in the car, these vehicles can generate problems and collide on the road, which can lead to traffic jams on the roads and vehicles can collide with each other.

-Social acceptance: A serious accident has been reported with an increase in the number of accidents from automated cars manufactured by Tesla. Social acceptability is a very important issue to be followed by people driving on the road as well as people using these automated

vehicles. People need to be informed about the features and facilities provided by these autonomous vehicles. They should be given appropriate training to work with these types of vehicles so that the challenges and problems solved with them can be solved.

-Quality of Service (QoS) Design Problems: When designing ITS, the most important concern is the QoS's provided by it, as shown in Fig. 6. ITS design should ensure the best quality of service. QoS has an impact on the availability, performance and scalability of ITS.

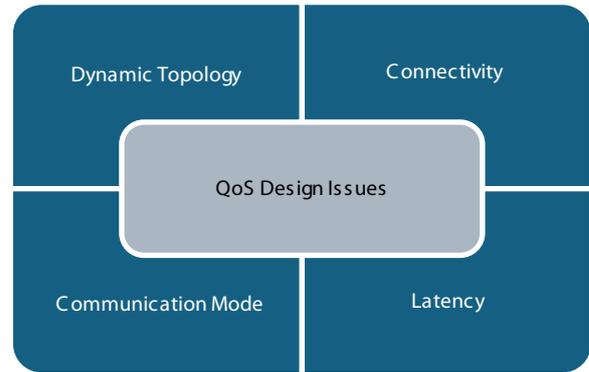


Fig. 6. QoS Design Issues.

ITS are based on the concept of mobile vehicles, i.e. their location is constantly changing. ITS must deal with real-time constraints, especially in the vehicle safety scenario [35]. Latency is the important requirement to measure ITS performance, different vehicles communicate in different ways, leading also to:

-Problems with communication technologies: There are several problems that arise when communication technologies are used in ITS. These issues need to be addressed for the successful implementation of ITS [36], which also raises the issues of vehicle spacing, confidentiality and security of information and timeliness for information exchange.

Vehicles are more vulnerable to security threats as this can compromise their safety. For example, Sybil Attack [37] is very harmful and difficult to identify in vehicle networks. The different attack categories for ITS are shown in Fig. 7.

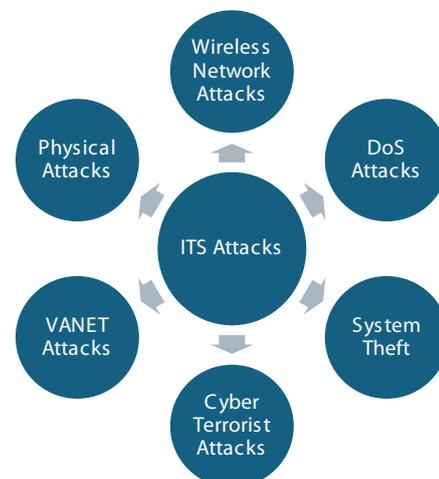


Fig. 7. ITS Attacks.

ITS involves the communication of information between different vehicles on the road that may compromise their integrity, authenticity, privacy and confidentiality, so these issues need to be addressed to address security challenges [32]. The various security issues are addressed together with possible solutions to overcome these problems [38]. Wireless networks are more vulnerable to security threats than physical attacks on ITS. As indicated in Table 4, these attacks aim to slow down and block ITS services, crash the ITS server, and gain access to confidential information from the database.

ML-based security solutions involve the use of artificial intelligence and help analyze data in the easiest way in a very short time. ML algorithms (Fig. 8) are applied to ITS, help to effectively detect security vulnerabilities (security systems). They can reduce the consequences of security attacks and help detect intrusions very easily in ITS [39].

The Intrusion Detection System (IDS) is used to detect these intrusion activities. IDS uses some attributes to classify network data into attacks or normal. ML techniques also help to detect known attacks more efficiently and with higher accuracy. Detecting unknown attacks is very difficult, as they are not previously assigned labels. So, IDS based on anomalies is the issue addressed to consider when detecting malicious activity in ITS. These anomaly-based approaches help to overcome the disadvantage of IDS. In this approach, network traffic is investigated, and if the behavior of the system deviates from its normal behavior, it means that it is an intrusion activity. Thus, the unsupervised learning model helps in detecting attacks.



Fig. 8. ML Security Techniques.

Typically, distributed DoS (DDoS) attacks are identified by these ML algorithms.

D. Traffic monitoring system

Some existing models offer a distributed system that guarantees flexibility and autonomy in the proposed modules [10]. In these modules the problems are solved with some optimization schemes. The solution of these optimization problems related to the intelligent transport system imposes autonomous computing, which is an emerging concept in computing. A quadruple paradigm is proposed: self-configuration, self-healing, self-optimization, and self-defense. This is operational in the proposal of four large modules as it includes: control point self-management, interference detection and propagation, dynamic route planning and section monitoring (Fig. 9).

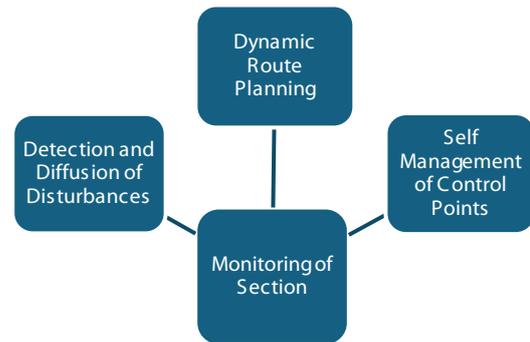


Fig. 9. Scheme of the structure of inter urban road network monitoring system.

The establishment of such an ITS project in countries lacking a well-developed infrastructure contributes to the infrastructural development of transport systems. Economically, it offers several openings in terms of sustainable. Building, installing and administering checkpoints requires a lot of work, which opens up a large infrastructure project horizon. The idea here is to define a modular system in which each module solves part of the problem and if possible, based on optimization models and according to performance criteria. This makes the system easier to understand, administer and improve.

E. AI in ITS Project Management

The use of artificial intelligence in the management of transport projects gives more accurate information about the time of completion of the project, more accurate reports, more accurate identification of risks [40]. This makes the management process more efficient and leads to project success [41], [42].

In the management of transport projects, large amounts of textual data are generated. The analysis of this data can improve management processes, reduce costs, increase efficiency, and more. This analysis is shown in Fig. 10 and includes a four-step process:

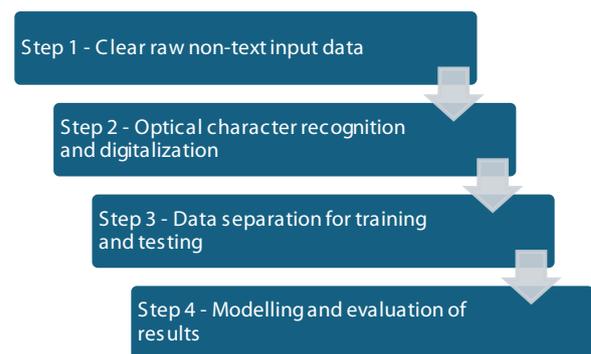


Fig. 10. Four-step model for text analysis in project management in transport.

- *The first step* aims to clear raw input data by removing data that is not textual.
- *The second step* (Engineering) is the stage in which with special methods the text is digitized. The importance of engineering for the final results is extremely great, as the information from the second step is fed to the algorithm and the correct digitization is the basis of the decisions made.

- In the *third step*, the data is divided into training data and testing data. This is a mandatory step for performing machine learning.
- In the last *fourth step* "Modelling and Evaluation" different methods and algorithms are used to obtain results from the textual data.

This is a new area of application of AI, as many projects contain a large amount of documentation and their multiplication allows errors and inaccuracies.

III. RESULTS AND DISCUSSION

The results of the work on the study can be classified into two aspects for the emergence and development of ITS: Transport related issues and Techniques involved in solving these issues. This raises a discussion about:

A. Transport issues

Due to population growth, traffic and transport are increasing, which also raises several topical issues such as traffic control, air pollution, crime control, disaster management, congestion control through appropriate navigation systems.

Various issues that have been focused on the literature review are summarized. Based on the study, it can be concluded that the main challenges in most of the work of ITS are related to traffic and congestion control, as well as disaster and accident management. Air pollution, efficient navigation and resource management are also important, although less focused on research.

B. Techniques involved in solving these issues

The specificity of the transport process is that different problems require to be solved in real time based on the dynamic information received to solve them. Technological solutions are diverse, often technologies of different generations, which reliably and securely need to communicate with each other. As an example, the use of various CCTV cameras can be used, as well as sensors that are used to provide real-time information. GPS technology is combined with different image processing techniques for more advanced navigation systems.

The use of advanced technologies such as VANETs, cloud computing, agent-based computing are being introduced to make the transport system more efficient and intelligent. Up to now sensors of VANETs, techniques for vehicle cloud computing are agent based. This is currently the best solution, and improvements due to technological advances are expected in the future, using GPS, intelligent infrastructure such as traffic lights, RFID readers, etc.

IV. CONCLUSION

Explosive growth separately in traffic and population density raised various issues such as air pollution, congestion and accidents which have become an important area for research.

The implementation of ITS is a very important issue, as it solves several problems related to the transport system. The design of ITS is very important for security and safety, and on the other hand it improves the road infrastructure system. ITS can therefore be used to address these transport-related issues. ITS combines various

technologies such as data collection, communication, machine learning and data mining to provide transportation and related services. These services include traffic control, navigation systems, driver assistance systems and fault detection systems. In addition to this, ITS also decides on transport related to issues such as disaster management, congestion control and air pollution. Further improvement of ITS includes the addition of new techniques such as IoV, cloud computing for vehicles, agent-based computing which includes the introduction of artificial intelligence into transport systems. By combining these techniques, ITS can be more effective in solving transport-related problems.

The systematic study of existing ITS examines them from different perspectives, the pros and cons of ITS on various issues related to security aspects and design challenges are taken into account. Many review articles have been published in the context of ITS, but none of them have discussed all aspects related to ITS. Much work needs to be done in the future in this research area. Open research questions in this ITS research include the identification of important indicators that impact on the effectiveness of ITS. This has to be done in the area of providing solutions for the dependability and security aspects of ITS.

V. ACKNOWLEDGMENTS

This study was supported by a grant from the Internal Research Projects Program funded by the state budget of the Ministry of Education in the Republic of Bulgaria (Project "Intelligent Transport Systems: Problem Areas and Advanced Solutions").

The grant covered the research work as well as the costs of open access publishing.

VI. REFERENCES

- [1] T. Garg and G. Kaur, "A Systematic Review on Intelligent Transport Systems," *Journal of Computational and Cognitive Engineering*, vol. 2, June 2022.
- [2] R. Salazar-Cabrera and A. Pachon, "Methodology for Design of an Intelligent Transport System (ITS) Architecture for Intermediate Colombian City," *INGENIERÍA Y COMPETITIVIDAD*, vol. 21, March 2019.
- [3] M. Shahraz, "Intelligent Transportation Systems: An Overview of Current Trends and Limitations," *INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH IN ENGINEERING AND MANAGEMENT*, vol. 06, December 2022.
- [4] J. Kołodziej, C. Hopmann, G. Coppa, D. Grzonka and A. Widłak, "Intelligent Transportation Systems – Models, Challenges, Security Aspects," in *Cybersecurity of Digital Service Chains: Challenges, Methodologies, and Tools*, J. Kołodziej, M. Repetto and A. Duzha, Eds., Cham, Springer International Publishing, 2022, p. 56–82.
- [5] A. Tafari, G. Khorasani, A. Yadollahi and M. Rahimi, "Evaluation of Intelligent Transport System in Road Safety," 2012.
- [6] Z. Bělinová, P. Bureš and P. Jestý, "Intelligent Transport System Architecture Different Approaches and Future Trends," in *Data and Mobility*, Berlin, 2010.
- [7] L. Zhu, D.-B. Nguyen, C.-R. Dow and S.-F. Hwang, "An Efficient Traffic Congestion Monitoring System on Internet of Vehicles," *Wireless Communications and Mobile Computing*, vol. 2018, p. 9136813, 2018.
- [8] J. Sherly and D. Somasundareswari, "INTERNET OF THINGS BASED SMART TRANSPORTATION SYSTEMS," 2015.

- [9] M. A. Javed, E. Ben Hamida and W. Znaidi, "Security in Intelligent Transport Systems for Smart Cities: From Theory to Practice," *Sensors*, vol. 16, 2016.
- [10] M. L. Mfenjou, A. A. A. Ari, W. Abdou, F. Spies and Kolyang, "Methodology and trends for an intelligent transport system in developing countries," *Sustainable Computing: Informatics and Systems*, vol. 19, pp. 96-111, 2018.
- [11] Z. Mahmood, "Connected Vehicles in the IoV: Concepts, Technologies and Architectures," in *Connected Vehicles in the Internet of Things: Concepts, Technologies and Frameworks for the IoV*, Z. Mahmood, Ed., Cham, Springer International Publishing, 2020, p. 3-18.
- [12] L. Zhang, *Traffic Congestion Reduction and Smart City Strategy - A Case Study in Shenzhen, China*, 2019.
- [13] D. Ushakov, E. Dudukalov, E. Kozlova and K. Shatila, "The Internet of Things impact on smart public transportation," *Transportation Research Procedia*, vol. 63, pp. 2392-2400, June 2022.
- [14] D. Dimitrov and I. Petrova, "Strategic planning and development of transport infrastructures based on agile methodology," *IOP Conference Series: Materials Science and Engineering*, vol. 664, p. 012033, October 2019.
- [15] I. Petrova, Models for the phased development of transport infrastructure, PhD thesis, 2022.
- [16] P. I., "Design of production systems and processes with erp systems in railway freight transport," *Mechanics Transport Communications*, vol. 21, no. 1, 2024.
- [17] L. Verhoeff, D. J. Verburg, H. A. Lupker and L. J. J. Kusters, "VEHIL: a full-scale test methodology for intelligent transport systems, vehicles and subsystems," in *Proceedings of the IEEE Intelligent Vehicles Symposium 2000 (Cat. No.00TH8511)*, 2000.
- [18] F. Yang, J. Li, T. Lei and S. Wang, "Architecture and key technologies for Internet of Vehicles: a survey," *Journal of Communications and Information Networks*, vol. 2, p. 1-17, 2017.
- [19] H. E. Im, I. Kageyama and Y. Ninakawa, "Construction of a traffic simulator for an evaluation tool of ITS," in *Proceedings of the IEEE Intelligent Vehicles Symposium 2000 (Cat. No.00TH8511)*, 2000.
- [20] T. Yuan, W. Da Rocha Neto, C. E. Rothenberg, K. Obraczka, C. Barakat and T. Turletti, "Machine learning for next-generation intelligent transportation systems: A survey," *Transactions on Emerging Telecommunications Technologies*, vol. 33, p. e4427, 2022.
- [21] M. A. Javed, S. Zeadally and E. B. Hamida, "Data analytics for Cooperative Intelligent Transport Systems," *Vehicular Communications*, vol. 15, pp. 63-72, 2019.
- [22] "Architecture Reference for Cooperative and Intelligent Transportation," U.S. Department of Transportation, [Online]. Available: <https://www.arc-it.net/>. [Accessed 22 2 2024].
- [23] R. Newman-Askins, L. Ferreira and J. Bunker, "Intelligent transport systems evaluation: From theory to practice," vol. 21, January 2003.
- [24] R. Eswaraprasad and L. Raja, "Improved intelligent transport system for reliable traffic control management by adapting internet of things," in *2017 International Conference on Infocom Technologies and Unmanned Systems (Trends and Future Directions) (ICTUS)*, 2017.
- [25] D. F. Murad, Meyliana, A. N. Hidayanto and HarjantoPrabowo, "IoT for Development of Smart Public Transportation System: A Systematic Literature Review," 2018.
- [26] A. Azimian, "Design of an Intelligent Traffic Management System," University of Dayton, 2011.
- [27] K. Ashokkumar, B. Sam, R. Arshadprabhu and Britto, "Cloud Based Intelligent Transport System," *Procedia Computer Science*, vol. 50, pp. 58-63, 2015.
- [28] S. Sharma and B. Kaushik, "A survey on internet of vehicles: Applications, security issues & solutions," *Vehicular Communications*, vol. 20, p. 100182, 2019.
- [29] X. Wang, F. Zhang, B. Li and J. Gao, "Developmental pattern and international cooperation on intelligent transport system in China," *Case Studies on Transport Policy*, vol. 5, pp. 38-44, 2017.
- [30] A. Balasubramaniam, A. Paul, W.-H. Hong, H. Seo and J. H. Kim, "Comparative Analysis of Intelligent Transportation Systems for Sustainable Environment in Smart Cities," *Sustainability*, vol. 9, 2017.
- [31] M. G. K. R. Prabha, "Overview of Data Collection Methods for Intelligent Transportation Systems," *The International Journal of Engineering and Science*, vol. 5, pp. 16-20, March 2016.
- [32] A. S. P. K. & S. Y. Zear, "Intelligent Transport System: A Progressive Review," *Indian Journal of Science and Technology*, vol. 9, no. 32, pp. 1-8, 2016.
- [33] Q. Hong, R. Wallace, E. Dennis, B. Reed, W. Tansil and M. Smith, "Management Procedures for Data Collected via Intelligent Transportation Systems," *Journal of Civil Engineering and Architecture*, vol. 9, September 2015.
- [34] H. Anandakumar, R. Arulmurugan and A. Roshini, "Intelligent Vehicle System Problems and Future Impacts for Transport Guidelines," in *2019 International Conference on Smart Systems and Inventive Technology (ICSSIT)*, 2019.
- [35] N. Khan, "Real time predictive monitoring system for urban transport," 2017.
- [36] A. Maimaris and G. Papageorgiou, "A review of Intelligent Transportation Systems from a communications technology perspective," in *2016 IEEE 19th International Conference on Intelligent Transportation Systems (ITSC)*, 2016.
- [37] J. R. Douceur, "The Sybil Attack," in *Peer-to-Peer Systems*, Berlin, 2002.
- [38] J. Harvey and S. Kumar, "A Survey of Intelligent Transportation Systems Security: Challenges and Solutions," in *2020 IEEE 6th Intl Conference on Big Data Security on Cloud (BigDataSecurity), IEEE Intl Conference on High Performance and Smart Computing, (HPSC) and IEEE Intl Conference on Intelligent Data and Security (IDS)*, 2020.
- [39] A. Lamssaggad, N. Benamar, A. S. Hafid and M. Msahli, "A Survey on the Current Security Landscape of Intelligent Transportation Systems," *IEEE Access*, vol. 9, pp. 9180-9208, 2021.
- [40] P. I., "Challenges to improve road safety solved with the help of artificial intelligence," *Proceedings of University of Ruse*, vol. 62, no. 4.1, pp. 34-39, 2023.
- [41] Dimitrov D., Petrova I., „Use of artificial intelligence in transport project management,“ *Mechanics Transport Communications*, том 21, № 3, 2023.
- [42] V. V. Okrepilov, B. B. Kovalenko, G. V. Getmanova and M. S. Turovskaj, "Modern Trends in Artificial Intelligence in the Transport System," *Transportation Research Procedia*, vol. 61, pp. 229-233, 2022.

Artificial Intelligence in Architecture and Art Education

Elina Elere

Riga Technical University
Institute of Architecture and Design
Technologies
Riga, Latvia
Elina.Elere@rtu.lv

Andra Ulme

Riga Technical University
Institute of Architecture and Design
Technologies
Riga, Latvia
Andra.Ulme@rtu.lv

Lucio De Paolis

University of Salento
Department of Engineering for
Innovation
Lecce, Puglia, Italia
lucio.depaolis@unisalento.it

Abstract. This article is written in the context of two European cultures from two countries with different histories, both universities collaborating in the field of digital arts. The aim of the study is to provide clear methods for the use of digital tools in higher education for students of architecture and visual arts. To achieve this objective, ten tasks have been set and the results are presented in this paper.

The methods used in the study include observation, photofixation, Prototyping interior design with artificial intelligence, literature studies, modelling, surveys, and interpretation of their results through graph-analytical methods.

The authors present the positive and critical aspects of education: artificial intelligence is powerful and fast at processing huge amounts of data that humans should be able to process over an incomparably longer period, but it is poor at judging people and art. AI accurately processes billions of websites and resources to offer the best results for our search queries, and it has beaten the reigning champions in many intellectual games. But based on their own and others' research, the authors show how inaccurate AI is, for example in predicting whether individuals who have previously used AI in their artwork might achieve better results than if they had produced their own work using their own talent and personal experience. AI is no better than a simple guess, and yet AI is being used to determine people's futures. One of the experts discussed by the authors is Zweig, who introduces us to the basics of AI and provides a toolkit for designing AI systems. Finally, all the respondents explore the ethics of AI and how we can shape the process, prepared us for the biggest question about AI: where we should use it - and where we should not with a particular focus on the quality of education, developing young people's creative abilities, fostering critical thinking and responsible decision-making.

Keywords: Artificial Intelligence, Architecture and Art Education, Prototyping Interior Design with artificial

intelligence, an experiment using AI-generated images, critical thinking.

I. INTRODUCTION

This article presents the results of a new research and experiment organised among 17-18 year old students of creative industries professions on 21 February 2024 at the Riga Art and Media Technical School. The aim of the experiment was to evaluate how young people use AI tools and software to generate visual materials for a studio project for a small apartment. The experiment was a success and the methods used led to a number of important insights for both the participants and the organisers. The results are presented in the paper.

The aim of the article is to provide clear methods for the use of digital tools in higher education for architecture and visual arts students. To achieve this goal, ten tasks were set, and the results are presented in this paper.

II. RESEARCH METHODOLOGY

Interactive experiences during study are emphasised according to Salama, (2015, pp. 229 - 232) as learning in dialogue with the teacher, with digital tools, with peers and play an important role as a pedagogical tool. The studios serve as a repository of collective knowledge that encourages critical and constructive conversations. These exchanges reveal an implicit understanding of design teaching and learning [26]. A definition that sums up this kind of conversation is critical conversation. The working definition of critical conversations in this research are talks that aim to analyse, structure and evaluate a project through different perspectives in order to solve problems, suggest alternatives or make decisions [26].

The stages of the analytical part of the research [16] – [19], which according to Miles, Huberman and Saldaña

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8063>

© 2024 Elina Elere, Andra Ulme, Lucio De Paolis. Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

(2014), and Merriam and Tisdell (2016), include initial analysis, abstraction, consolidation, and verification [15]. The analytical process involved a cyclical process of induction and deduction that lasted for one. An essential part of the interpretive analysis was writing down reflections and discussing them with peers [13]. Dialogue with the teacher, the professional who issues the design brief, is very important in the initial analysis. As a result of these discussions, the student gains insight into the object, the main requirements for designing with digital tools, the deliverables and evaluation criteria, the project deadlines. The next phase of the analytical process is the research, during which the student learns about the site and its design constraints, the environment, the building architecture, the building structures, and the civil engineering structures [2]-[3]. In the exploratory part, the student carries out surveys, notes, interviews, observations, sketching, analogue research and analysis. All the information obtained is summarised by the student in the form of notes and visual material in the project portfolio.

The notes created in each student's description of interior design, including his personal experience in design studies and peer work observation, were exported from MAXQDA, combined and re-analysed with all student notes in the description of each project's Work Folder, Design Studio Observation, and Interviews. After that, all the notes on each study project were collected in the project portfolio. The purpose of the notes was to interpret the data into new concepts in order to answer the questions of the study. Thus, the process of interpretation of the student at the stage of abstraction of data analysis was guided.

The insights that the student gained in the process of work were integrated into the conceptual framework. The process of perfecting the conceptual framework and developing the coding scheme and notes continued with the new data to saturation. The data were collected in the final version and provided new input to the study.

The coding categories were linked and rearranged as mind map charts to obtain new comprehension categories [4]. The new concepts that emerged from notes and links were combined with a conceptual framework to guide the categorization process. This marked the beginning of the last deductive phase of the analysis. As a result, students had to summarize the obtained data in a well-reviewed description, tables, graphs so that they could be entered into AI image and text generation tools. The analytical results of the interviews of teachers and students were analysed. The components for the analytical results were structured according to meaning; their in-depth analysis was followed by a reconstruction measure, which resulted in findings and claims.

According to Seale (1999), since qualitative research reflects several possibilities, positivity criteria for validity and reliability can be revised using the original criteria [16]. He recognizes the translated terms of reliability (internal validity), portability (generalizer), reliability (loyalty), affirmative ability (objectivity), and authenticity, put forward by Lincoln and Guba as a means

of determining the reliability of realistic exploration (Seale, 1999, pp. 45–46).

Reliability in this study was determined by triangulating (measuring and verifying) evidence, conducting a comparative analysis, clarifying the position of the researcher, and reporting deviant cases. The transparency of the research process [17], the triangulation and reflection of the coding process ensured reliability (Mason, 2018). Confirmation was demonstrated by triangulating information, methods and coding systems, spending significant time on the ground, maintaining a database and displaying audit trails of the analytical process (Patton, 2015) [18], [20].

Personal experience of students was also significant, which allowed approaching the analytical process in more detail. Portability, not generalization, was ensured by giving rich descriptions and highlighting the uniqueness of the case (Maxwell, 2013) [19], [22], working with AI tools, during the process of generating interior design. Ethical issues were addressed by ensuring the confidentiality of participants and maintaining the protocol during data collection.

In design research (Cotsaftis, 2023) and when thinking about ethics, indeed, more and more many researchers are trying to challenge the utilitarian view of nature as an unlimited resource for human activity [32]. Authors around the world do this by criticizing examples in the history of design that focus on human flourishing at the expense of planetary conditions (Fletcher, et al., 2019; St. Pierre, 2019), without thinking sustainably (Bratuškins & Treija, 2019), highlighting the reducing binary link between nature and culture outlined in sustainability discourses (Fletcher, 2017; Williams & Collet, 2021; Cotsaftis, 2023) [20], [22], [32]; studying efforts to reassess humanity's relationship with nature through biodesign (Sawa, 2016; Bratuškins & Treija, 2019) [6]; or again analysing the interdependence between organisms and Earth forces (Haraway & Endy, 2019) [7] – [11]. In addition, critical reflections on the biological approach to design and innovation have drawn attention to the risks associated with the strengthening of new colonial and capitalist thinking precisely in these design approaches. For example, the works look at how some practices maintain the Enlightenment's understanding of nature as a world beyond it in order to capitalize human civilization from it (Fisch, 2017; Goldstein & Johnson, 2015) [32], [34]. While other works focus on the concepts of *biopiracy* and *biocolonialism*, by which indigenous peoples' knowledge is both erased and profits from *biodesign* companies (Ginsberg & Chieza, 2018; Ginsberg et al., 2019) [32]. Through research to promote critical thinking, the suggested works have had a big impact on young architects and designers, incentivizing them to focus on more sustainable solutions in their projects.

III. EXPERIMENT AND INTERPRETATION OF DATA

In the design department at the Riga Art and Media Technical School (RMMT), young people from 16 to 20 years old study. The experiment involved 2nd year 23 of the 29 students "Fig. 1", whose works will be further

analysed. The aim of the experiment was to find out what artificial intelligence (AI) programmes young people could use in their study projects in the field of interior design, what would be the results obtained, the conclusions drawn, and how young people would collect the obtained data in order to use them in the study process.

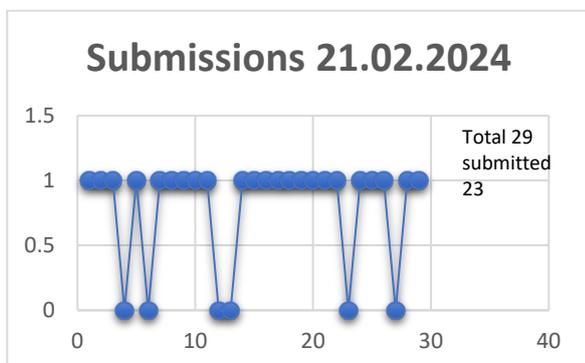


Fig.1. RMMT 2nd year students who participated in the experiment 21.02.2024

All participants in the experiment agreed to voluntarily participate in the process of generating images using various AI programs. Mainly programs such as:

- Midjourney (midjourney.com)
- DALL-E (openai.com)
- Adobe Firefly (adobe.com/lv/products/firefly.html)
- PixLR (pixlr.com)
- Fotor (fotor.com)
- Neuro-Holst (<https://neuro-holst.ru/>)
- Canva (canva.com)
- Imagine (imagine.art)

The participants of the experiment were given the task – to choose any program with the help of which to generate no less than 4 images for the interior of their studio type residential environment in such a way that it meets the requirements of the project, the artistic concept, the list of requirements and wishes of the client created in the project, the possibilities and requirements of the architecture and building structures of the object. Visualizations were to be performed within 4 academic hours and after the lesson the work had to be submitted in an aggregated form, with its comments on the process, conclusions about the results. Students initially had a lot of excitement and did not know which programs offered the free version, what the possible results would be. It could be observed that most of students (80%) switched to English in order to enter data into the programs as accurately as possible. The first results were received within minutes of "Fig.2, Fig.3" and this encouraged others to use the same programs (mainly Neuro-Holst was used by young people whose native language is Russian or Ukrainian), Latvian students used PixLR, Midjourney.

In both images, "Fig.2" and "Fig. 3", it can be observed that in the relatively realistic visualizations there

is a series of errors that could not occur if the visualizations were modelled with some design program that students use daily in their interior design projects, such as *ArchiCad*, *SketcUp*, or *Revit*.



Fig.2. Bedroom interior created by Sindy Jacobson with the help of PixLR AI tools.

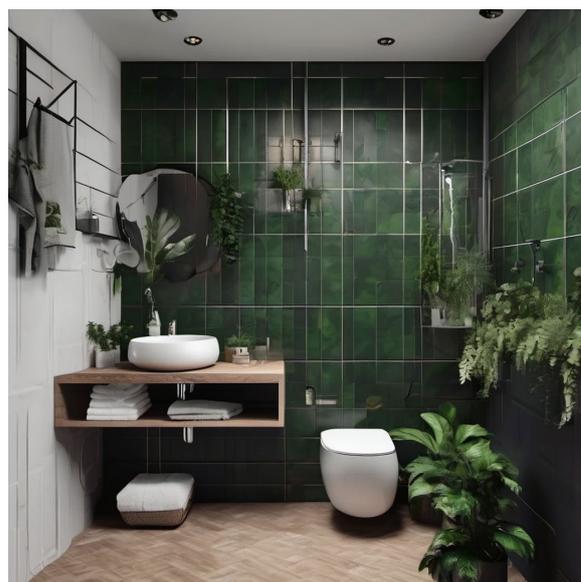


Fig.3. Bathroom interior created by Sindy Jacobson with the help of PixLR AI tools.

Referring to the sources discussed above, after discussing the results with the students, it is concluded that the participants of the experiment shared two groups – one, whose participants wanted to incorporate more biophilic design into their works, use sustainable materials and make designs user-friendly, the other group members it was important to create a modern, luxury residential environment, made of expensive materials, without delving into the guidelines of the circular economy. At this age, young people pay great attention to fashion trends, colors, are less interested in well-being or the reuse of materials. In their conclusions, the majority of respondents (78%) acknowledged that AI can be used in

the process of creative studies as a tool for the rapid reflection of ideas but cannot rely on its quality. The students admitted that it was interesting to try different programs and find out what their capabilities are. Everyone had analysed the images obtained and used the critical thinking methods "Fig.4." to describe the results achieved.

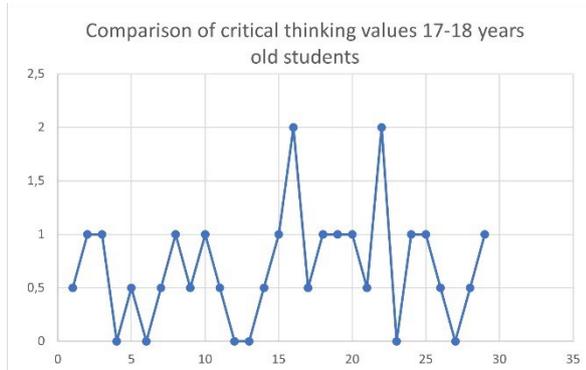


Fig.4. Critical thinking results of RMMT 2nd year students in the experiment 6 participants did not participate (0 point).

In "Fig. 4" it can be observed that only 2 young people (9%) out of 23 in this age group have very high observational and critical thinking abilities, 10 students (44%) have knowledge and interest in their chosen profession only at the initial stage, and 47% of students have critical thinking well developed. 6 students did not come to class due to various circumstances, mainly due to illness. They have a 0 point because the entries have not been submitted.



Fig.5. The interior of the sanitary room created by Anastasia Kaimachnikova with the help of Midjourney AI tools.

"Fig 5" shows that in the image generated by the AI, you can already read the much-needed water flush button above the toilet in the design of the built-in sanitary equipment, but the faucet, unfortunately, is located on the right side of the sink, not behind it and the bathtub is away from the wall, but inside it there are unnecessary several openings. The depth of the bathtub and the rest of the overall dimensions are not ergonomic. The same can be said about the arrangement of other sanitary facilities. Such mistakes would not have been made by man. Now let's look at another example.



Fig.6. The kitchen interior generated by Elizabeth Krukop with the help of PixLR AI tools.

For the most part, the conclusions were related to noticed errors and inaccuracies in the design of furniture and equipment. The design of light fixtures or their location, it was found that the images generated by AI contain unrealistic plants, errors in the symmetrical rhythmic arrangement of tiles, building structures or heating elements, as in the representation of fireplaces and stoves, but the sink may be depicted from the same material as kitchen cabinets "Fig 6".

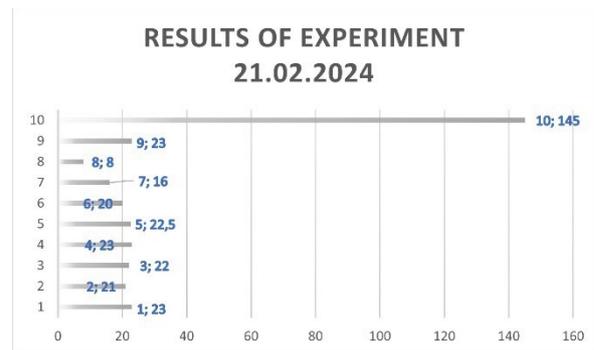


Fig.7. The results of the experiment of RMMT 2nd year students are inspired by 10 mandatory criteria.

The students were very enthusiastic about generating images and a total of 145 images of "Fig.7" were sent in and analysed, indicating a tendency to send at least one image more than was required. Several authors (26%) had submitted more than 7 images, carefully analysing them (criterion 10).

The remaining criteria were mostly (80%) fulfilled in full. Two criteria (7th - assessment of professional knowledge and 8th - creation of bibliographic content) were partially met. This indicates that it is important for students to acquire more profession-related expertise and skills, as well as to be attentive to respect copyright, even when using artificial intelligence. The language barrier, not just the lack of attention, could be an explanation for some young people who were even in text generation were used AI tools.

IV. RESULTS AND DISCUSSION

A. Critical thinking

The quality of the students' critical reflections and the number of conclusions they incorporated into their design process workbooks, varied. This fact also revealed how

highly they value critical thinking and how they intend to use it in their study projects [11] – [12]. In turn, the lecturers boosted the students' self-confidence in their learning by motivating them or pointing out changes in their study habits. Such stimulated meta learning processes can promote the internalisation of tacit knowledge, help in the communication process and contribute to the development of soft skills.

B. The analytical process

During the analytical process [13] – [15], students conducted initial analysis, abstraction, consolidation and verification of the project. During the analytical process, a cyclical process of induction and deduction took place, during which learners could prepare for the experiment. An essential part of the interpretive analysis was writing down reflections and discussing them with peers. By sharing their impressions during the experiment, the students gained confidence that they could prepare a project of a higher quality than AI. This was a breakthrough in their introspection and motivation. Many believed in their own abilities and later wrote in their self-analysis that they were very inspired by technology and appreciated how much they could do themselves, how precise the design had to be to avoid errors like those seen in the images generated by the AI.

C. Visual communication language

While the visual design processes in the creative industries are developed in detail during the study process, over the years the visual language becomes increasingly implicit. Spatial references to the volume of forms and materials, for example, can become more symbolic. This means that the visual language becomes more complex and coded.

The verbalisation of design arguments is always a point of contention amongst academics because drawings are the voice of the designer [7] – [8]. Developing a quality spatial composition is important in design, not only in the use of colour and material textures, which young people usually learn most quickly, but also in the coherence of spatiality, light, and mood. Using AI tools, many young people discovered unexpected compositions that inspired them immensely. Images and drawings, according by Goldschmidt, G., Hochman, H., & Dafni, I. (2010) [9], are seen as key factors to trigger discussion and explain the designer's thought process in an interior design project. Students are asked for arguments, explanations why they have made certain choices at the same time, according to the tutor, putting the validity of their ideas into words reveals students' critical thinking skills. Poggenpohl (2018) argues that concepts will require even more discussion and reasoning if they are radically new (p. 185) [4]. She adds that designers will need to defend their ideas through verbalisation in collaboration with people from other, non-design disciplines [4]. Design students need to be taught to participate in discussions with other disciplines Design students at RMMT are involved in freely participating in discussions with representatives of other disciplines on an equal basis, using a common verbal language, whether it be Latvian, English or Russian. Nowadays, young people in our country understand English better than their native language. There are completely different language barriers

than the generation of authors. Nowadays, augmented reality, virtual reality tools and artificial intelligence software are integrated into the visualisation of interior design projects De Paolis L, Chiarello S, Gatto C et al (2022) [33].

V. CONCLUSIONS

The information and technology tools that have been tested in this experiment are evolving rapidly in recent years and are increasingly being used to train a new generation of designers and architects.

Midjourney.com, Pixlr.com, Canva.com, Neuro-holst, imagine.art simplifies combined learning by allowing prospective students from art, design and architecture classes to work together on design projects and simulate real-world design scenarios, helping students understand how illustrations are used for announcement and influence in various creative projects and professions. This experience gives students the opportunity to develop their ideas, inspires and prepares them for future academic and professional careers.

By incorporating Canva.com as an artificial intelligence (AI) platform in creative projects, educators have the opportunity to create a modern and engaging environment for both students and clients, where future interior designers and architects can develop their visualisation skills. The visual nature of the platform encourages creativity, but it is also necessary to take into account the mistakes that AI still makes and to teach students to identify and correct them. AI platforms such as Midjourney and PixLR encourage the practice of visual language and provide students with valuable digital skills, visual communication skills for developing presentation material, which are necessary in today's globalised world.

Although the AI software visualises the design concept very quickly (within minutes), the experiment participants agreed that there are still many illogical errors in the visualisations. The programmes are not yet able to deal with symmetrical tile layouts, light fixtures and individual furniture details, as well as various rhythmically arranged interior elements. All participants indicated that it was an interesting challenge to use AI programmes, but they would certainly not do so for the final visualisation of the project. Currently, the programmes are useful for generating new ideas, testing quick results in visualisations, designing the work, but for project visualisations everyone would still use the proven design programmes, like *ArchiCad* and similar.

Many universities (Aalto University. (n.d.), The Institute for Ethical AI in Education (2021), The University of Adelaide (2023), University of Oulu, University of Tartu. (2023), Riga University of P. Stradiņš, and others whose contributions are not summarised in this article) have already developed and published guidelines for the methodological use of AI in academic work and pedagogical didactics. Most of these methods are for faster verbal and text retrieval, data processing, with less focus on the generation and use of visual data and quality images in creative professions.

In this article, the authors provide insights into the usefulness of using specific AI techniques to create visual

images. The recommendations are based on the authors' experience in early 2024. Understanding how fast technology is evolving, it is concluded that methods that are recommended today will be considered obsolete soon. AI should always be used responsibly, and students should be advised on the ethical use of AI tools, in compliance with the Copyright Act and other regulations. Where ethical considerations such as the risk of plagiarism and the authenticity of students' work come up for discussion, the need to balance the challenges of AI in the learning environment with the development of students' critical thinking and the demonstration of academic integrity should be emphasised.

The experiment presented here summarises the results generated by different AI programmes that have been used to solve students' critical thinking tasks and stimulate their creative thinking. Students reported that they were inspired to use new technologies and would like to enrich their experience of using new technologies in this way. From an educator's point of view, this experience also enhances the learning of technology in terms of creativity and some research skills.

REFERENCES

- [1] Akalin, A. un Sezal, I. (2009). The Importance of Conceptual and Concrete Modelling in Architectural Design Education. *International Journal of Art & Design Education* , 28 (pp.14.–24) <https://doi.org/10.1111/j.1476-8070.2009.01589.x>
- [2] De Paolis L, Chiarello S, Gatto C et al (2022) Virtual reality for the enhancement of cultural tangible and intangible heritage: The case study of the Castle of Corsano. *Digit Appl Archaeol Cult Herit*. <https://doi.org/10.1016/j.daach.2022.e00238>
- [3] DE PAOLIS L, FAGGIANO F, GATTO C ET AL (2022) IMMERSIVE VIRTUAL REALITY FOR THE FRUITION OF ANCIENT CONTEXTS: THE CASE OF THE ARCHAEOLOGICAL AND NATURALISTIC PARK OF SANTA MARIA D'AGNANO IN OSTUNI. *DIGIT APPL ARCHAEOLOGICAL CULT HERIT*. <https://doi.org/10.1016/j.daach.2022.e00243>
- [4] Dr. Aruna Venkatesh, Dr. Henry Ma (2021). Critical conversations as a tool for students' tacit knowledge construction: An interpretive research in interior design studio interactions. *International Journal of Educational Research Open, Elsevier*, <https://doi.org/10.1016/j.ijedro.2021.100076>
- [5] Bratuškis, U., Treija, S. "Epoch and School: Beginnings of Architectural Education at the Riga Polytechnic" *Architecture and Urban Planning*, vol.15, no.1, 2019, pp.75-80. <https://doi.org/10.2478/aup-2019-0010>;
- [6] Bratuškis, U., Treija, S., Babris, M. Non-formal Education in Architecture: Latvian Experience. *Journal of Architecture and Urbanism*, vol. 24, issue 1. Vilnius: VGTU Press, 2018, pp. 46–51. ISSN: 2029-7955, <https://doi.org/10.3846/jau.2018.1843>.
- [7] Cossentino, J. (2002). Importing Artistry: Further lessons from the design studio. *Reflective Practice*, 39-52. <https://doi.org/10.1080/14623940220129861>
- [8] Fernandez-Antolin, MM., del Río, J.M. & Gonzalez-Lezcano, RA. Building performance simulation tools as part of architectural design: breaking the gap through software simulation. *Int J Technol Des Educ* 32, 1227–1245 (2022). <https://doi.org/10.1007/s10798-020-09641-7>
- [9] Goldschmidt G, Hochman H, Dafni I. The design studio "crit": Teacher–student communication. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing*. 2010;24(3):285-302. DOI: <https://doi.org/10.1017/S089006041000020X>
- [10] J. Goldstein, E. Johnson. Biomimicry: New natures, new enclosures. *Theory, Culture & Society*, 32 (1) (2015), pp. 61–81, DOI:10.1177/0263276414551032
- [11] D. Haraway, D. Endy. Tools for multispecies futures. *Journal of Design Science* (2019), DOI: 10.21428/7808da6b.05eca6f1
- [12] Kurilovas, E., & Vinogradova, I. (2016). Improved fuzzy AHP methodology for evaluating quality of distance learning courses. *International Journal of Engineering Education* , 32 (4), 1618–1624.
- [13] S.B. Merriam, E.J. Tisdell. *Qualitative Research: A Guide to Design and Implementation* (4th ed), Jossey-Bass, San Francisco Retrieved from (2016) Available: <http://site.ebrary.com.ezproxy.lib.polyu.edu.hk/lib/polyu/reader.action?docID=11075643>
- [14] L. Schatzman, A.L. Strauss. *Field Research: Strategies for a Natural Sociology*. Prentice-Hall, Englewood Cliffs, NJ (1973)
- [15] M.B. Miles, A.M. Huberman, J. Saldaña. *Qualitative Data Analysis: A Methods Sourcebook*. (3rd ed), SAGE Publications, Inc, Thousand Oaks, California (2014)
- [16] C. Seale. *The Quality of Qualitative Research*. SAGE, London (1999)
- [17] J. Mason. *Qualitative Researching*. (3rd ed), SAGE, London; Thousand Oaks, California (2018)
- [18] M.Q. Patton. *Qualitative Research & Evaluation Methods: Integrating Theory and Practice* (4th ed), SAGE Publication, Thousand Oaks, California (2015), Retrieved from <https://play.google.com/books/reader?id=CM9BQAAQBAJ&pg=GBS.PT4.w.8.0.5>
- [19] J.A. Maxwell. *Qualitative Research Design: An Interactive Approach* (3rd ed), SAGE, Los Angeles, California (2013)
- [20] K. Fletcher, L. St Pierre, M. Tham. *Design and nature: A partnership*, Routledge, London (2019)
- [21] L. St Pierre. *Design and nature: A history* K. Fletcher, et al. (Eds.), *Design and nature: A partnership*, Routledge, London (2019), pp. 92-108 <https://doi.org/10.4324/9781351115151>
- [22] N. Williams, C. Collet. Biodesign and the allure of "grow-made" textiles: An interview with carole collet. *GeoHumanities*, 7 (1) (2021), pp. 345-357, 10.1080/2373566x.2020.1816141 <https://doi.org/10.1080/2373566x.2020.1816141>
- [23] Nicol, D., & Pilling, S. (2005). Architectural education and the profession preparing for the future. In D. Nicol & S. Pilling (Eds.), *Changing architectural education: Towards a new professionalism* (2nd ed., pp. 1-21). London and New York: Taylor & Francis Group.
- [24] Park, S. (2020). Rethinking design studios as an integrative multi-layered collaboration environment. *Journal of Urban Design* , 25 (4), 523–550. doi: 10.1080/13574809.2020.1734449
- [25] Qureshi, H. (2020). Collaborative architectural design studio environment: An experiment in the studio of Architectural Design-I *Archnet-IJAR: International Journal of Architectural Research* , 14 (2), 303–324. <https://doi.org/10.1108/ARCH-12-2018-0049>
- [26] Salama, (2015) A.M.A. Salama., *Spatial Design Education: New Directions for Pedagogy in Architecture and Beyond*. Ashgate Limited, Farnham, Surrey; Burlington, VT Retrieved from (2015) <https://ebookcentral.proquest.com/lib/polyu-ebooks/reader.action?docID=1969407&ppg=1>
- [27] Donald A. Schön (1988) *Toward a Marriage of Artistry & Applied Science in the Architectural Design Studio*, *Journal of Architectural Education*, 41:4, 4-10, DOI: 10.1080/10464883.1988.10758496
- [28] Smith, K. M. (2013). Recognition of problem insufficiency: a proposed threshold concept emergent in student accounts of memorable interior design educational experiences. *Journal of Interior Design*, 38 (4), 37–54. Available: <https://doi.org/10.1080/10464883.1988.10758496>
- [29] Tai, N.-C. (2022). Applications of augmented reality and virtual reality on computer-assisted teaching for analytical sketching of architectural scene and construction. *Journal of Asian Architecture and Building Engineering* , 22 (3), 1664–1681. DOI: 10.1080/13467581.2022.2097241
- [30] Wendler, W. V., & Rogers, J. S. (1995). The design life space: verbal communication in the architectural design studio. *Journal of Architectural and Planning Research*, 12(4), 319–336. <http://www.jstor.org/stable/43029175>
- [31] Pooya Lotfabadi & Aminreza Iranmanesh (2024) Evaluation of learning methods in architecture design studio via analytic hierarchy process: a case study, *Architectural Engineering and Design Management*, 20:1, 47-64, DOI: 10.1080/17452007.2023.22370540.
- [32] Cotsaftis, N. Williams, G. Chyon, J. Sadar, D. Mohajer Va Pesaran, S. Wines, S. Naarden, *Designing conditions for coexistence*, *Design Studies*, Volume 87, 2023, 101199, ISSN 0142-694X, [Accessed January 12, 2024] <https://doi.org/10.1016/j.destud.2023.101199> available:

- <https://www.sciencedirect.com/science/article/pii/S0142694X23000406>
- [33] De Paolis L, Faggiano F, Gatto C et al (2022) Immersive virtual reality for the fruition of ancient contexts: the case of the archaeological and naturalistic park of Santa Maria d'Agnano in Ostuni. *Digit Appl Archaeol Cult Herit*. DOI: [10.1007/s10055-023-00840-w](https://doi.org/10.1007/s10055-023-00840-w)
- [34] Fisch, M. (2017). The nature of biomimicry: Toward a novel technological culture. *Science, Technology & Human Values*, 42(5), 795e821, <https://doi.org/10.1177/0162243916689599>
- [35] Aalto University. (n.d.). Tips for using artificial intelligence for students. Izgūts no: [Tips for using artificial intelligence for students | Aalto University](#)
- [36] The Institute for Ethical AI in Education. (2021). The Ethical Framework for AI in Education. The University of Buckingham. Izgūts no: [The Institute for Ethical AI in Education | University of Buckingham](#)
- [37] The University of Adelaide. (2023). Artificial Intelligence. Izgūts no: [Using AI tools in your studies - Artificial Intelligence - How do I guides at The University of Adelaide](#)
- [38] UNESCO. (2021). Recommendation on the Ethics of Artificial Intelligence. Izgūts no: <https://unesdoc.unesco.org/ark:/48223/pf0000381137> [Recommendation on the Ethics of Artificial Intelligence - UNESCO Digital Library](#)
- [39] University of Oulu. (n.d.). Guidelines for the Use of Artificial Intelligence in Education. Izgūts no: <https://www.oulu.fi/en/for-students/studying-university/guidelines-use-artificial-intelligence-education> [Guidelines for the Use of Artificial Intelligence in Education | University of Oulu](#)
- [40] University of Tartu. (2023). University of Tartu guidelines for using AI chatbots for teaching and studies. Izgūts no: [University of Tartu guidelines for using AI chatbots for teaching and studies | Tartu Ülikool \(ut.ee\)](#)

Calculation of Human Fatigue in the Environment of Linguistic Variables

Matīss Eriņš
 Riga Technical University
 Riga, Latvia
 Matiss.Erins@rtu.lv

Zigurds Markovičs
 Riga Technical University
 Riga, Latvia
 Zigurds.Markovics@rtu.lv

Abstract. In order to reduce the number of accidents in such sectors of work, such as, driving vehicles, the operator's work on the radar screen, a system is required capable of determining the degree of fatigue of a particular person at a given moment of time according to the data received from sources of information, preventing arbitrary fall asleep and providing recommendations for further action regarding rest options up to work suspension. The system shall be suitable for a situation where the space of the measured parameters consists predominantly of parameters with no numerical values (gradations). There is only a linguistic description with a scoring scale. For this parameter group, it is proposed to use the theories of the non-strict and linguistic variables for the implementation of decision procedures. It not only brings a portion of the system's operating algorithm calculations into an environment of non-strict mathematics and also allows the decision to return to the normal environment. The work provides a calculation algorithm in a non-strict environment and a description of the resulting computer system.

Keywords: decision making, human fatigue, linguistic variables, membership functions.

I. INTRODUCTION

In this work, a methodology for determining the level of fatigue and sleepiness is proposed, a set of parameters to be measured or obtained has been created, which has the highest possible informativeness and the lowest possible disturbing impression or inconvenience to the person being tested. The objective parameters to be measured are only eye blink frequency and electroencephalogram (EEG) α , β and θ wave characteristics as it is covered in the previous work of the authors [1]. The emphasis of the previous work was to research the connection of different fatigue indices in relation to mental or physical types of human fatigue. The following article covers decision making in case of mental fatigue. Another research was performed by the authors to distinguish the non-standard relations between mental fatigue and drowsiness to create a fast alert block in case

of driver drowsiness condition is detected [2]. However, the fatigue decision making core component is covered in-depth in the current paper.

II. MATERIALS AND METHODS

The fatigue detector input parameters are organized in two groups – objective and subjective measurement parameters. The subjective parameters to be used are organized into 3 groups: the anamnesis questionnaire contains 8 parameters, the survey questionnaire before the start of work includes 3 parameters and during the process intervals, when performing cognitive function tests, another 4 parameters are obtained. Such a combination of input parameters confirms the idea that it is necessary to apply non-strict set theory and linguistic variables [3], [4]. A linguistic variable differs from a numerical one in that its values are not numbers, but words or concepts, for example, the expression of pain is a linguistic variable with the values “weak”, “moderate”, “strong”, “very strong”. The situation with the non-strict and linguistic variables can be demonstrated with Fig. 1, where two linguistic variables “stress level” and “night work intensity” obtained from the anamnesis questionnaire are shown.

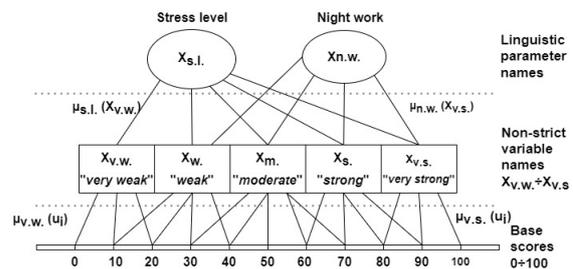


Fig. 1. Linguistic and non-strict variable relations.

Their values are gradations “very weak” (v.w.), “weak” (w.), “moderate” (m.), “strong” (s.), “very strong” (v.s.), which in turn are non-strict variables with values from the base (universal) numerical scale U. At the lowest

Print ISSN 1691-5402
 Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8044>

© 2024 Matīss Eriņš, Zigurds Markovičs. Published by Rezekne Academy of Technologies.
 This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

level with compliance function $\mu_{v.w.}(u_i) \div \mu_{v.s.}(u_i)$ it is possible to find the values for the non-strict variables, from “very weak” to “very strong” gradation.

At the highest level with compliance functions for linguistic variables Stress level $\mu_{s.l.}(X_{v.w.}) \div \mu_{s.l.}(X_{v.s.})$ and Night work $\mu_{n.w.}(X_w.) \div \mu_{n.w.}(X_{v.s.})$ it is possible to find the values for the corresponding linguistic variables $X_{s.l.}$ and $X_{n.w.}$.

The base (universal) numeric scale is selected depending on the nature of the task. For example, the Karolinska KSS scale [5] of the somnolence self-assessment can be 1÷10, while subjective self-assessment scales [6] are usually simplified in the 1÷5 range. Other parameters, such as human age on a scale corresponding to a numeric size of 0÷100. Fig. 2 shows the lowest level matching bell shape membership functions [7] and base scale 0÷100, or percent scale.

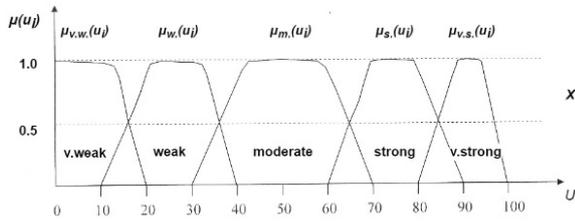


Fig. 2. Non-strict variable membership functions.

If differential diagnostic tasks [8] are addressed where pain levels, s-diagnoses and n-diagnoses are observed instead of $N_{v.w.}$, then the non-strict variable averages can be found at the lowest level (1):

$$N_{v.w.} = \frac{\sum_{u_i \in U} u_i * \mu_{v.w.}(u_i)}{\sum_{u_i \in U} \mu_{v.w.}(u_i)} \quad (1)$$

Linguistic averages for $L_{s.l.}$ and $L_{n.w.}$ can be found at the highest level (2):

$$L_{s.l.} = \frac{\sum_{X_t \in T} N_t \mu_{s.l.}(X_t)}{\sum_{X_t \in T} \mu_{s.l.}(X_t)} ;$$

$$L_{n.w.} = \frac{\sum_{X_t \in T} N_t \mu_{n.w.}(X_t)}{\sum_{X_t \in T} \mu_{n.w.}(X_t)} \quad (2)$$

where T- sets of linguistic values corresponding to $X_{s.l.}$ and $X_{n.w.}$ parameters; X_t – gradation elements of each set.

This results in Ψ - selectivity of the parameter (3):

$$\Psi = L_{s.l.} - L_{n.w.} \quad (3)$$

The fatigue case does not correspond to this calculation example when determining which of the possible diagnoses is correct.

In the case of fatigue, the set of all linguistic parameters promotes and reflects human fatigue levels and can therefore be considered as a vectorial multi-element criterion. It is proposed to use the fuzzy logic and fuzzy control methods. This means that the aggregation methods must be applied to obtain the aggregated evaluation from all non-strict and linguistic variables that serve as the final decision, choosing the following steps depending on the degree of fatigue.

An example calculation is given to this by determining the level of fatigue from two linguistic variables. In this example, the input parameters are $X_{s.l.} = 81$ and $X_{n.w.} = 62$.

Stress level (Fig. 3) refers to the term “strong” (s.), which corresponds to “stress at work and at home” with $\mu_s = 0.9$ and to the term “very severe” (v.s.), which corresponds to “stress at work and at home for long periods” with $\mu_{v.s.} = 0.1$.

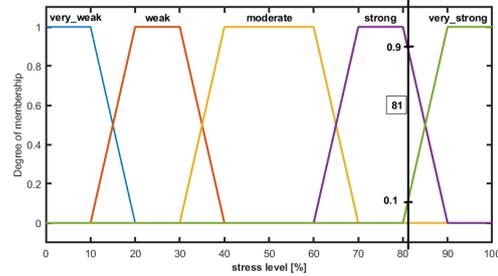


Fig. 3. Membership functions of parameter “stress level”.

The expression of night work (Fig. 4) refers to the term “moderate” (m.), which corresponds to “weekly” with $\mu_m = 0.8$ and to the term “strong” (s.), which corresponds to “every 4th night” with $\mu_s = 0.2$.

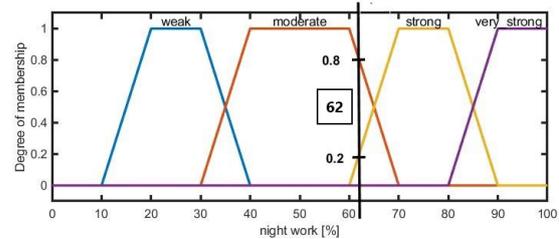


Fig. 4. Membership functions of parameter “night work”.

The output parameters are the sleep deprivation level value and the decision taken on further actions of the recommendations. Specific situation is defined, which characterizes focus on 4 linguistic gradations and their combinations. To formulate the decision for each of the situations the experts can formulate the following decision rules in the logical rule base given in table 1.

TABLE 1 PRODUCTION RULE ACTIVATIONS

Rule No.	IF ($X_{s.l.}$)	AND ($X_{n.w.}$)	THEN
R1	$\mu_s = 0.9$	$\mu_m = 0.8$	Lunch break
R2	$\mu_s = 0.9$	$\mu_s = 0.2$	Pause
R3	$\mu_{v.s.} = 0.1$	$\mu_m = 0.8$	Lunch break
R4	$\mu_{v.s.} = 0.1$	$\mu_s = 0.2$	Lunch break

Four sets of conditions are given, relating to the and the logical operator. The minimum rule is used (table 2), and the breakdown is (4):

$$\mu_{A \wedge B} = \min\{\mu_A, \mu_B\} \quad (4)$$

TABLE 2 MINIMUM RULE CALCULATION

Rule No.	Min rule result	Decision
R1	0.8	Lunch break
R2	0.2	Pause
R3	0.1	Lunch break
R4	0.1	Lunch break

Whereas the three rules (R1, R3, R4) give the same decision, but with different linguistic gradations, maximum rule must be applied (5):

$$\mu_{AVB} = \max\{\mu_A, \mu_B\}, \quad (5)$$

where $\max(0.8, 0.1, 0.1) = 0.8$.

Linguistic decision is given (Fig. 5):

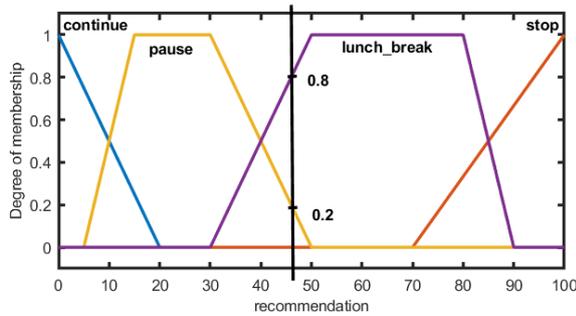


Fig. 5. Linguistic decision parameter about further action.

- decision “Lunch break” with $\mu = 0.8$.
- decision “Pause” with $\mu = 0.2$.

Result obtained in the non-strict environment with linguistic variables. To find a technical conclusion in numerical terms, the strict numerical value needs to be resolved, by using defuzzification method. This can be done using defuzzification techniques, such as, center of sums (COS) [9], center of gravity (COG) [10], mean of maximum (MOM) [11]. In this case, the linguistic mean method (COS) is used (6):

$$L_{COS} = \frac{\sum_{x \in A} x_i \mu(x_i)}{\sum_{x \in A} \mu(x_i)}, \quad (6)$$

where A - points characterising, the linguistic conclusion obtained as 0.2 and 0.8; L – level of fatigue [%], which is calculated as follows (7):

$$L = \frac{0.2 \cdot 6 + 0.2 \cdot 45 + 0.8 \cdot 45 + 0.8 \cdot 82}{2} = 55,9\% \quad (7)$$

The resulting decision (Fig. 6) is then checked against the value of $L=55.9\%$, which corresponds to the linguistic output class for “Lunch break”.

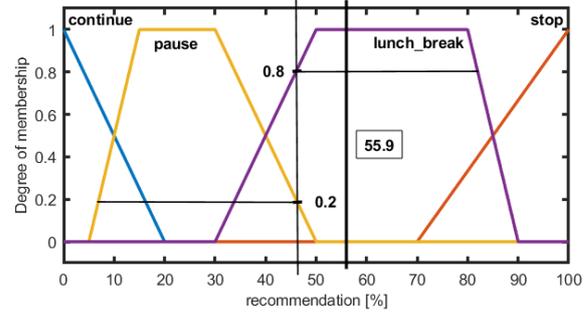


Fig. 6. Defuzzification results in real environment.

III. RESULTS AND DISCUSSION

A modular multi-level decision-making system is proposed. The overall structure of the decision-making system divided into 3 levels (DM1 - determination of fatigue components, DM2 - obtaining fatigue assessment, DM3 – recommendations), where each layer of decision making consists of expert-systems (Fig. 7).

The rationale for the three-tier decision-making system is based on a breakdown of fundamental problems addressed by each level of decision-making systems. The parameter input for this expert system shall consist of a subjective objective component. In the course of the work, it has been found that it is not appropriate to apply the exact 10 ball scales as they do not correspond to the experts' assessment capabilities. Also, it is considered, that the quantitative and qualitative input data from objective measurements and subjective surveys will need to apply separate expert logic and configuration of decision-making controller.

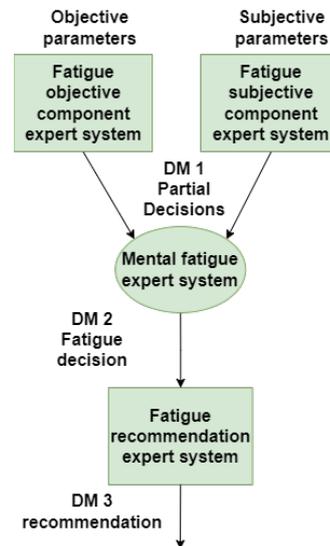


Fig. 7. Linguistic decision parameter about further action.

The first decision making level DM1 uses fuzzification to convert each input parameter to 3 grade scale corresponding to low (L), medium (M) and high (H). It's like a traffic light principle. This decision is also based on the fact that the assessment of fatigue is carried out under the working conditions of the field of use (the driver making the route). Partial values for drowsiness levels from input parameter values on discrete ordinal scale L-M-H are expected to be determined in all input information blocks. Fatigue decision component relies on

13 subjective inputs and 6 objective inputs which require expert validated membership functions in scales. A membership function example for human reaction test result [ms] (Fig. 8) is converted into reaction time linguistic scale with three discrete values [L-M-H].

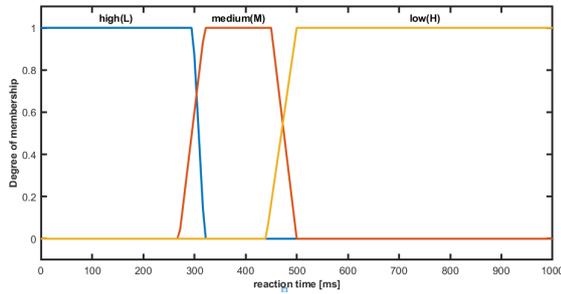


Fig. 8. DM1 membership function for reaction time input.

The subjective input component is divided into two logical groups, S1 and S2. Intermediate score S1, or pre-flight or pre-workout survey, for logically structured human survey data. Intermediate score S2 shall be based on the selected 4 test activities and their results. Intermediate evaluations from these two branches form the subjective component's resulting fatigue partial decision.

The logical structure of the decision algorithm for the objective mental fatigue component (O) consists of 6 objective input parameters, which are divided into three logical groups and can be obtained respectively between the O1 - O3 ratings from physiological sensor data or by using machine learning algorithms to process the incoming signals into discrete decision inputs. Intermediate assessment O1 contains the resulting input values of the first group of algorithms to be obtained using a simple detector of the relative alpha and beta band presence of the electroencephalogram band distribution. The eye blink frequency is obtained using either a video processing technique [12] or an electroencephalogram-defined blinking frequency. The intermediate assessment O2 contains selected electroencephalogram indices J1-involvement in the task and J2 - attention groups of indices based on the common characteristics of these two indices that characterize human attention. The intermediate assessment O3 contains a logical summary of the two electroencephalogram indices J3 – stress and J4 – alertness, which, by the characteristics of these two indices, characterises mental performance [1]. Intermediate evaluations from these three branches form the objective component's resulting fatigue partial decision.

For the synthesis of the set of decision laws from expert knowledge, it is proposed to use a form that is understandable to the person – a table method where the relationship between linguistic gradations of input and output parameters can be realistically implemented. Confirmation of the relationship is the result of an expert vote. The criterion of completeness of the knowledge base is used to verify that the number of cause-effect laws is sufficient to cover all gradation combinations between input parameters and exit decision. If the number of laws is insufficient, there is a problem in deciding because there is no link between any of the gradations in the entrance set and the exit decision. Redundancy is created

if the number of laws is excessive above the measure of sufficiency. The number of decision laws for each of the expert systems is given in table 3 and in total 76 expert decision rules are distributed across 4 expert systems (table 3).

TABLE 3 NUMBER OF DECISION RULES FOR EACH EXPERT MODULE

Expert system	Number of expert rules
DM1 Objective component	27
DM1 Subjective component	28
DM2- Fatigue decision	9
DM3 – Fatigue recommendations	12

The method of defuzzification is proposed to be used COG (centre-of -gravity) of parameters in the partial decision level DM1 and DM2. However, for conversion of final recommendation in DM3 the system uses COS (centre-of-sums) method. The exit partial decision for each component in DM1 is a linguistic variable with a gradation L-M-H that is respectively “low,” “medium,” and “high.” And forms the input for DM2 (Fig. 9).

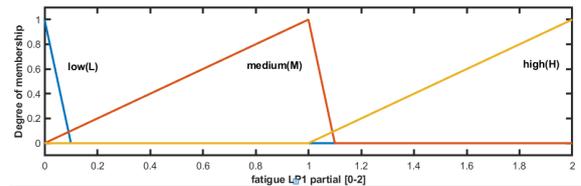


Fig. 9. DM1 partial decision output membership function.

Partial decisions at this level from entrance data, and the mental fatigue decision DM2, are described in this way as the fuzzy variables with three linguistic gradations which use normal distribution statistical Gaussian distribution for the output membership function of the DM2 fatigue level decision (Fig. 10).

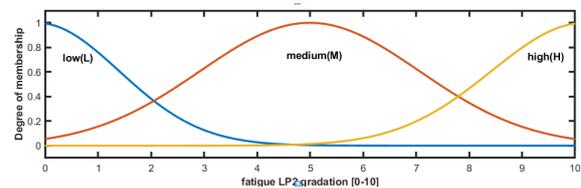


Fig. 10. DM2 fatigue level decision output membership function.

The expert system structure was modelled by using MATLAB Fuzzy Logic Toolbox 2022 and Octave Fuzzy-logic-toolbox. Decision modules are created in the language standard FCL (IEC 61131-7) for the control of fuzzy sets. Modular structure or system tree of decision-making controllers is a function used in this simulation environment to model complex decision systems. Each expert system decision block can be modelled separately by creating the input, output activation functions and the production rules so that a FIS object is formed. Mamdani Type I expert modules are used in the current architecture. The expert modules (FIS objects) then can be linked

together, and chained structure called FIS tree, so that the next system input receives the previous output decision. The formed structure shall be uniform according to the characteristics of the modular system. Formally, the tree is responsible for the decision levels of DM1 and DM2, where the input values are semantic non-rigid values processed by algorithms and classifiers. All parameters use semantic gradation 3 linguistic classes when simplified numerically with values in scale [0÷2]. Formally, the complexity of such a tree as a monolith block is characterised by 19 input parameters with 3 gradations with 6852 variations in input data, so it is proposed to split decision making into 4 blocks.

Each decision controller has one parameter output associated with the next module as an input parameter. The subjective module combines 3 decision-making blocks because, as things stand, individual blocks have simplified logic. As the amount of knowledge increases, it would be necessary to transform the structure by splitting logic into 3 blocks and using a separate decision aggregation module. The decision logic of the objective component is divided into 4 modules describing the processing of input decisions in 3 intermediate blocks and the decision aggregation block of the objective component.

Overall, each expert system needs to validate the accuracy of decision-making against at least the synthesised test data of the base decision tree. The unit tests shall, as far as possible, cover the combinations of input parameters and exit decision classes (L-M-H) of each decision system module. The user interface was designed to use all system steps by a human expert and to observe the intermediate results for each expert-system module. To support the six steps of decision making, the following six decision-making expert system modules were created:

- Subjective component,
- Objective parameter monitoring,
- Unordinary situation decision module,
- Fatigue decision,
- Alerts,
- Recommendations.

The expert interface supports three main decision-making process scenarios: pre-flight survey, monitoring scenario during the activity and alert scenario when the system controls alert actuators. In the website expert module is interfaced in a separate column and the decision chain is linked left to right allowing to transparently interact with the system and test the formed decisions in each step. Logical examples of combinations executed during system testing using the directly created client API interface were generated to simulate end-user capabilities and the environments used.

In the MATLAB simulation environment, such decisions may have a different result due to differences in the implementation of the Fuzzy logic engine, so the result was validated at MATLAB first and then compared on the realised system through tests. Because expert logic

is made up of knowledge laws, their testing uses the generation of logical combination for the input output pairs. The system must produce a decision at any combination of these input parameters, which were also tested automatically. The baseline criterion for such testing per module 0 deviations from the expected decision. Table 2 summarises the results of the unit tests:

TABLE 2 MINIMUM RULE CALCULATION

Module name	Unit test count for each module	Unit test fault count
DM1 Objective component	279	0
DM1 Subjective component	200	0
DM 2 – Mental fatigue decision component	9	0
DM3- Recommendations	518	0
Total	1006	0

The purpose of system tests is to check the correct functioning of the entire system in three given scenarios of driver pre-evaluation. To carry out automated testing of these scenarios, it is first necessary to identify the modules involved in each scenario. In this case the pre-evaluation tests used subjective inputs and the monitoring during drive used objective component inputs. Test data, or expert system input parameter values, are formed as combinations of input data from unit test inputs. Validation of system operation is based on the assumption that decisions resulting from the combination should be consistent with those laid down in the rules of expert decisions and appropriate alarm or recommendation should be provided at the system exit. So, the number of faulty tests must be a total of 0. System tests also feed input parameter values that are not defined within the formal boundaries of the parameters. The purpose of the system is to prevent input of such values or to inform you of incorrect parameter assignment. The baseline criterion for such testing per module 0 deviations from the expected decision. The desired condition was reached during testing as a result of 6 iterations over 279 driver pre-evaluation tests and 479 monitoring cases with driver recommendation.

IV. CONCLUSIONS

The following article proposes a transparent multi-level expert-system modular solution for simplified use by domain experts in the domain area of human fatigue evaluation.

The mathematical theories of fuzzy sets and fuzzy logic are still relevant topic nowadays and such decision-making systems are mostly used in areas of expert linguistic descriptions and fuzzy logic, the application area of medicine expertise requires a transparent decision making and models that can be constructed by non-expert in machine learning domain.

For the fatigue evaluation system that is described in this article the possible application areas are medical treatment institutions for patient rehabilitation,

construction companies or hazardous substance providers, operator or air traffic controls, sports, educational and military institutions.

The theoretically feasible system should be divided into smaller modules to further exploit the possibilities to reduce the complexities of each module and improve the performance of the decision-making system during the implementation phase. In this case, the timing of the simulation decisions does not differ significantly when comparing the two structures, so the simulation basically uses the possibly simplified structure described in the first case. In the further use of the system, it follows from the perspective of modulation adaptation that it is necessary to implement the finer modules, which can be used independently and linked to each other by creating structures suitable for other applications.

REFERENCES

- [1] M. Eriņš and Z. Markovičs, "Unordinary situation assessment of human fatigue and drowsiness in expert decision-making systems," *Engineering for Rural Development*, pp. 325-331, 2022.
- [2] E. Butkevičiūtė, M. Eriņš, and L. Bikulciene, "Mobile Platform for Fatigue Evaluation: HRV Analysis," In: *Information and Software Technologies: 25th International Conference (ICIST.2019): Proceedings. Communications in Computer and Information Science. Vol.1078, Lithuania, Vilnius, 10-12 October, 2019*. Cham: Springer Nature Switzerland AG, 2019, pp.541-552.
- [3] L.A. Zadeh, "Fuzzy Sets," *Information Control*, vol. 8, pp. 338-353, 1965.
- [4] L.A. Zadeh, "The Concept of a Linguistic Variable and Its Application to Approximate Reasoning-1," *Information Sciences*, vol. 8, pp. 199-249, 1975.
- [5] M. Sallinen, M. Harma, R. Akila, A. Holm, R. Luukkonen and H. Mikola, "The effects of sleep debt and monotonous work on sleepiness and performance during a 12-h dayshift," *Journal of Sleep Research*, vol. 13, pp. 285-94, 2004.
- [6] M. Fabbri, A. Beracci, M. Martoni, D. Meneo, L. Tonetti, and V. Natale, "Measuring Subjective Sleep Quality: A Review," *International journal of environmental research and public health*, vol. 18(3), p. 1082, 2021.
- [7] J. Zhao and B. K. Bose, "Evaluation of membership functions for fuzzy logic controlled induction motor drive," *28th Annual Conference of the Industrial Electronics Society. IECON 02, Seville, Spain*, pp. 229-234, 2002.
- [8] J. Osis, J. Grundspeņķis, and Z. Markovičs, *Topological Modeling of Complex Heterogeneous Systems: Theory and Applications*. Rīga: RTU, pp. 207-214, 2012.
- [9] E.H. Mamdani and S. Assilian, "An experiment in linguistic synthesis with a fuzzy logic controller," *International Journal of Man-Machine Studies*, vol. 7(1), pp. 1-13, 1975.
- [10] T. Takagi and M. Sugeno, "Fuzzy identification of systems and its applications to modeling and control," in *IEEE Transactions on Systems, Man, and Cybernetics*, vol. SMC-15, no. 1, pp. 116-132, Jan.-Feb. 1985.
- [11] C. C. Lee, "Fuzzy Logic in Control System: Fuzzy Logic Controller - Part I & II," *IEEE Transactions on Systems, Man and Cybernetics*, Vol. 20, No. 2, pp. 404-435, 1990.
- [12] M. Eriņš and D. Muska, "Methodology for selection and decision making of gradation of sleepiness using algorithms for face video image processing," *Engineering for Rural Development*, pp.1666-1673. ISSN 1691-3043, 2020.

Management approaches and application areas of information security in organizations

Ivan Gaidarski
Institute of Robotics
"St. Ap. and Gospeller
Matthew"
Bulgarian Academy of
Sciences
Sofia, Bulgaria
ivangaidarski@ir.bas.
bg

Neda Chehlarova
Institute of Robotics "St. Ap.
and Gospeller Matthew"
Bulgarian Academy of
Sciences
Sofia, Bulgaria
nedachehlarova@ir.bas.bg

Abstract. In organizations, two types of communication can be distinguished, predetermining approaches to Information Security (IS): communication based on equality - "Network communication" (Networks from/in organizations) and "Hierarchical organizational communication". A primary task of IS in an organization is to protect sensitive data in both types of communication. The IS approach must be tailored and cover all options – a holistic approach. Existing IS management approaches can be divided into two large groups: Information security approaches in Network Communications and data security approaches in Hierarchical Organizational Communication. Approaches to managing IS in network communications include Firewalls, Intrusion Detection Systems (IDS), Intrusion Prevention Systems (IPS), Anti-Virus, Anti Malware, Endpoint Protection, Perimeter Security and Cyber-threat intelligence systems. IS management approaches in Hierarchical Communication include Data Classification and Data Leakage Prevention (DLP) systems. In the article are examined the areas of application of the different approaches to information security in an organization - External network, Network Perimeter, Internal network, Computer equipment, Applications and Data.

Keywords: *communications, competence, data, digital information, management, protection, security*

I. INTRODUCTION

The daily development of Information and Communication Technologies (ICT) in all spheres of life requires constant support and monitoring in maintaining the security and accessibility of data and information between the parties involved in specific economic relations. At the state and international level, policies and strategies regarding the qualification of employees in the field of information security (IS) and work with ICT continue to be updated in accordance with various

regulations and security standards such as EU GDPR [1], ISO 27001 [2], Sarbanes-Oxley Act [3], HIPAA [4], PCI Security Standards [5], as well as local regulations such as the Minimum Requirements for Network and Information Security Ordinance [6].

In the National Strategic Document "Digital Transformation of Bulgaria for the period 2020-2030 [7], objective IV. Unlocking the potential of data includes an emphasis" on expanding the volume of open data generated and processed by government institutions and businesses and facilitating data sharing between private entities."

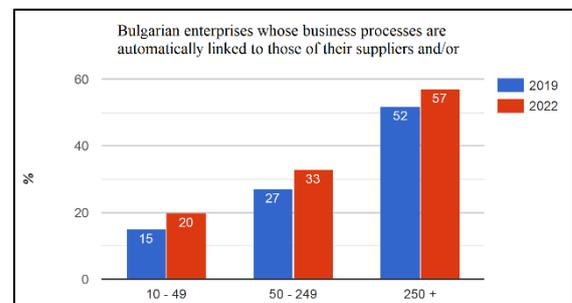


Fig. 1. Bulgarian enterprises whose business processes are automatically linked to those of their suppliers and/or consumers.

"Fig.1" shows the National Statistical Institute of Bulgaria data from the last two state observations regarding "Enterprises whose business processes are automatically connected to those of their suppliers and/or consumers" [8]. In 2023, there is a 5% decrease in organizations with the number of employees "10-49" and a 3% decrease in those with "50-249", compared to the data from 2017. Large enterprises in the country have continued their digital policy in the past year - 36%, which is almost double the value compared to small and medium-sized enterprises.

Print ISSN 1691-5402
Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8062>

© 2024 Ivan Gaidarski, Neda Chehlarova. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

The enterprises that have a written policy for managing ICT security processes in the country [9] are presented in “Fig.2”. A 5% increase in 2022 is observed for all enterprises, regardless of their size. Here again, enterprises with more than 250 employees have the highest percentage - 57%, which is double the value compared to the small "10-49".

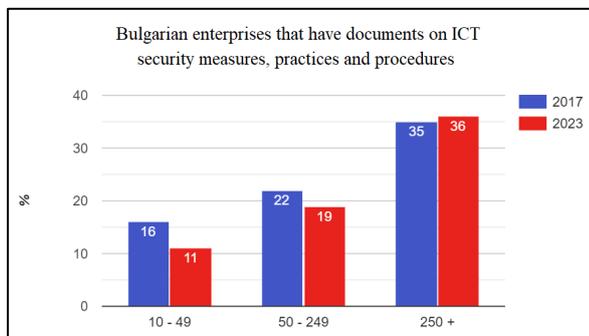


Fig. 2. Bulgarian enterprises that have documents on ICT security measures, practices and procedures.

Despite the positive national trends, in 2022 Bulgaria is still in one of the last places in the European Union according to the same indicators. With average European values of over 35%, just over 20% of the surveyed organizations in our country have a similar approach to their information security policy [10].

In this article, the main approaches to information security (IS) in modern organizations are examined, depending on its structure and communication inside and outside it [11].

II. MATERIALS AND METHODS

In the first part of the study the types of communication in modern organizations are examined. Regardless of the specifics of its activity, every contemporary organization has a clearly defined structure with established relationships between employees. With the development of organizations, the need arises for effective coordination of the main activities, and accordingly for evolution in their organizational structure. It is gradually changing from a flat to a vertical hierarchical structure, with different levels of management, roles and responsibilities for employees. Organizational roles are a set of clearly defined rights and responsibilities described in the job description of the respective position. They reflect the needs of the organization, not the personal qualities of the employees occupying a given position. Thus, the relevant position does not depend on specific individuals and allows flexibility when changing employees. As organizations evolve as social structures, communication among its employees changes from simply sending and receiving messages to processing and interpreting messages inside and outside the organization, as well as the information contained in them. The contemporary organization operates as a large-scale integrated system in which individual day-to-day operations are interdependent. Hence the need for standardized communication procedures and their formalization.

Natural day-to-day communication between employees can be defined as informal communication. It does not follow a given form, pattern or certain formalized rules. Informal communication is vital to an organization because

it is how everyday tasks are carried out. It is characterized by the fact that it does not obey a strict hierarchy, in contrast to formal communication, which follows the hierarchical structure of the organization. Formal communication follows strictly formalized rules, with set templates that are characteristic of a given type of organization. It is characterized by the observance of certain priorities and subordination, such as messages descending from management down the structure. From the point of view of the communication implementation approaches, two types can be distinguished: *Network communication*, ensuring equality between its participants and *Hierarchical organizational communication* based on the hierarchical structure of the organization [12].

Next part of the study examines the approaches for information security management and areas of information security application in the organizations.

Based on the main types of communication, two main types of IS management approaches can be defined - IS approaches in *Hierarchical organizational communication* and IS approaches in *Network communications* “Fig. 3”.

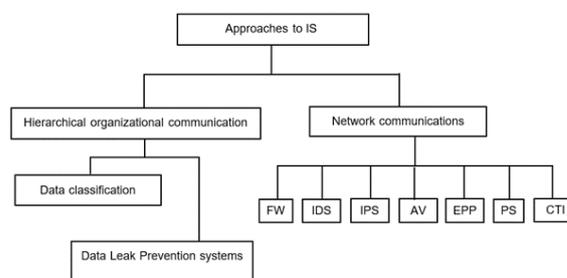


Fig. 3. Approaches to IS based on the type of communication.

IS management approaches in *Network communications* include various hardware and software solutions such as: Cyber-Threat Intelligence (CTI), Antivirus and AntiMalware (AV), Endpoint Protection (EPP), Intrusion Detection Systems (IDS), Intrusion Prevention Systems (IPS), Firewalls (FW), Perimeter Security (PS).

Cyber-Threat Intelligence collects raw data on emerging or existing threats, analyses them and provides real-time information on currently evolving cyber-threats targeting the organization. They provide a comprehensive picture of the threats to the organization outside its protected perimeter [13], [14].

Antivirus and AntiMalware solutions protect an organization's applications and files by scanning them for viruses, Trojans, and other malicious code in real-time, and eliminating them when detected [13] - [15].

End Point Protection solutions protect the so-called endpoints - any device that can process data - workstations, servers, mobile and IoT. Protection includes both threats and data leakage, corruption or falsification [13], [14].

Intrusion Detection Systems solutions monitor and analyse the organization's internal network traffic, identifying potential malicious applications or attempts to penetrate the protected network [13], [14].

Intrusion Prevention Systems work together with IDS systems, eliminating detected threats [13] - [15].

FireWalls are tasked with preventing unauthorized access by monitoring incoming and outgoing network traffic and filtering it according to set criteria [13].

Perimeter Security provides the protection of data and resources in the perimeter of the corporate IT network [16], [17].

Hierarchical Communication IS management approaches include Data Classification (DC) and Data Leak Prevention (DLP) solutions.

Data Classification solutions allow organizations to accurately identify protected data by marking it according to the organization's adopted classification system. Visual markers (labels) and metadata are used, which unambiguously identify the protected information. DC systems also ensure accurate identification of the creators of the corresponding document or message, for example emails, ensuring personal responsibility for their content. Tagging reduces the risk of sensitive data leaking into the organization by enabling accurate identification from other IS approaches, such as Data Leak Prevention systems [17], [18].

Data Leak Prevention solutions provide detection and subsequent prevention of attempts to leak sensitive data outside the organization's protected network [15,16]. Sensitive data can include both corporate information (patents, know-how, trade secrets, bank accounts and credit card numbers) and personal data such as social security number, residential addresses, medical data and others, subject to protection by various standards and regulations [13], [15].

IS approaches, in addition to having a certain functionality in relation to the object of protection (data, applications), are also characterized by a certain area of application, defining their place in the ICT infrastructure of the organization. As an example, the multilayer protection model of "Fig.4" can be used. Each layer is subject to unique threats and different IS approaches are used to protect against them.

The External network layer includes networks external to the organization, for example the Internet. A characteristic feature of external networks is that they are unprotected. For their protection, IS approaches such as Vulnerability Analysis, Audit, Virtual Private Networks, Logging, Demilitarized Zone, Penetration Tests and SIEM are used.

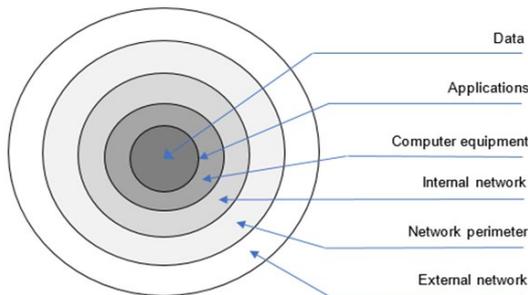


Fig. 4. Multilayer model for protection.

Network perimeter is the border area between the unprotected external network and the protected internal network. In this area of application, approaches to IS such as AntiVirus and AntiMalware, Static and Dynamic Packet Filtering, Proxy Server, Firewalls, Vulnerability Analysis and Penetration Tests find application.

Internal network is the protected internal network of the organization. It is usually well protected as the organization conducts its day-to-day operations within it. The IS

approaches used in the internal network include solutions such as AV, IDS, IPS solutions, access control, encryption solutions, etc.

Computer equipment – a unifying term for the ICT infrastructure of the organization - servers, workstations, mobile devices and peripheral devices connected in a network. IS approaches include Endpoint protection, Firewalls, Authentication, Logging, Password hashing, Audit and DLP solutions.

Applications – the software applications installed on the computer equipment and used in the day-to-day activities of the organization. These include Data Classification, Data validation, Content filtering, Audit tools.

Data – includes the data collected, generated, used, analysed and processed in the organization. This includes data owned by the organization but used by third parties such as suppliers and partners. IS approaches include Access control, Data backup, Encryption solutions, Data classification and DLP solutions.

III. RESULTS AND DISCUSSION

The use of innovative approaches for IS management in organizations in the Republic of Bulgaria allows effective protection of their information resources and, in particular, the protection of their sensitive information from leakage or replacement. For example, the widespread introduction of Data Classification Systems, Document Management Systems (DMS) and Content Management Systems (CMS) [19].

Another suitable example is the results of the implementation of a solution for Data Leak Prevention of the manufacturer Acronis DeviceLock [20] in 18 Bulgarian organizations from different sectors, including the national security sector. As a result of the monitoring of the data flows in the endpoints - workstations and laptops, the following general conclusions were drawn "Fig.5" - reduction of incidents of leakage of sensitive data, limitation of channels of data leakage, increase of visibility of sensitive data in the organization by scanning Data-in-rest data and improving compliance with internal and external security policies and regulations [21].

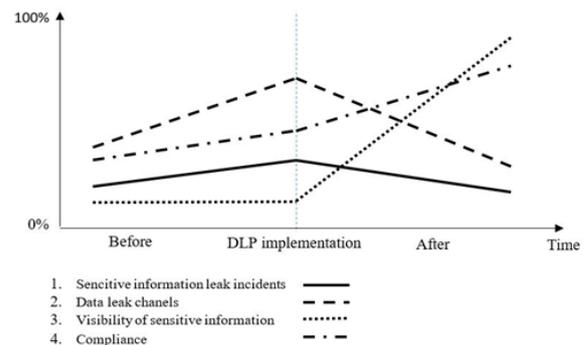


Fig. 5. Generalized results from DLP system validation.

According to data from Statista, the estimated market share of DLP revenue for 2025 will grow 3 times to 3.5 billion compared to the reported values in 2019 [22].

IV. CONCLUSION

The increase in the complexity of communications and the current processes of digitization at the state and international level lead to new and stricter requirements for

the protection of the information resources of modern organizations. These requirements also define changes in the environment in which the information systems of a given organization operate. In the design of modern information security systems (ISS), it is mandatory to provide flexible mechanisms for easy addition and updating of new requirements to the ISS and their rapid implementation, without the main activity of the organization being affected. The complex protection of the organization's sensitive information requires the effective combination of traditional IS approaches within network and hierarchical organizational communication, as well as the addition of innovative IS approaches.

ACKNOWLEDGEMENT

This work was supported by the NSP DS program, which has received funding from the Ministry of Education and Science of the Republic of Bulgaria under the grant agreement no. Д01-74/19.05.2022.

REFERENCES

- [1] General Data Protection Regulation. [Online]. Available: <https://www.gdpreu.org/>, [Accessed February 24, 2024].
- [2] ISO 27001 Official Page. [Online]. Available: <https://www.iso.org/isoiec-27001-information-security.html>, [Accessed February 24, 2024].
- [3] Sarbanes-Oxley Act. [Online]. Available: <https://www.investor.gov/introduction-investing/investing-basics/role-sec/laws-govern-securities-industry#sox2002> [Accessed February 24, 2024].
- [4] B. Herold, R. Beaver, "The Practical Guide to HIPAA Privacy and Security Compliance," 2nd Edition, CRC Press, 2014.
- [5] PCI Security Standards. [Online]. Available: <https://www.pcisecuritystandards.org/> [Accessed February 24, 2024].
- [6] Ordinance on the minimum requirements for network and information security. [Online]. Available: https://www.mtite.government.bg/sites/default/files/nar_minimalnite_iziskvaniq_mrejova_in_fo_sigumost-072019.pdf [Accessed February 24, 2024]. (in bulgarian).
- [7] National strategic document "Digital transformation of Bulgaria for the period 2020-2030", adopted by Decision No. 493 of the Council of Ministers of 21.07.2020. [Online]. Available: <https://www.strategy.bg/StrategicDocuments/View.aspx?lang=bg-BG&Id=1318> [Accessed February 24, 2024], (in bulgarian).
- [8] NSI. "Enterprises whose business processes are automatically linked to those of their suppliers and/or consumers". [Online]. Available: https://infostat.nsi.bg/infostat/pages/reports/query.jsf?x_2=719 [Accessed February 24, 2024].
- [9] NSI. Enterprises that have documented ICT security measures, practices and procedures. [Online]. Available: https://infostat.nsi.bg/infostat/pages/reports/query.jsf?x_2=1365 [Accessed February 24, 2024].
- [10] Eurostat. ICT security in enterprises. Enterprises with documents on measures, practices or procedures on ICT security, 2022. [Online]. Available: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=ICT_security_in_enterprises&oldid=583136#Documents_on_measures.2C_practices_or_procedures_on_ICT_security [Accessed February 24, 2024].
- [11] I. Gaidarski, Method and models for development of information security systems in organization, PhD thesis, Department of "Communication systems and services" at Institute of information and communication technologies, Bulgarian Academy of sciences. ICT-BAS, 2022.
- [12] B. Wahlstrom, "Perspectives of Human Communication," Wm.C.Brown Publishers, 1992.
- [13] M. Rhodes-Ousley, "Information Security the Complete Reference," 2nd Edition, The McGraw-Hill, 2013.
- [14] Y. Diogenes, E. Ozkaya, "Cybersecurity - Attack and Defence Strategies," Packt Publishing Ltd., 2018.
- [15] C. Pfleeger, S. Pfleeger, J. Margulies, "Security in Computing," 4th Edition, Prentice Hall, 2015.
- [16] M. Ciampa, "Security+ Guide to Network Security Fundamentals," 4th Edition, Course Technology, Cengage Learning, 2015.
- [17] G. Santana, D. Cruz, "Modelling a network security systems using multi-agents systems engineering, Systems, Man and Cybernetics," IEEE International Conference, Vol. 5, November 2003, DOI: 10.1109/ICSMC.2003.1245655.
- [18] Guidelines for Data Classification, Carnegie Mellon University. [Online]. Available: <https://www.cmu.edu/iso/governance/guidelines/data-classification.html> [Accessed February 24, 2024].
- [19] A. Madzharov, "Technical implementation of a reporting system and its workflows," Proceedings of International Scientific Conference "Defense Technologies" (DefTech 2019), "Vasil Levski" National Military University – Artillery, Air Defence and CIF Faculty, 2019, pp. 316-322.
- [20] DeviceLock Web Page. [Online]. Available: <https://www.acronis.com/en-us/products/devicelock/> [Accessed February 24, 2024].
- [21] I. Gaydarski, Z. Minchev, "Conceptual Modeling of Information Security System and Its Validation Through DLP Systems," Proceedings of BISEC 2017, Belgrade Metropolitan University, 2017, pp. 36-40, DOI:10.13140/RG.2.2.32836.53123.
- [22] Statista. Data loss prevention (DLP) market revenue forecast worldwide from 2019 to 2025. [Online]. Available: <https://www.statista.com/statistics/986319/worldwide-dlp-market-revenue-forecast/> [Accessed February 24, 2024].

Decision Tree Methods in Grain Yield Forecasting

Peter Grabusts

Rezekne Academy of Technologies
Institute of Engineering
Rezekne, Latvia
peteris.grabusts@rta.lv

Oleg Uzhga-Rebrov

Rezekne Academy of Technologies
Institute of Engineering
Rezekne, Latvia
rebrovs@tvnet.lv

Lasma Prizevoite

Rezekne Academy of Technologies
Faculty of Engineering
Rezekne, Latvia
lasma.prizevoite@gmail.com

Inta Kotane

Rezekne Academy of Technologies
Faculty of Economics and
Management
Rezekne, Latvia
inta.kotane@rta.lv

Abstract. Traditional methods for forecasting yield, which rely on human judgment, often fall short of providing accurate and reliable forecasts. The application of artificial intelligence (AI) methods for predicting grain harvest is becoming increasingly relevant to balance performance indicators of companies in the grain-growing industry and forecast future results. It is important to consider the specific operations of companies in the industry and the factors influencing the harvest when using such methods, as these are essential for future decision-making. The main goal of the study is to explore the use of decision analysis methods in forecasting the yield of companies in the grain-growing industry. An analytical study has been conducted on the potential of using AI methods, including the analysis of decision tree-building methods and their application possibilities. In a practical study, a decision tree is constructed using CHAID, and the impact of various factors on decision-making quality in the grain-growing industry is analyzed. Subsequently, neural networks are used to predict potential yield based on the companies' historical data from previous periods.

Keywords: CHAID, decision analysis, decision tree, grain yield, neural networks.

I. INTRODUCTION

The topicality of the topic is because the continuous changes and challenges of the grain-growing industry, which include the influence of various factors on grain harvest volumes, require grain-growing companies to adapt to new technologies, including the opportunities offered by AI, to maintain competitiveness and promote sustainable development.

AI can be used in the agricultural sector to improve production efficiency, resource management, and decision-making. In recent years, the world has seen rapid advances in agricultural technology, changing and improving farming practices. These innovations are becoming increasingly important as global challenges such as climate change, population growth, and resource scarcity threaten the sustainability of the food system. The introduction of AI solves many problems and helps to alleviate several disadvantages of traditional agriculture [1]-[6].

It is neural networks (NN) that are increasingly used in research for the needs of the agricultural industry [7], the learning ability and accuracy of NN in various stages of agriculture achieve remarkable results [8], thus they are used in production impact prediction and other aspects of agriculture based on a wide range of independent variables, thus optimizing the storage and transportation processes and allowing to predict the incurred costs depending on the chosen direction of management [9]. The spectrum of applications of NN is very wide, they are used to support agricultural production, making it more efficient and providing the highest possible quality products [10].

To achieve more effective business performance, industry specialists and managers should use the advantages provided by AI by choosing suitable AI technologies and adapting them to the specifics of the industry and the company, thus improving the accuracy of economic activity, decision-making, customer experience, optimization of resources, and as a result, improving the overall results of the company or efficiency and competitiveness indicators of the organization.

Print ISSN 1691-5402
Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8023>

© 2024 Peter Grabusts, Oļegs Uzhga-Rebrov, Lasma Prizevoite, Inta Kotane.
Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

Cereal farming is one of the leading agricultural sectors, where all-season farmers must face the challenge of effectively planning and implementing activities to increase yield and quality.

Yield forecasting is a critical factor in grain-growing enterprises, as it affects resource use decisions, that is, the use of agricultural land and cash, as well as the quality and quantity of harvest. Traditional yield forecasting methods are often unable to provide sufficiently accurate and reliable forecasts, as it is impossible to predict individual factors affecting agriculture based on them. AI application provides new crop forecasting opportunities in the grain-growing industry [11],[12].

In general, crop forecasting modeling based on AI methods and data analysis is an indispensable tool for companies in the grain-growing industry, ensuring greater efficiency, sustainable production, and competitiveness in the market. This allows companies to respond to the continuous changes determined by both natural conditions and the market situation.

The study aims to investigate the application of decision analysis methods in forecasting the yield of companies in the grain-growing industry. Decision tree-building methods and their application possibilities are analyzed. Forecasting of potential yield is performed based on historical company data for previous periods.

II. MATERIALS AND METHODS

A. Grain Yield Factors

Cereal farming is defined as the basic branch of agricultural production – the cultivation of cereals to supply the food industry with raw materials and livestock with fodder. Cereal cultivation is one of the most popular agricultural sectors. Every new season is like a challenge for farmers when they must plan actions to increase yield and quality. Tillage, sowing, fertilizing, plant protection - everything is planned in favor of the harvest, considering account the farm's financial condition, so that the result is economically efficient.

Cereal harvest volumes may depend on various factors influencing them; therefore, it is important to study their parameters and influence indicators (factors influencing the yield of winter cereal crops will not be considered within the scope of the work).

It can be concluded that such factors as grain weight, grain sowing depth, seed quality, soil quality, sowing rate, air temperature, rainfall, and type of tillage can affect grain yield, and for each of the factors, an index of influence on grain yield is defined.

The authors analyze the following factors influencing the grain yield and their impact indicators (see Table 1). The code system is provided by the authors.

As can be seen in Table 1, an important factor that affects the amounts of grain harvest is the seed germination of the grain variety used. Early growth and vigor of many cereal cultivars have been determined to be affected by seed size and weight. Based on the study [13], it is determined that the optimal sowing depth is 6 cm, which ensures the durability of seedlings and good results of crop germination.

Harvest volumes are influenced by the selected grain seed quality. The main indicator of seed quality is the protein content in the grain, where the E quality class is designated as high, with a protein content in the grain >14.5%, the A quality class is medium, with a protein content in the grain 14%, as well as the B quality class is low, with a protein content in the grain 12 - 13%.

An important factor is the quality of the soil, an important indicator characterizing the quality of the soil is the pH level, which is relatively easy for the farmer to determine by soil analysis, which for cereals in general is on average 6.0 to 6.5 pHKCl.

TABLE 1 COMPENDIUM OF FACTORS AFFECTING GRAIN YIELD

N	Factor	Affects	Impact score	Code
1	Germination (grain weight per thousand grains)	Favorable	51 grams and over	1
		Medium	26 – 50 grams	2
		Unfavorable	1 – 25 grams	3
2	Germination (grain sowing depth)	Favorable	60 – 69 mm	1
		Medium	70 – 83 mm; 23 – 59 mm	2
		Unfavorable	84 mm and more; 22 mm and less	3
3	Grain seed quality (protein content)	Favorable	14.5% and more	1
		Medium	13.1 – 14.4%	2
		Unfavorable	13% and less	3
4	Soil quality (pHKCl level)	Favorable	6 – 6.5	1
		Unfavorable	5.9 and below 6.6 and above	2
5	Sowing rate (amount of viable seeds per m2)	Favorable	400 – 500 and more	1
		Medium	300 – 399	2
		Unfavorable	299 and less	3
6	Temperature	Favorable	20 – 25 °C	1
		Medium	26 – 31 °C; 7 – 25 °C	2
		Unfavorable	32 °C and above; 6 °C and below	3
7	Amount of precipitation per year	Favorable	50-100 cm	1
		Unfavorable	49 cm and less 101 cm and above	2
8	Type of soil treatment	Traditional tillage	-	1
		Minimum tillage	-	2
		Direct sowing	-	3

The seeding rate can affect the size of the crop, thus its quality and yield volumes. Based on the data collected in Table 1, it can be concluded that the highest harvest volumes can be achieved if the sowing is on average 400-500 viable seeds per m^2 .

The growth process of cereals is significantly affected by the temperature range. The optimum temperature is 20-25°C, which means that germination is more efficient in this temperature range. Each 1°C increase in temperature above the average temperature of 23°C reduces grain yield by about 10% [14], while temperatures above 32°C negatively affect cereal growth, and temperatures below 6°C for long periods are critical [15].

Rainfall is an important factor in the grain-growing industry. If there is insufficient rainfall, cereals cannot grow, and yields may be limited. Most cereals require between 50 and 100 cm of rainfall per year [16]. Moisture or drought stress causes about 30-70% loss of cereal productivity during the crop growing period [17].

As can be seen in Table 1, three types of tillage are distinguished with different characteristic indicators. Traditional tillage refers to plowing, which includes turning the soil, which ensures the availability of nutrient elements in the entire layer of the arable layer, limits weeds, and facilitates the easier execution of other technological operations. Minimum tillage is a method where the soil is not turned over. The maximum depth of cultivation is no deeper than 10 cm and/or the percentage of plant residues left on the soil surface is determined in percent, usually 30%, applying the mentioned method reduces the risk of erosion and crust formation because straw residues remain on the soil surface [9]. Direct sowing, on the other hand, is a method where the seed is placed in the soil without cultivating the previous crop, mainly used in dry regions.

Considering all the invoices affecting the yield, the authors selected the following average yield intervals and assigned them the corresponding codes to be used as classifiers in decision trees and NN (see Table 2). We define 5 classes that describe the quality of the harvest.

TABLE 2 AVERAGE YIELD INTERVALS AND THEIR ASSIGNED CODES

Average yield interval (t/ha)	Affects	Code
1.0 - 1.9	Very unfavorable	1
2.0 - 2.9	Unfavorable	2
3.0 - 4.0	Medium	3
4.1 - 5.1	Favorable	4
5.2 - 6.5	Very favorable	5

Grain yield forecasting is an important aspect of agriculture that helps farmers make informed decisions about crops grown [18], which is essential for resource optimization and investment planning for sustainable production [19].

B. Decision Tree Construction Methods

Decision trees are one of the most effective data mining tools that allow you to solve classification and regression problems. They are hierarchical tree structures consisting of decision rules of the form "If ... Then ...". The rules are automatically generated during the learning process on the training set and, since they are formulated almost in natural language, decision trees as analytical models are more verbalizable and interpretable than NN.

The decision tree is a method of representing decision rules in a hierarchical structure consisting of two types of elements - nodes and leaves. The nodes contain decision rules and check the compliance of examples with this rule using any attribute of the training set.

Then the rule is applied again to each subset and the procedure is repeated recursively until a certain condition for stopping the algorithm is reached. As a result, the last node is not checked or split and is declared a leaf. The worksheet determines the solution for each example included in it. For a classification tree, this is the class

associated with the node, and for a regression tree, this is the modal interval of the target variable corresponding to the leaf.

Let a training set S be given, containing n examples, for each of which a class label is given $C_i (i = 1..k)$ and m attributes $A_j (j = 1..m)$, which are assumed to determine whether an object belongs to a particular class. Then three cases are possible:

1. All examples of the set S have the same class label C_i (that is, all training examples belong to only one class). Training in this case does not make sense, since all the examples presented to the model will be of the same class, which will "learn" to recognize the model. The decision tree itself in this case will be a leaf associated with the class C_i . The practical use of such a tree is pointless since it will assign any new object only to this class.
2. The set S does not contain examples at all, i.e. is the empty set. In this case, a leaf will also be created for it (applying a rule to create a node to an empty set is pointless), the class of which will be selected from another set (for example, the class that occurs most often in the parent set).
3. The set S contains training examples of all classes C_k . In this case, it is necessary to split the set S into subsets associated with classes. To do this, select one of the attributes A_j of the set S which contains two or more unique values (a_1, a_2, \dots, a_p) , where p is the number of unique values of the attribute. The set S is then split into p subsets (S_1, S_2, \dots, S_p) , each of which includes examples containing the corresponding attribute value. Then the next attribute is selected, and the partition is repeated. This procedure will be repeated recursively until all examples in the resulting subsets are of the same class.

The procedure described above underlies many modern algorithms for constructing decision trees. When using this technique, the construction of a decision tree will occur from top to bottom (from the root node to the leaves).

Currently, a significant number of decision tree learning algorithms have been developed: ID3 (Iterative Dichotomizer 3), CART (Classification and Regression Tree), C4.5, C5.0, NewId, ITRule, CHAID (Chi-square automatic interaction detection), CN2, etc. [20-21].

CHAID determines the relationship between a response variable and others, so you can forecast how to have the biggest impact. The CHAID algorithm splits nodes to produce chi-square values. A chi-square value is the difference between a standard and the results observed in your data. The maximum chi-square value is the most statistically significant result in the CHAID decision tree. It is the strongest relationship between two variables of the found chi-square values.

Advantages of the CHAID algorithm:

- fast learning process.
- generation of rules in areas where it is difficult for an expert to formalize his knowledge.
- extracting rules in natural language.
- intuitive classification model.
- high prediction accuracy, comparable to other data analysis methods (statistics, NN).
- construction of nonparametric models.

III. RESULTS AND DISCUSSION

To characterize the enterprises of the grain-growing sector and their performance indicators, four agricultural enterprises whose main activity is grain cultivation were selected. The study used real data and the initial data contained the indicators of the factors influencing the harvest and the harvest volumes in the period from 2011 to 2023.

The research methodology is based on the following sequence of actions:

1. A decision tree is created based on the initial data.
2. Based on these data, an NN is constructed and trained.
3. NN testing is carried out to be able to predict the yield at certain factor indicators.

The resulting decision tree is shown in Figure 1.

As can be seen in Figure 1, the CHAID decision tree is divided into 12 nodes, and for each of the factors, a chi-square value is indicated, which indicates the difference between the expected result and the actual data. The root node is the yield interval, which is the starting point in the decision tree and on which all other data depends.

The highest chi-square value is observed for the factor “precipitation”, which means that this is the most statistically significant result in the created decision tree. The decision tree is divided into further nodes, after which the most significant factor that has the greatest influence on the dependent factor becomes the new variable, thus indicating which variables are most effective for this distribution of data.

Based on the collected indicators, because of a result of the CHAID decision tree analysis, the importance of factors is determined: temperature, grain weight, precipitation, sowing depth, and seeding rate.

The CHAID decision tree model summarizes the influence and importance of the factors but requires the addition of NN analysis to be able to predict grain yields. A Multilayer Perceptron (MLP) was chosen for training. Also, in the NN, the yield interval is defined as a target that depends on the other factors influencing the yield. The training quality of the created NN model is defined as 71.2%, which means that the model is relatively accurate. As a result of NN training, the importance of factors is determined: temperature, precipitation, sowing depth, sowing rate, grain weight, seed quality, and soil quality.

The important factors obtained by training decision trees and NN differ because in both cases different training algorithms are used, and as a result, the factors may have different effects. Each algorithm uses different characteristics and relationships inherent in the data.

Based on the data trained by the NN, companies in the grain-growing industry can make forecasts of the next year's harvest, considering the obtained reliability index, which would provide an opportunity to identify and eliminate possible yield reductions or other adverse factors affecting the harvest, which generally affect the company's operation.

For example, based on the results of the created forecasting model on the possible indicators of the 2024 grain harvest with the changed value of the “precipitation” factor from favorable to unfavorable, it can be concluded that considering the known possible factors affecting the harvest, the 2024 harvest with a 77% reliability index also, in this case, will be very unfavorable.

To increase the prediction reliability of the created model, a much larger and more diverse amount of data would be needed (60 records were used in our study), which would allow the model to learn from more versatile data, thus significantly improving the prediction efficiency.

IV. CONCLUSIONS

Forecasting in the grain-growing industry contributes to sustainable agriculture, as more accurate forecasts help reduce the use of unproductive resources, and by using crop forecasting modeling, grain companies can more effectively adapt to fluctuations in market demand, ensuring that the yield is in line with demand, but does not exceed it, preventing potential losses.

Companies in the grain-growing sector need to gather data on the factors influencing grain yield and production volumes annually. By utilizing a pre-existing forecasting model, they can then predict the grain yield for the following year. This enables the company to adjust to evolving conditions, optimize resources, and implement necessary measures to enhance potential yield volumes.

The decision tree model could be enhanced by incorporating other factors that affect grain yield, enabling a more comprehensive evaluation of potential future grain yield.

Conceptually, the solution developed in this study is not groundbreaking, but its implementation in cereal production companies offers a glimpse into the use of modern technologies in practical operations. It can be inferred that predicting grain yield is a crucial element of agriculture that aids in resource optimization. CHAID decision trees and NN are valuable tools in this area, offering more precise predictions and aiding in decision-making for agricultural processes.

The authors conclude that the developed solution is viable and enables yield prediction based on the developed proposed yield impact factors.

The future direction of research will be related to the introduction of additional factors that will make the model work more accurately.

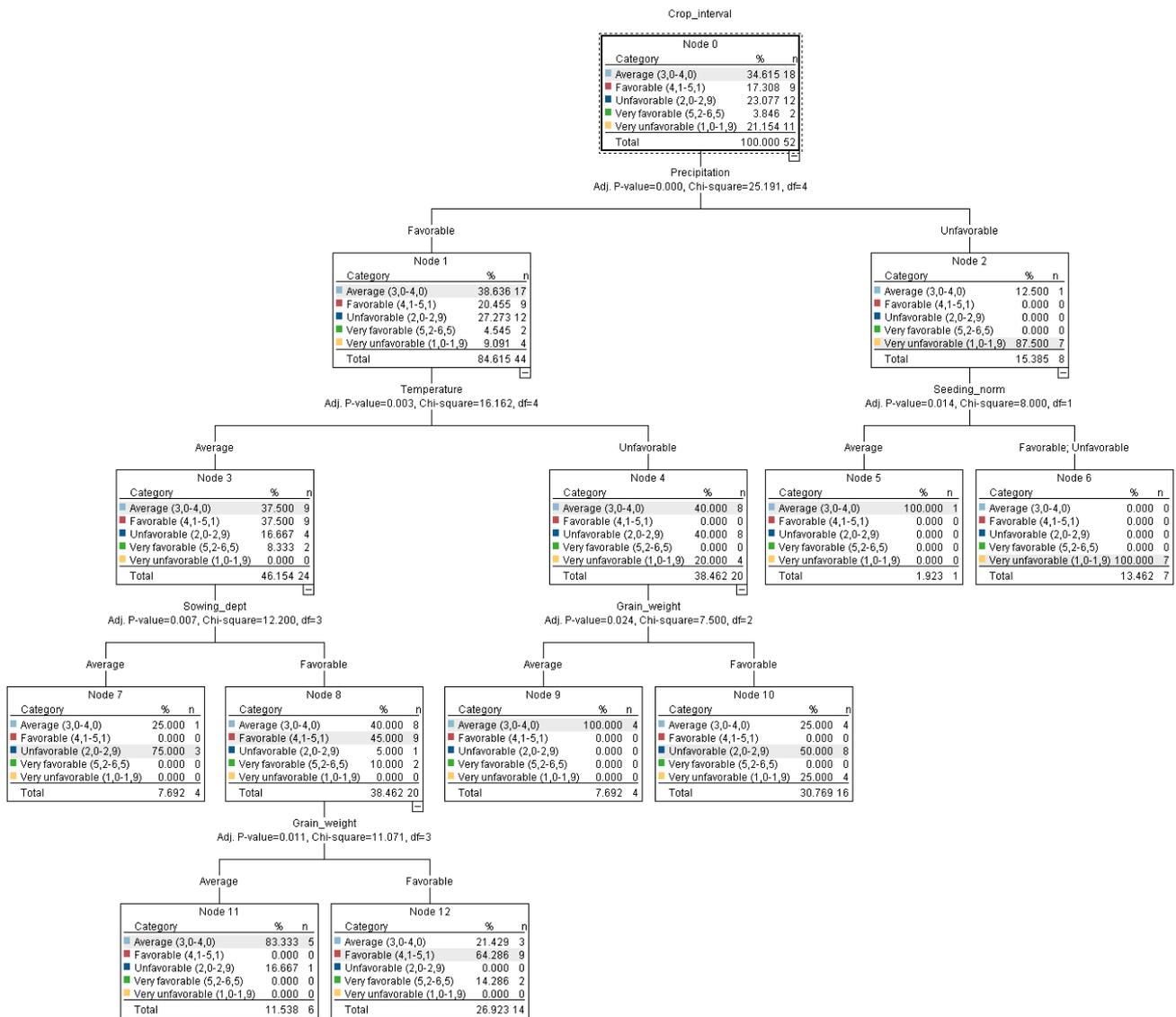


Fig. 1. Decision tree of CHAID performance result.

REFERENCES

- [1] "AI in Agriculture — The Future of Farming," [Online] Available: <https://intellias.com/artificial-intelligence-in-agriculture/>
- [2] M. Javaid, A. Haleem, I.H. Khan, and R. Suman, "Understanding the potential applications of Artificial Intelligence in Agriculture Sector," *Advanced Agrochem*, Vol. 2, Issue 1, 2023. <https://doi.org/10.1016/j.aac.2022.10.001>
- [3] T. Talaviya, D. Shah, N. Patel, H. Yagnik, and M. Shah, "Implementation of artificial intelligence in agriculture for optimisation of irrigation and application of pesticides and herbicides," *Artificial Intelligence in Agriculture*, Vol. 4, p.58-73, 2020. <https://doi.org/10.1016/j.aiia.2020.04.002>
- [4] J. Jung, M. Maeda, A. Chang, M. Bhandari, A. Ashapure, and J.L. Bowles, "The potential of remote sensing and artificial intelligence as tools to improve the resilience of agriculture production systems," *Current Opinion in Biotechnology*, Vol. 70, p.15-22, 2021. <https://doi.org/10.1016/j.copbio.2020.09.003>
- [5] A. Subeeh and C.R. Mehta, "Automation and digitization of agriculture using artificial intelligence and internet of things," *Artificial Intelligence in Agriculture*, Vol. 5, p.278-291, 2021. <https://doi.org/10.1016/j.aiia.2021.11.004>
- [6] D.I. Patricio and R. Rieder, "Computer vision and artificial intelligence in precision agriculture for grain crops: A systematic review," *Computers and Electronics in Agriculture*, Vol. 153, p.69-81, 2018. <https://doi.org/10.1016/j.compag.2018.08.001>
- [7] Y. Amapatzidis, V. Partel, and L. Costa, "Agroview: Cloud-based application to process, analyze and visualize UAV-collected data for precision agriculture applications utilizing artificial intelligence," *Computers and Electronics in Agriculture*, Vol. 174, 2020. <https://doi.org/10.1016/j.compag.2020.105457>
- [8] V. Meshram, K. Patil, V. Meshram, D. Hanchate, and S.D. Ramkteke, "Machine learning in agriculture domain: A state-of-art survey," *Artificial Intelligence in the Life Sciences*, Vol. 1., 2021. <https://doi.org/10.1016/j.aillsci.2021.100010>
- [9] S. Kujawa and G. Niedbala, *Artificial Neural Networks in Agriculture*. MDPI, 284 p., 2021. <https://doi.org/10.3390/books978-3-0365-1579-3>
- [10] G. Niedbala and S. Kujawa, "Artificial Neural Networks in Agriculture," *Agriculture*, Vol. 11, Issue 6, 2021. <http://dx.doi.org/10.3390/agriculture11060497>
- [11] K.N. Patel, S. Raina, and S. Gupta, *Artificial Intelligence and its Models*. JASC: Journal of Applied Science and Computations, 2020.
- [12] A. Sharma, M. Georgi, M. Tregubenko, A. Tselykh, and A. Tselykh, "Enabling smart agriculture by implementing artificial intelligence and embedded sensing," *Computers & Industrial*

- Engineering, Vol. 165, 2022. <https://doi.org/10.1016/j.cie.2022.107936> [Accessed: Feb. 1, 2024].
- [13] J.J. Blake, J.H. Spink, and C. Dyer, "Factors affecting cereal establishment and its prediction," 2003. [Online] Available: https://projectblue.blob.core.windows.net/media/Default/Research%20Papers/Cereals%20and%20Oilseed/rr51_complete_final_repo_rt.pdf [Accessed: Feb. 1, 2024].
- [14] S. Narayanan, "Effects of high temperature stress and traits associated with tolerance in wheat," Open Access Journal of Science, Vol.2, Issue 3, p.177-186, 2018. <https://doi.org/10.15406/oajs.2018.02.00067>
- [15] M. Gammans, P. Merel, and A. Ortiz-Bobea, "Negative impacts of climate change on cereal yields: statistical evidence from France," Environmental Research Letters, Vol. 12, Issue 5, 2017. DOI 10.1088/1748-9326/aa6b0c
- [16] NICHE Agriculture, "How Rainfall Affects Crop Health," [Online] Available: , from <https://www.nicheagriculture.com/how-rainfall-affects-crop-health/> [Accessed: Feb. 1, 2024].
- [17] T.N. Liliane and M.S. Charles, "Factors Affecting Yield of Crops," Agronomy - Climate Change & Food Security, 2019. DOI: 10.5772/intechopen.90672
- [18] JavaTpoint, "Crop Yield Prediction Using Machine Learning," [Online] Available: <https://www.javatpoint.com/crop-yield-prediction-using-machine-learning> [Accessed: Feb. 1, 2024].
- [19] A. Sreerama and B.M. Sagar, "A Machine Learning Approach to Crop Yield Prediction," International Research Journal of Engineering and Technology (IRJET), Vol. 07, Issue 05, 2020. [Online] Available: <https://www.irjet.net/archives/V7/i5/IRJET-V7I5I246.pdf> [Accessed: Feb. 1, 2024].
- [20] S. Murthy, "Automatic construction of decision trees from data: A Multi-disciplinary survey," Data Mining and Knowledge Discovery, Volume 2, pages 345–389, 1998.
- [21] L. Rokach and O. Maimon, Data Mining with Decision Trees: Theory and Applications (2nd Edition), (Series in Machine Perception and Artificial Intelligence, vol. 81, 2015.

A Survey of Data Quality in Industrial Networks and Enhancing Their Reliability Complex Indicator for the Needs of the Industry

Ekaterina Hristova

Faculty of Technical Sciences
Konstantin Preslavski University of
Shumen
Shumen, Bulgaria
ekaterinakonstantinova@abv.bg

Daniel Denev

Faculty of Technical Sciences
Konstantin Preslavski University of
Shumen
Shumen, Bulgaria
d.denev@shu.bg

Tsvetoslav Tsankov

Faculty of Technical Sciences
Konstantin Preslavski University of
Shumen
Shumen, Bulgaria
c.cankov@shu.bg

Abstract. With the evolution of the industrial sector, the establishment and administration of production units have emerged as primary concerns for each industrial enterprise. For the control process, emphasis is placed on programmable devices and industrial networks. Through them, manufacturing enterprises face two main questions, "What reliability could they provide?" and "Is it possible to improve the current devices they use." In this article, an experimental study related to the information level of an industrial network is carried out. It aims to increase the quality and speed of her workflow. Monitoring and data extraction of the communication of programmable devices is carried out as well. A method for improving data transmission in the same network is proposed. A statistical method is used to analyze the general reliability. Also the present article aims to develop a computational model of a complex indicator of the reliability of a system of programmable devices. The choice is based on the fact that many enterprises rely on the rapid processing of information and greater reliability of programmable devices.

Keywords: *Monitoring, Programmable logic controllers, Reliability, Risky technical system.*

I. INTRODUCTION

With the development of automation and industrial networks, many enterprises have come to rely on the fast and reliable transmission of data, as well as the general and field reliability of each machine. Based on this, a massive search for optimization solutions begins. A fundamental step towards achieving this goal is the statistical analysis of a given industrial system. Statistics is a mathematical method used to collect, systematize and interpret quantitative data, with an emphasis on examining the characteristics of the entire population by drawing inferences from a representative sample. The process of

statistical analysis involves collecting and analyzing in detail the vast amount of information needed to detect trends and gain valuable insights. In a professional context, statisticians process raw data and examine relationships between variables in order to uncover patterns and trends that provide important information to relevant interested parties. Statisticians working in a variety of sectors play a key role in generating new scientific discoveries, formulating business strategies and fostering innovation [1].

With the progress of time and technological processes, many new possibilities for improving network communication are discovered. Each new methodology can be viewed as a better version of its previous one. One of the latest advances in the advancement of network communication is the implementation of intelligent devices such as switches and routers. While years ago, most devices performed simple tasks, today, thanks to new technologies, they perform much more complex functions. These devices retain their functionality, providing opportunities for use by both scientists and ordinary users. Scientists and engineers use them to research and improve work processes. The present study drew attention to the early work of other researchers. Ivanka Georgieva, author of Automation Systems with Programmable Logic Controllers, explains the best and most efficient way to work with programmable devices. She shares her experiences on preparing simulation software so that the researcher or the average user can get the most out of any automation system. Another researcher, Ivan Popchev, examines risk in network communication and its reliability. Evgeni Gindev from the G.S. Rakovski Military Academy in Sofia also focuses on general and field reliability of risky technical systems. The following studies follow the research of Nikolay

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8036>

© 2024 Ekaterina Hristova, Daniel Denev, Tsvetoslav Tsankov. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

Petrov also, who examines the reliability indicators of various systems.

II. MATERIALS AND METHODS

Each specific statistical study has for its object a certain extensive phenomenon that manifests itself in certain time and space frames. The process involves three interrelated steps: statistical observation, statistical clustering, and statistical analysis.

- The first stage, statistical observation, focuses on gathering initial empirical information as part of the overall study;
- In the second stage with the use of statistical clustering, the primary data must be summarized and systematized so that they are prepared for the application of statistical analysis methods;
- The third and final stage includes the statistical analysis itself, which must meet the goals and expected results that preceded the conduct of the overall statistical study.

Much scientific research is concerned with comparing the distribution of two or more variables. The peculiarity of these comparisons is that the conclusions drawn must refer to entire populations, and the data available to the researcher cover only a sample of it. Therefore, assumptions - hypotheses are initially formulated, and subsequently a check is made to see if the data from the sample confirms or rejects them.

- Zero (H0) - claims that there is no statistically significant difference in the compared statistical indicators. Although some variation may be observed in the samples, it is random and cannot be generalized to the general populations;
- Alternative (H1) - claims that the observed difference in the compared statistical indicators in the samples is statistically reliable and can be generalized for the general populations.

The degree of certainty with which the alternative hypothesis is accepted as true is called the guarantee probability (P). The risk of making a mistake by accepting the alternative hypothesis as true is called the significance level (α). After forming the hypotheses, an appropriate statistic (criterion) is selected, which is calculated according to the parameters detailed in the hypotheses. A final decision is made by comparing the tabular (theoretical) value of the criterion with the empirical (calculated from sample data).

To conduct a test procedure and for the purposes of the research in three stages, a test setup is organized with a control and test group of industrial devices and a switch playing the role of a key test element. The test group setup is shown in Fig. 3. Fig. 1 shows the approach for organizing the three stages of the test set-up. Four types of industrial controllers (Toshiba V200, Omron NX, Allen Bradley SLC-500, Siemens S7-1500) were selected for the purposes of the study. Each current test setup includes five industrial controllers of the given type applied to the respective stage. In addition, a Cisco Nexus 9300 smart switch is added for the test setup.

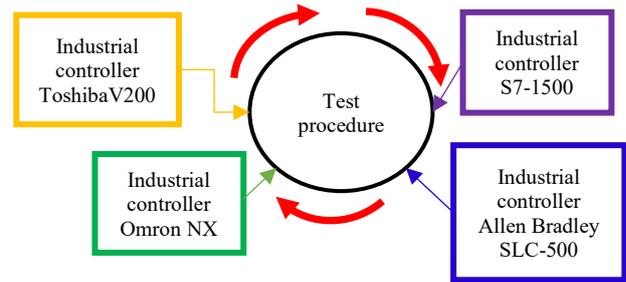


Fig. 1. Organizing the test setup.

Using activity diagrams in Fig. 2 an algorithm for conducting a test valid for each stage is presented.

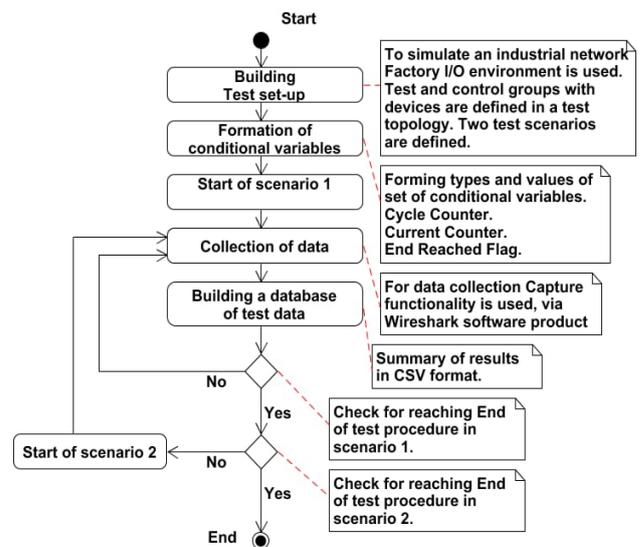


Fig. 2. Algorithm for conducting a test from a given stage.

In both types of test setups, a workstation with the following purpose is used:

- Management of test applications;
- Storage of intermediate data;
- Storage of test results.

For the purposes of the study, the following applications were selected:

- Factory I/O – integrated environment for network simulations;
- Wireshark – an application for analyzing network protocols and network data;
- Rstudio – an integrated environment for the synthesis of scripts intended for analyzing data.

To form an empirical set of results, the following set of criteria is established:

1. Port number;
2. Number of packages;
3. Packet size in bytes;
4. Total number of packages;
5. Number of sent packages;
6. Number of packets received.

According to these criteria, sets of tables 1, 2, 3 with the empirical data were formed.

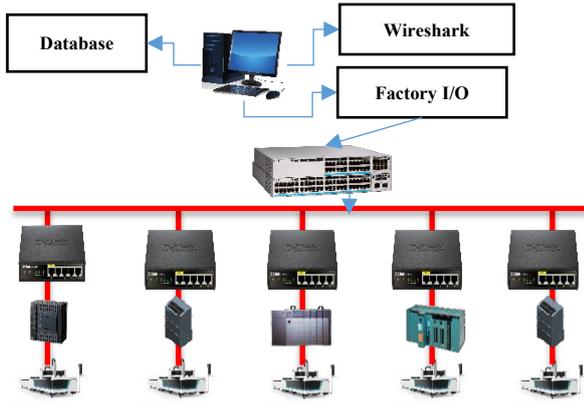


Fig. 3. Industrial network diagram with test set of devices.

TABLE 1 PROFINET NUMERICAL DATA FOR CONTROLLER OMRON NX AFTER IMPROVEMENT

Addresses	Packets	Bytes	Total Packets	Percent Filtered
Omron NX	40	8848	40	100.00%
Omron NX	30	455	30	100.00%
Omron NX	39	744	43	92.00%
Omron NX	55	311	55	100.00%
Omron NX	10	350	10	100.00%
Omron NX	15	886	15	100.00%
Omron NX	5	578	5	100.00%

TABLE 2 PROFINET NUMERICAL DATA FOR CONTROLLER ALLEN BRADLEY SLC 500 AFTER IMPROVEMENT

Addresses	Packets	Bytes	Total Packets	Percent Filtered
AB SLC 500	80	5961	80	100.0%
AB SLC 500	500	18966	500	100.0%
AB SLC 500	92	400	101	91.0%
AB SLC 500	20	1566	20	100.0%
AB SLC 500	40	2610	40	100.0%
AB SLC 500	500	1515	560	88.0%
AB SLC 500	29	451	32	90.0%

III. RESULTS AND DISCUSSION

On the basis of the theoretical formulation, the statistical study was carried out to test hypotheses and prove the results of the improvement of the industrial network. Graphical representation of information and data using visual elements such as charts, graphs, maps, and visualization tools provide an accessible way to see and understand trends, deviations, and patterns in data. It provides an excellent way to present data to non-technical audiences without confusion. For the purpose of the study, the data from the aforementioned controllers are presented in scatter plots. Such observations are called paired or repeated, i.e. to each x_i corresponds y_i . [2], [9], [10]

TABLE 3 PROFINET NUMERICAL DATA FOR CONTROLLER S7-1500 AFTER IMPROVEMENT

Addresses	Packets	Bytes	Total Packets	Percent Filtered
S7-1500	100	8410	100	100.0%
S7-1500	445	22886	500	89.0%
S7-1500	186	714	200	93.0%
S7-1500	45	2285	50	91.0%
S7-1500	25	8365	30	86.0%
S7-1500	285	1410	300	95.0%
S7-1500	36	366	40	92.0%

The figures show a distinct difference in the measurements before and after the additional optimization level was applied. But even so, no conclusion can be drawn about the exact magnitude of the effect of the Cisco Business 220 Smart Switch on the controllers in the network.

- Omron NX – (Fig. 4, Fig. 5)

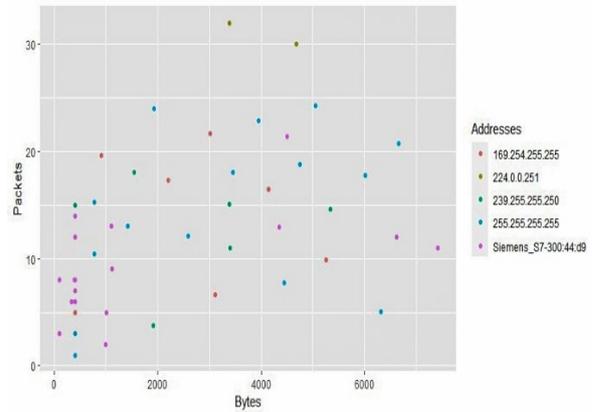


Fig. 4. Dot plot of an Omron NX controller.

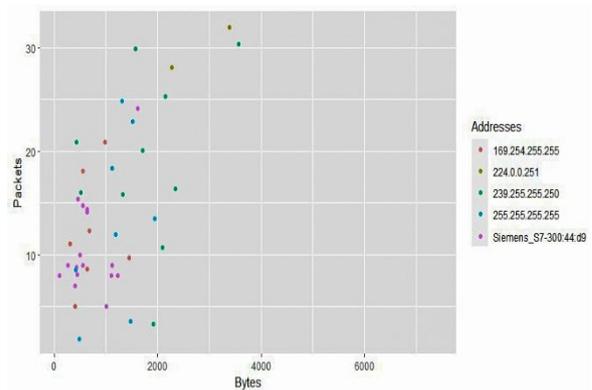


Fig. 5. Dot plot of an Omron NX controller after improvement.

- S7-1500 – (Fig. 6, Fig. 7)

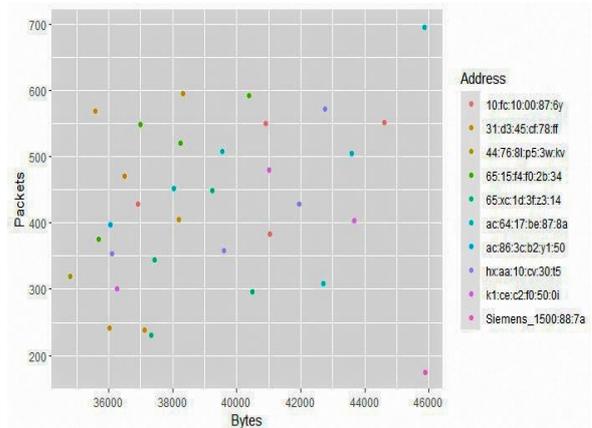


Fig. 6. Dot plot of an S7-1500 controller.

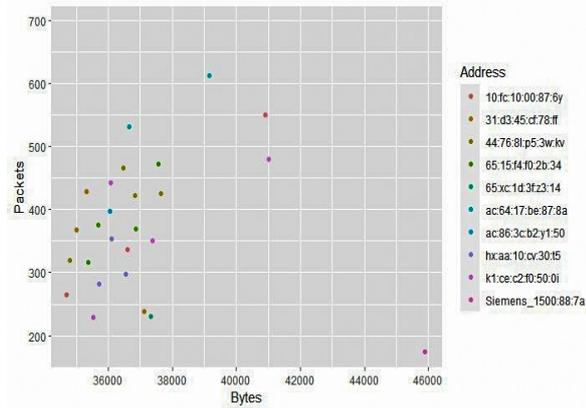


Fig. 7. Dot plot of an S7-1500 controller after improvement.

Despite the inability to estimate the exact magnitude of the switch's impact from the dot plots, the numerical values in the samples indicate a possible improvement in the number of packets and bytes transmitted between controllers in the industrial network.

- $H_0: m_y - m_x = 0$, i.e. no significant difference between data downloaded before adding the switch;
- $H_1: m_y > m_x$, i.e. there is a significant improvement in network reliability, packet transmission, and system performance optimization after connecting additional devices;

Statistics are used:

$$U_x = \sum_{i=1}^{n_x} \sum_{j=1}^{n_y} \delta_{ij} \quad (1)$$

where

$$\delta_{ij} = \begin{cases} 1, & x_i > y_j \\ \frac{1}{2}, & x_i = y_j \\ 0, & x_i < y_j \end{cases} \quad (2)$$

When testing H_0 , the confidence region for testing the hypothesis W takes the form

$$W = \{U_{1-\alpha} \leq U_x\}, P(W) = \alpha \quad (3), (4)$$

In practice, it is most often worked with $\alpha = 0,05$ which show the huge significance after optimization.

- Enhanced data density measurement methods

```
library(readxl)
library(fitdistrplus)
Profinet_before_raw <-
read_excel("Statistics/Profinet_OmronNX
_before.xlsx",
range = "C2:C29")
Profinet_after_raw <- read_excel("Statistics/
Profinet_OmronNX_after.xlsx",
range = "C2:C29")
as.numeric(unlist(Profinet_before_raw))
as.numeric(unlist(Profinet_after_raw))
Diff = Profinet_after - Profinet_before
plotdist(Diff, histo = TRUE, demp = TRUE)
```

```
library(readxl)
library(fitdistrplus)
Profinet_before_raw<- read_excel("Statistics/
Profinet_S7-1500_before.xlsx",
range = "C2:C29")
Profinet_after_raw <- read_excel("Statistics/
Profinet_S7-1500_after.xlsx",
range = "C2:C29")
as.numeric(unlist(Profinet_before_raw))
as.numeric(unlist(Profinet_after_raw))
Diff = Profinet_after - Profinet_before
plotdist(Diff, histo = TRUE, demp = TRUE)
```

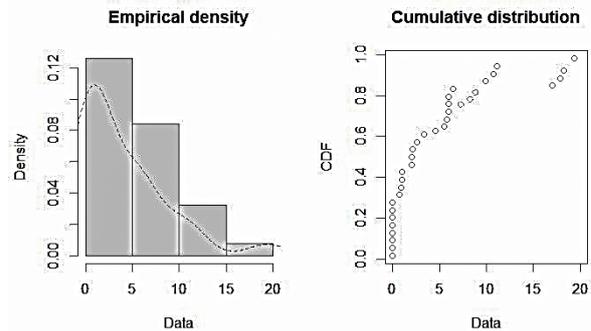


Fig. 8. Empirical density and cumulative frequency function plot of an Omron NX controller.

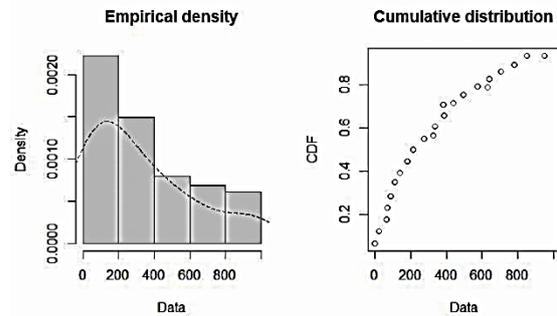


Fig. 9. Empirical density and cumulative frequency function plot of an S7-1500 controller.

- Wilcoxon test on the two-sample data for an Allen Bradley SLC-500 controller

```
median(Profinet_before_Allen Bradley SLC-500)
median(Profinet_after_Allen Bradley SLC-500)

wilcox.test(Profinet_before, Profinet_after,
paired = TRUE, exact=FALSE)
```

Wilcoxon signed rank test with continuity correction

alternative hypothesis: true location shift is not equal to 0

p-value (0,01415) < α (0,05)

Due to the existence of a significant difference between p and α , the hypothesis H_0 is rejected and H_1 is accepted as true.

- Improvement Effect Size Investigation on a Toshiba V200 Controller

```
wilcox.test(Profinet_before_Toshiba-V200,
Profinet_after_Toshiba-V200, paired = TRUE,
exact=FALSE)
Zstat_3<-qnorm(test_3$p.value/2)

#Effect size using
abs(Zstat_3)/sqrt(10)
```

```
##[1] 0.7858644
d = 0,79 => large
```

Effect size: very small - 0.01, small - 0.20, medium - 0.50, large - 0.80, very large - 1.20, huge - 2.0.

Cisco Nexus 9300 intelligent switch shows a significant impact on the operation of network controllers by optimizing their operation, improving the reliability of transmitted information and electronic products, and improving the speed of packet transmission between devices.

Fig. 10 observes the magnitude of the effect on all involved programmable controllers in the industrial network.

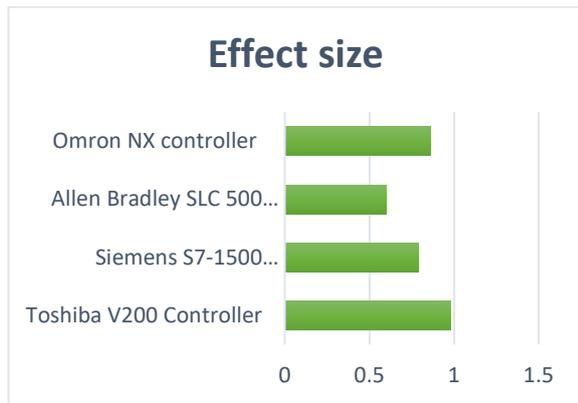


Fig. 10. Magnitude of the effect on all involved PLC.

A complex indicator of the reliability of risky technical systems (in particular, programmable devices and equipment) is the probability of normal functioning $P_{H\Phi}(\tau, t)$, expressing the probability that at any moment τ the product is operational and will continue to work without failure for a certain interval from time t , i.e. in the interval $\tau, \tau + t$. [3], [7], [8]

This general indicator of reliability for programmable devices in the industry can be defined as "the probability that the planned task (production of a product or processing of information) will not fail due to the fault of the electronic component composition". It is determined by:

$$P_{H\Phi}(\tau, t) = K_{\Gamma}(\tau) \cdot P_{BP}(\tau, \tau + t) \quad (5)$$

where: $K_{\Gamma}(\tau)$ - the readiness ratio of risky technical systems at a moment τ ;

$P_{BP}(\tau, \tau + t)$ – probability of failure-free operation of risky technical systems in an interval $(\tau, \tau + t)$.

With an established SR process (stationary random process), when no failure has occurred in the interval $(\tau, \tau + t)$ of $P_{H\Phi}(\tau, t)$ it is called the coefficient of operational readiness. $K_{O\Gamma}(t)$ is defined by the expression:

$$K_{O\Gamma}(t) = K_{\Gamma}(t) \cdot P_{BP}(t) \quad (6)$$

The operational readiness coefficients $K_{O\Gamma}(t)$ and the readiness coefficient $K_{\Gamma}(t)$ are provided in the standards as standardized complex indicators. Which of the two should be chosen depends on the way the respective product functions. [4]

For products with high reliability $K_{\Gamma}(t)$ is suitable, because the efficiency of their use will depend most on the recovery time.

For products where reliability is lower and critical, $K_{O\Gamma}(t)$ will be suitable.

Example: Through operational observations of a group of the same type of recoverable products, it was found that a total of $n = 5$ failures were obtained (table 4), and the total working time between failures is $\sum_{i=1}^n t_{0i} = 450 h$, the total recovery time is $\sum_{i=1}^n t_{Bi} = 22,5 h$ and the total stay in scheduled maintenance and repairs in the observed interval is $\sum_{i=1}^j t_j = 92,5 h$. It is assumed that there is an established normal operation process where the event flows (failures, recoveries) are stationary. To determine the reliability indicators at an operating time $t_p = 30 h$ and a recovery time $t_B = 2 h$.

TABLE 4 NUMERICAL RELIABILITY INDICATORS

Parameter	Values
Number of failures	5
Total working time between failures	450 h
Total recovery time	22,5 h
Total stay in scheduled repairs	92,5h
Working time	30 h
Recovery time	2 h

Solution: For the fail-safe metrics, we get:

$$n \cdot h_{daily}, 5 \cdot 3h_{daily} = 15 h_{daily} \quad (7)$$

$$30_{day} \cdot 15h_{daily} = 450 h \quad (8)$$

$$\bar{T}_0 = \frac{\sum_{i=1}^n t_{0i}}{n} = \frac{\sum_{i=1}^5 t_{0i}}{5} = \frac{450}{5} = 90 h \quad (9)$$

$$\bar{\omega} = \frac{1}{\bar{T}_0} = \frac{1}{90} = 11 \cdot 10^{-3} h^{-1} \quad (10)$$

$$P_{BP}(t) = \exp(-\bar{\omega} \cdot t_p) \quad (11)$$

$$P_{BP}(t) = \exp(-11 \cdot 10^{-3} \cdot 30) = 0,71892 \approx 0,719 \quad (12)$$

For the reparability indicators, it is obtained:

$$\bar{T}_B = \frac{\sum_{i=1}^n t_{Bi}}{n} = \frac{\sum_{i=1}^5 2h}{5} = \frac{22,5}{5} = 4,5 h \quad (13)$$

$$\bar{\mu} = \frac{1}{\bar{T}_B} = \frac{1}{4,5} = 0,22h^{-1} \quad (14)$$

$$P_B(t_B) = 1 - \exp(-\bar{\mu} \cdot t_B) \quad (15)$$

$$P_B(t_B) = 1 - \exp(-0,22 \cdot 2) = 0,35882 \quad (16)$$

For the complex reliability indicators, it is obtained:

$$K_{\Gamma\Pi} = \frac{\sum_{i=1}^n t_{oi}}{\sum_{i=1}^n t_{oi} + \sum_{i=1}^n t_{Bi} + \sum_{j=1}^k t_j} = \frac{450}{450+22,5+92,5} = \frac{450}{565} = 0,79646 \quad (17)$$

$$K_{\Gamma} = \frac{\sum_{i=1}^n t_{oi}}{\sum_{i=1}^n t_{oi} + \sum_{i=1}^n t_{Bi}} = \frac{450}{450+22,5} = \frac{450}{472,5} = 0,95238 \quad (18)$$

$$K_{O\Gamma}(t) = K_{\Gamma} \cdot P_{BP}(t) = 0,952 \cdot 0,719 = 0,68469 \quad (19)$$

In the theory of reliability, models have been developed for estimating the probability function for normal operation $P_{H\Phi}(\tau, t)$ and for the cases when one or more failures may occur and be removed in the process of operation. For the electronic component composition in the systems of programmable devices, these models are applicable when the random time T_B for failure removal does not exceed the definitely permissible time $t_{B,доп}$ for the controller to stay in a faulty state, i.e. $T_B \leq t_{B,доп}$. Such a model applicable to programmable devices is presented in [5]. In it, it is assumed that the total time to restore operability in the case of the n number of failures of the assembly line is much smaller than the considered operation time of the controller in the mode of information processing and task execution t_{BD} , i.e. $\sum_{i=1}^n t_{Bi} \ll t_{BD}$.

When determining the probability of normal operation $P_{H\Phi}(\tau, t)$ it is assumed that for the time t_{BD} no failure should occur. If it is assumed that in an established process of operation of the programmable devices, after the moment τ in the interval $(\tau, \tau + t)$, a failure has occurred, which will be removed by the maintenance personnel before the expiration of the time t_{BD} . For the calculation of the probability of normal functioning the following equation is suggested:

$$P_{H\Phi}(t, t_{BD}) = K_{\Gamma} \cdot P_{BP}(t) \cdot \{1 + [1 - P_{BP}(t)] \cdot P_B(t_{BD})\} \quad (20)$$

Example: With an established process of operation of a given series of programmable devices (Omron NX controller – Fig. 11), it is known that the readiness factor is $K_{\Gamma} = 0,99$; the probability of failure-free operation for a certain time for carrying out an operation t_{BD} is $P_B(t_{BD}) = 0,8$, and the probability of restoring the operability of the controller in the production enterprise t_{BD} is $P_B(t_{BD}) = 0,96$. To determine the probability of

normal operation of $P_{H\Phi}(t, t_{BD})$ of a programmable device of this series, if the appearance and removal during time t_{BD} allows only one failure.



Fig. 11. Programmable controller Omron NX [1].

Solution: After substitution in (20) we get:

$$P_{H\Phi}(t, t_{BD}) = K_{\Gamma} \cdot P_{BP}(t) \cdot \{1 + [1 - P_{BP}(t)] \cdot P_B(t_{BD})\} = 0,99 \cdot 0,8 \cdot [1 + (1 - 0,8) \cdot 0,96] = 0,944 \quad (21)$$

If no failure is allowed to occur in the same period, the probability of normal operation $P_{H\Phi}(t, t_{BD})$ (in this case, it is the coefficient of operational readiness $K_{O\Gamma}$) will be:

$$P_{H\Phi}(t, t_{BD}) = K_{O\Gamma} = 0,99 \cdot 0,8 = 0,792 \quad (22)$$

This academic publication presents an evolutionary study aimed at improving industrial networks and creating a complex indicator of their reliability. It examines smart switches and new software solutions, making the next-generation improvement accordingly. The research covers a variety of new techniques that have not yet received sufficient attention in the academic literature. The improvement of industrial networks using smart switches as a potential research area has been less explored. Previous research and improvement approaches are often based on techniques from previous generations. Furthermore, the present study confirms and complements previous qualitative results achieved by other scholars in the field. Also noted are gaps in the development of reliable communication, as well as old methods and approaches that are not optimal. As time progresses, the improvement of network communication becomes more and more important, especially due to the growing need for more reliable data transmission. This kind of network communication enhancement not only supports more reliable data transmission in industrial networks, but is also applicable in classical communication networks. This scientific paper demonstrates that the model presented in it has significant differences compared to all other models.

IV. CONCLUSIONS

From the proposed article, it can be concluded that by combining knowledge, skills and technical means from several scientific and applied fields, the goal is achieved, namely - improvement of the information level in industrial communication. It provides better reliability as well as information protection with less data loss. Smart switches show a significant impact on programmable devices and provide a wide range of opportunities to improve industrial communication. Based on the computational model, it can be summarized and

concluded that an efficient method is presented for industrial enterprises to calculate their reliability index, according to the number of their programmable devices and their operating time. After shaping the final solutions, the manufacturing companies get a general idea of the devices they own and their field reliability. Future development of a software plug-in for the Wireshark program is planned, through which a direct connection to the simulation program will be made. Through it, in a simulation process, industrial networks will be analyzed in real time, which in turn will facilitate other future developments and improvements. A future development is also planned in which the complex metric algorithm will be shortened and offer a more convenient calculation.

V. ACKNOWLEDGEMENTS

This current scientific paper and the research conducted would not have been possible without the wonderful support of Assoc. Prof. Eng. Valentin Atanasov. His commitment, expertise and precision in work were a source of inspiration and encouraged the progress of our business in the right direction. We also express our gratitude to the dean of our faculty, Prof. Sabin Ivanov, who secured the funding of the research through the acquisition of a smart switch.

REFERENCES

- [1] E. Gindev, An Introduction to the Theory and Practice of Reliability, Part 1. Basics of applied reliability, AI, Prof. Marin Drinov", Sofia, 2000, ISBN 954-430-608-0.
- [2] I. Popchev, I. Radeva, The new paradigm and the risk in the relationship "human – digital" environment, BAS Magazine, No. 5, Sofia, 2019, pp. 72-77.
- [3] I. Popchev, Six topics and literature on risk management, NBU, Bulgaria, Sofia, 2012, pp. 50-89.
- [4] I. Georgieva, Integrated Automation Systems with Programmable Logic Controllers, Bulgaria, Blagoevgrad, 2016, ISBN 954-8118-06-8.
- [5] N. Petrov, Reliability as a Technical-Economic Problem in Cybernetization of Society, Dissertation for the award of the National Academy of Sciences, Doctor of Economic Sciences, VSU, Chernorizets Hrabar, 2015, ISBN 978-954-92960-8-2,400.
- [6] N. Petrov, Reliability and risk as a global cyber problem, Studio RB ,”G. Rakovski”, 2019, ISBN 978-954-90476-0-8, pp. 45-55.
- [7] N. Petrov, V. Dimitrov and V. Dimitrova, Reliability of Technology Systems in Industrial Manufacturing, Monograph, "AkiNik Publications", New Delhi, India, 2019, ISBN: 978-93-87072-59-6.
- [8] N. Petrov, D. Baskanbayeva, S. Satybaldi, On exponentially large-scale events and the risk of their occurrence, Magazine "Science, Education, Intellect", No. 15, 2021, ISSN 2603-476X, pp. 61-77.
- [9] St. Stanev, St. Zhelezov, Computer and network security, Shumen, 2005, ISBN 954-577-306-5.
- [10] I. Tsonev, S. Stanev, Computer networks and communications, Shumen, 2008, ISBN 978-954-577-420-1.

A Generalized Net Model of Command and Control System

Rosen Iliev
Bulgarian Defense Institute
„Professor Tsvetan Lazarov“
Sofia, Bulgaria
r.iliev@di.mod.bg

Miroslav Kochankov
Bulgarian Defense Institute
„Professor Tsvetan Lazarov“
Sofia, Bulgaria
m.kochankov@armf.bg

Abstract. The relevance of the topic is related to the search for ways to support management in the military field by improving the command and control system (C2-system) of the armed forces. The purpose of the paper is to present an original generalized net model (GN-model) of a command and control system for the needs of the armed forces, including three main elements - personnel, structure and equipment, procedures. Through the integration of these three elements in the created GN-model to provide an opportunity for more detailed testing of different implementation options of the C2-system, even before its implementation in the process of managing the armed forces. To verify the GN-model, a simulation was performed in the GN IDE simulation environment and some results are presented. Some possible applications of the GN-model for the analysis and improvement of the C2-system of the armed forces are described.

Keywords: *Generalized net, modeling, command and control systems, armed forces.*

I. INTRODUCTION

The command and control system (C2) supports the process of managing troops and forces by ensuring comprehensive and covert preparation of combat actions and operations, timely response to changes in the situation and successful performance of assigned tasks under any conditions.

A command and control system is a unity of personnel, infrastructure, equipment, and procedures that enables commanders and their staffs to exercise command and control. It includes the following elements [13]:

- Personnel – of the command and headquarters implementing the planning and management

processes, as well as of the personnel ensuring their activity;

- Infrastructure and equipment – military command and control center with the relevant equipment for the work and life of the personnel;
- Procedures – standard operating procedures for staff operations in planning and directing operations developed at all levels of command and control.

The command and control system can be seen as built up of three integrated levels – the "headquarters" level, the "combat platform" level, the "soldier" level. These levels of classification were also used as the basis for the original model of a generalized net command and control system presented below. More information about the nature, tools and services used for these levels can be found in another publication by the authors [14].

II. MATERIALS AND METHODS

The generalized nets themselves are based on the Theory of generalized nets, which was defined in 1982 by K. Atanassov [1], [2], [3]. In the following years, the theory developed in two varieties – special and general, and found application for modeling a wide class of tasks, processes and phenomena. An application of other modeling nets, such as N-nets (a variation of Petri nets), has been used in [10]. Other studies related to modeling can be found in [11], [17] as well as countering various command and control system threats [6], [8], [9], [12], [15], [16].

Atanassov's theory of generalized nets was used to create the generalized network model of a command and control system presented below.

A GENERALIZED NET MODEL OF A COMMAND AND CONTROL SYSTEM

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8035>

© 2024 Rosen Iliev, Miroslav Kochankov. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

The operation model of the command and control system can be described by a generalized net E as follows:

$E = \{Z1, Z2, Z3, Z4\}$ where

- Z1 – situational analysis and action at the "soldier" level
- Z2 – Situation Analysis and Actions at the "Battle Platform" level
- Z3 – tactical (operational) assessment and actions at the "headquarters" level
- Z4 – Commander decision making and control

The schematic of the generalized net E is shown in Fig. 1.

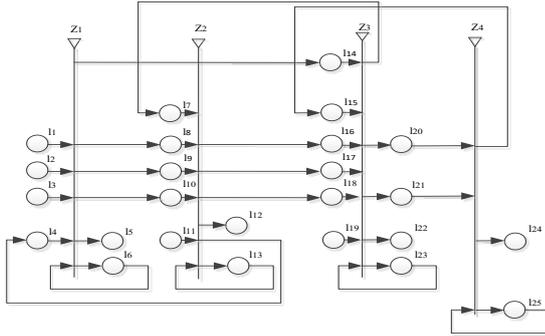


Fig.1. GN model of C2 system

The tokens of a generalized net E are:

α – personnel (soldiers, sergeants, officers, staff), with the following characteristics: $X_\alpha(e^{\alpha_{p1}}, e^{\alpha_{p2}}, \dots, e^{\alpha_{pk}}, \dots, e^{\alpha_{pk}})$, where $e^{\alpha_{pi}}$ is the estimate of i -th parameter from k ($i \leq k$) basic evaluation parameters for personnel;

β – infrastructure (control points, resources, etc.) necessary for the work of the headquarters, with the following characteristics: $X_\beta(e^{\beta_{q1}}, e^{\beta_{q2}}, \dots, e^{\beta_{qi}}, \dots, e^{\beta_{qm}})$, where $e^{\beta_{qi}}$ is the estimate of the i th object/resource out of n ($i \leq n$) required objects/resources;

γ – procedures (sequence of actions, algorithms, information and logistics services, documentation, etc.), with the following characteristics: $X_\gamma(e^{\gamma_{v1}}, e^{\gamma_{v2}}, \dots, e^{\gamma_{vi}}, \dots, e^{\gamma_{vs}})$, where $e^{\gamma_{vi}}$ is an evaluation of the i th type of procedure from s ($i \leq s$);

δ – equipment (equipment, weaponry, tools, etc.), and δ' tokens are used for individual equipment, and δ'' tokens are used for collective equipment, with the following characteristics: $X_\delta(e^{\delta_{w1}}, e^{\delta_{w2}}, \dots, e^{\delta_{wi}}, \dots, e^{\delta_{wt}})$, where $e^{\delta_{wi}}$ is an estimate of the i th equipment type from t ($i \leq t$);

ι – information (data, orders, orders, etc.), with the following characteristics: $X_\iota(e^{\iota_{h1}}, e^{\iota_{h2}}, \dots, e^{\iota_{hi}}, \dots, e^{\iota_{hm}})$, where $e^{\iota_{hi}}$ is an estimate for the availability and usefulness of necessary information from m ($i \leq m$).

$e^{\alpha_p}, e^{\beta_q}, e^{\gamma_v}, e^{\delta_w}$ and e^{ι_h} are functions of the generalized net, which include estimated parameters with values in the following intervals: $\{0,1\}$ – for the general case; $[0,1]$ – for normal fuzziness, or $[0,1] \times [0,1]$ – for intuitionistic fuzziness [4].

For more flexible estimation of different parameters, intuitionistic fuzzy estimators are used.

For the generalized net model of C2-system functioning, the estimates $e_k^{\{\alpha, \beta, \gamma, \delta, \iota\}}$ look like this:

$$e_j^{\{\alpha, \beta, \gamma, \delta, \iota\}} = \{ \langle \mu_j, v_j \rangle \mid (\mu_j, v_j \in \mathbb{R} \ \& \ \mu_j \geq 0 \ \& \ v_j \geq 0 \ \& \ \mu_j + v_j \leq 1) \}, \text{ for } j=1, \dots, k, \text{ where:}$$

μ_j – degree of certainty (certainty) about the estimation of a given parameter of the system;

v_j – degree of uncertainty regarding the estimation of a given parameter of the system;

$\pi_j = 1 - \mu_j - v_j$ – degree of uncertainty about the estimation of the values of a given parameter.

The description of the individual transitions is as follows

$$Z1 = \langle \{l_1, l_2, l_3, l_4, l_6\}, \{l_5, l_6, l_8, l_9, l_{10}, l_{14}\}, \tau_1, M_1, \vee(l_1, l_2, l_3, l_4, l_6) \rangle,$$

where

l_1 – entry position into which tokens α (personal composition) with characteristics $X_\alpha(e^{\alpha_{p1}}, e^{\alpha_{p2}}, \dots, e^{\alpha_{pi}}, \dots, e^{\alpha_{pk}})$ enter;

l_2 – initial input position into which δ' tokens (individual equipment) enter, with characteristics: $X_{\delta'}(e^{\delta'_{w1}}, e^{\delta'_{w2}}, \dots, e^{\delta'_{wi}}, \dots, e^{\delta'_{wn}})$;

l_3 – initial input position, where γ tokens (procedures) with characteristics $X_\gamma(e^{\gamma_{v1}}, e^{\gamma_{v2}}, \dots, e^{\gamma_{vi}}, \dots, e^{\gamma_{vn}})$ and ι (information) enter, with characteristics: $X_\iota(e^{\iota_{h1}}, e^{\iota_{h2}}, \dots, e^{\iota_{hi}}, \dots, e^{\iota_{hm}})$;

l_4 – position in which α, δ', γ and ι -tokens enter, coming from transition Z_2 (battle platform);

l_5 – position in which α -tokens (personnel) who have suffered and are unable to perform their duties enter;

l_6 – position in which tokens enter, in waiting or processing mode;

l_8 – position in which α -tokens (personnel) enter, which participate in transition Z_2 (combat platform);

l_9 – position in which δ' -tokens (individual equipment) enter, which participate in transition Z_2 (combat platform);

l_{10} – position in which γ -tokens (procedures, orders, orders, etc.) and ι -tokens (information) necessary for transition Z_2 (combat platform) enter;

l_{14} – transition position Z_3 (headquarters), into which α -tokens (personnel, staff involved in the headquarters, control points), γ -tokens (procedures, orders, orders, etc.), ι -tokens (information from sensors, etc., received directly at headquarters from the battlefield).

	l_5	l_6	l_8	l_9	l_{10}	l_{14}
l_1	F	T	$W_{1,8}$	F	F	$W_{1,14}$
l_2	F	T	F	$W_{2,9}$	F	$W_{2,14}$
l_3	F	T	F	F	$W_{3,10}$	$W_{3,14}$
l_4	F	T	F	F	F	$W_{4,14}$
l_6	$W_{6,5}$	$W_{6,6}$	$W_{6,8}$	$W_{6,9}$	$W_{6,10}$	$W_{6,14}$

T – allowed transition (True), F – forbidden transition (False)

$W_{1,8}$ – "there is an α -token involved in a combat platform (in a crew)";

$W_{1,14}$ – "there are α -tokens performing tasks directly from the headquarters (referees, persons with special missions, etc.);

$W_{2,9}$ – "individual equipment does not need further inspection" (in l_6);

$W_{2,14}$ – "there are δ -tokens necessary for the needs of the headquarters (individual equipment – tools, technical means, etc.);

$W_{3,10}$ – "there are procedures (γ -tokens) and information (ι -tokens) that do not need further verification" (in l_6);

$W_{3,14}$ – "there are γ -tokens and ι -tokens necessary for the needs of the headquarters (primary information from the battlefield, information from sensors, reports, execution of combat orders, orders, etc.);

$W_{4,14}$ – "there are α -, γ -, δ - and ι -tokens that need to be further analyzed (personnel to occupy other combat positions, change in combat orders, need for new equipment, new information received from the combat field or headquarters, etc.);

$W_{6,5}$ – "has α - or δ -tokens (personnel or equipment) that have been analyzed as incapable of performing their duties or functions;

$W_{6,6}$ – "there are tokens in processing or waiting";

$W_{6,8}$ – "there are α -tokens after analysis or waiting for transition Z_2 " (performing tasks in a combat platform or for further movement in GN);

$W_{6,9}$ – "there are δ -tokens after analysis or waiting for transition Z_2 " (performing tasks in a combat platform or for further movement in GN);

$W_{6,10}$ – "have γ - or ι -tokens after analysis or waiting for Z_2 transition" (performing tasks in combat platform or for further movement in GN);

$W_{6,14}$ – "there are α - or γ - or ι -tokens which, after analysis, are needed directly for the headquarters.

		l_5	l_6	l_8	l_9	l_{10}	l_{14}		
$M_1 =$	l_1	0	N	N	0	0	$m_{1,14}$		N
	l_2	0	N	0	N	0	$m_{2,14}$		–
	l_3	0	N	0	0	N	$m_{3,14}$		the
	l_4	0	N	0	0	0	$m_{4,14}$		maxi
	l_6	$m_{6,5}$	N	N	N	N	$m_{6,14}$		mu
									m
									num

ber of tokens;

$m_{1,14}$, $m_{2,14}$, $m_{3,14}$, $m_{4,14}$, $m_{6,14}$ have values from 0 to the maximum allowable number of tokens for direct transition to Z_3 ($<N$);

$m_{6,5}$ – from 0 to the maximum allowed number of α -tokens losses.

$Z_2 = \{l_7, l_8, l_9, l_{10}, l_{11}, l_{13}\}, \{l_4, l_{12}, l_{13}, l_{16}, l_{17}, l_{18}\}, r_2, M_2, l_8 \wedge (l_7 \vee l_9 \vee l_{10} \vee l_{11} \vee l_{13})$;

where

l_7 – position in which γ and ι -tokens enter, coming from transition Z_3 (instructions, orders, etc.);

l_{11} – initial entry position into which δ tokens enter (common, collective equipment), with characteristics: $X_\delta(e^{\delta_{w1}}, e^{\delta_{w2}}, \dots, e^{\delta_{wi}}, \dots, e^{\delta_{wn}})$;

l_{12} – position in which δ -tokens (equipment, combat platforms, etc.) enter, which are unable to perform their functions or destroyed;

l_{13} – position in which tokens enter, in waiting or processing mode;

l_{16} – position in which α -tokens (personnel) enter, which participate in transition Z_3 (headquarters);

l_{17} – position in which δ -tokens (equipment) enter, which participate in transition Z_3 (headquarters);

l_{18} – position where γ -tokens (procedures, orders, orders, etc.) and ι -tokens (sensory, intelligence and other information) necessary for transition Z_3 (headquarters) enter.

		l_4	l_{12}	l_{13}	l_{16}	l_{17}	l_{18}
$r_2 =$	l_7	F	F	T	F	F	F
	l_8	F	F	T	F	F	F
	l_9	F	F	T	F	F	F
	l_{10}	F	F	T	F	F	F
	l_{11}	F	F	T	F	F	F
	l_{13}	$W_{13,4}$	$W_{13,12}$	$W_{13,13}$	$W_{13,16}$	$W_{13,17}$	$W_{13,18}$

$W_{13,4}$ – "there is α -, δ -, γ - or ι -tokens destined for Z_1 transition" (after processing)

$W_{13,12}$ – "there are δ -token, unable to perform their functions or destroyed";

$W_{13,13}$ – "there is a processing or waiting process"

$W_{13,16}$ – "has processed α -tokens intended for transition Z_3 (headquarters)"

$W_{13,17}$ – "has processed δ -tokens intended for transition Z_3 (HQ)"

$W_{13,18}$ – "has processed γ - and ι -tokens intended for transition Z_3 (headquarters)"

		l_4	l_{12}	l_{13}	l_{16}	l_{17}	l_{18}
$M_2 =$	l_7	0	0	N	0	0	0
	l_8	0	0	N	0	0	0
	l_9	0	0	N	0	0	0
	l_{10}	0	0	N	0	0	0
	l_{11}	0	0	N	0	0	0
	l_{13}	$m_{13,4}$	$m_{13,12}$	$m_{13,13}$	$m_{13,16}$	$m_{13,17}$	$m_{13,18}$

$m_{13,4}$, $m_{13,13}$, $m_{13,16}$, $m_{13,17}$, $m_{13,18}$ have values from 0 to the maximum number of tokens allowed ($<N$);

$m_{13,12}$ – from 0 to the maximum number of δ -token losses allowed.

$Z_3 = \{l_{14}, l_{15}, l_{16}, l_{17}, l_{18}, l_{19}, l_{23}\}, \{l_7, l_{20}, l_{21}, l_{22}, l_{23}\}, r_3, M_3, l_{17} \wedge (l_{14} \vee l_{15} \vee l_{16} \vee l_{18} \vee l_{19} \vee l_{23})$;

where

l_{15} – position in which tokens α_i ($i = 1, \dots, k$) enter – personnel ensuring the implementation of the information process between the headquarters and the commander;

l_{19} – initial input position in which β -tokens enter, with characteristics $X_\beta(e^{\beta_{q1}}, e^{\beta_{q2}}, \dots, e^{\beta_{qi}}, \dots, e^{\beta_{qm}})$, which initiate the elements of the infrastructure;

l_{20} – position that is occupied by α -tokens (personnel), which participate in transition Z_4 (commander, command);

l_{21} – a position in which γ -tokens (reports, proposals for decisions, etc.) and ι -tokens (information from headquarters, intelligence data and other information) necessary for decision-making by the commander enter;

l_{22} – position in which γ -tokens (rejected reports, proposals, etc.) and ι -tokens (rejected false, unnecessary or useless information) enter, results of the work of the staff or commander (returned from Z_4 to Z_3 through position l_{15});

l_{23} – position in which tokens enter, in waiting or processing mode.

	l_7	l_{20}	l_{21}	l_{22}	l_{23}
$r_3 =$	l_{14}	F	F	F	T
	l_{15}	F	$W_{15,2}$	F	T
	l_{16}	F	F	F	T
	l_{17}	F	F	F	T
	l_{18}	F	F	F	T
	l_{19}	F	F	F	T
	l_{23}	W_{23}	$W_{23,2}$	$W_{23,2}$	$W_{23,23}$

$W_{15,20}$ – "there are α -tokens that directly participate in the commander's decision-making process"

$W_{23,7}$ – "there is γ - or ι -token" (battle orders, instructions, etc. prepared for dispatch)

$W_{23,20}$ – "there are α -tokens involved in transition Z_4 " (persons of staff involved in the commander's decision-making process)

$W_{23,21}$ – "there are γ - or ι -tokens intended for the commander" (prepared decision options, draft orders, situational assessment reports, etc.)

$W_{23,22}$ – "there is γ - or ι -tokens which are unnecessary (false, useless)"

$W_{23,23}$ – "there is a processing or waiting process"

	l_7	l_{20}	l_{21}	l_{22}	l_{23}
$M_3 =$	l_{14}	0	0	0	N
	l_{15}	0	$m_{15,20}$	0	N
	l_{16}	0	0	0	N
	l_{17}	0	0	0	N
	l_{18}	0	0	0	N
	l_{19}	0	0	0	N
	l_{23}	$m_{23,7}$	$m_{23,20}$	$m_{23,21}$	$m_{23,22}$

$m_{15,20}$, $m_{23,7}$, $m_{23,20}$, $m_{23,21}$, $m_{23,22}$ have values from 0 to the maximum number of tokens allowed ($<N$);

$m_{23,22}$ – from 0 to the maximum number of γ - or ι -token losses allowed.

$Z_4 = \langle \{l_{20}, l_{21}, l_{25}\}, \{l_{15}, l_{24}, l_{25}\}, r_4, M_4, \vee(l_{20}, l_{21}, l_{25}) \rangle$, where

l_{24} – final position in which α -tokens (staff officers), γ -tokens (generated orders and orders from the command /commander/) and ι -tokens (decisions made, results of decision implementation, control results, etc. enter);

l_{25} – position in which tokens (α and ι) enter, in waiting mode or information processing and decision making.

	l_{15}	l_{24}	l_{25}
$r_4 =$	l_{20}	$W_{20,15}$	F
	l_{21}	F	F
	l_{25}	$W_{25,15}$	T

$W_{20,15}$ – "there is α -tokens that carry out direct orders from the commander"

$W_{25,15} = \neg W_{20,15}$

$W_{20,25}$ – "there is α -tokens, γ -tokens and ι -tokens with commander's final decisions"

$W_{25,25}$ – "there is a processing or waiting process"

	l_{15}	l_{24}	l_{25}
$M_4 =$	l_{20}	$m_{20,15}$	0
	l_{21}	0	0
	l_{25}	$m_{25,15}$	P

$m_{20,15}$, $m_{20,14}$, $m_{20,25}$, $m_{25,15}$, $m_{625,25}$ have values from 0 to the maximum number of tokens allowed for this transition ($<N$).

MODEL SIMULATION AND RESULTS

The presented OM-model of a command and control system is simulated in the GN IDE simulation environment [5, 6]. Some of the model simulation results obtained are shown in Fig. 2 to 5.

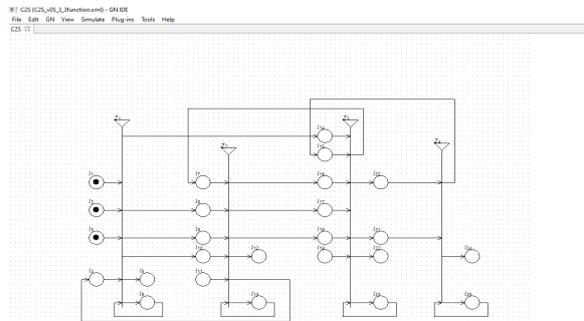


Fig.2. Simulation of the OM-model of a C2 system using the GN IDE simulation environment (step 1)

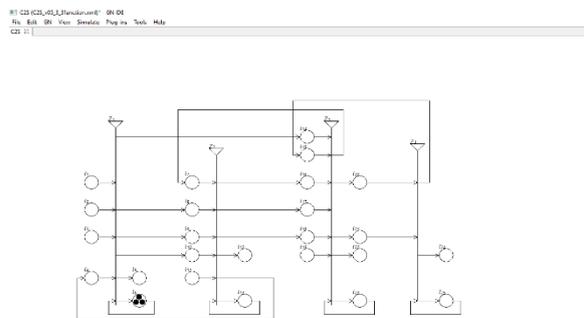


Fig.3. Simulation of the OM-model of a C2 system using the GN IDE simulation environment (step 2)

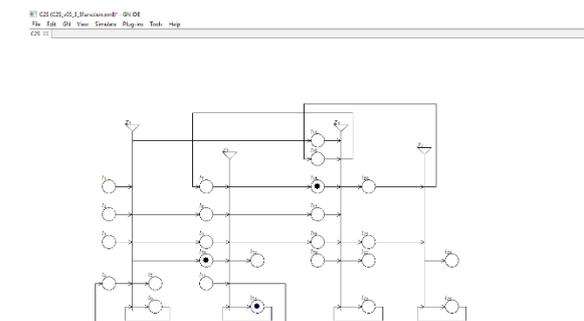


Fig.4. Simulation of the OM-model of a C2 system using the GN IDE simulation environment (step 4)



Fig. 5 Simulation of the OM-model of a C2 system using the GN IDE simulation environment (step 6)

From the simulations of the GN-model, it was established that it is a flexible tool for testing different implementation options of the C2-system, even before its implementation in the process of managing the army forces. By means of the GN-model, different implementation variants of a C2-system can be simulated. This is done by changing the individual characteristics of the main three components - personnel, structure and equipment, procedures, can only be done by setting different values of the parameters of the corresponding cores in the model (α -, β -, γ -, δ -, ι -tokens). Also, by changing the rules of interaction between these components (by changing the corresponding predicates $W_{x,y}$), one can track what the changes in the output of the model will be. All this will help to compile a more realistic assessment of the impact of one or other input factors on the output of the system, which in turn will enable the realization of a more stable and efficient C2-system.

CONCLUSION

From the research done, it was found that no other C2-system model based on the use of generalized nets has been created at the moment with which to compare it, but we undoubtedly expect other, more advanced OM-models with such a purpose to appear in the future.

The proposed OM-model of a C2-system can be successfully used to analyze and improve command and control at the tactical and operational level. By simulating different situations, the interrelationships between the main elements of the C2-system can be studied, as well as the possible ways of its optimization.

The presented generalized model of a command and control system can be refined and expanded by taking into account the influence of external and internal adverse factors, the degree of fulfillment of the set tasks – by using numerical or verbal assessments, planning the necessary resources for the functioning of the system, etc.

ACKNOWLEDGEMENTS

This work was supported by the NSP “Security and defence” program, which has received funding from the Ministry of Education and Science of the Republic of Bulgaria under the grant agreement no. Д01-74/19.05.2022.

REFERENCES

- [1] K. Atanassov. Theory of Generalized nets (an algebraic aspect). AMSE Review, 1, №2, 27-33, 1984.
- [2] K. Atanassov, (ed.). Applications of Generalized nets. World Scientific, Singapore, New Jersey, London 1993.
- [3] K. Atanassov. Generalized Nets, World Scientific, Singapore, New Jersey, London 1991
- [4] K., Atanassov, Intuitionistic Fuzzy Sets: Theory and Applications. Springer-Verlag, 1999
- [5] N, Angelova, M. Todorova and K. Atanassov. (2016) GN IDE Implementation, improvements and algorithms. 69.411-420
- [6] P., Boyanov, Using a specialized software for comprehensive monitoring the suspicious states in computer networks, a refereed Journal Scientific and Applied Research (Licensed in EBSCO, USA), Konstantin Preslavsky University Press, ISSN 1314-6289, vol. 6, 2014, pp. 148-154.
- [7] D.G. Dimitrov. GN IDE – A software tool for Simulation with generalized nets. Proceedings of Tenth International Workshop on Generalized nets, Sofia, 2009, 70-75.
- [8] Hr. Hristov, P. Boyanov, and T. Trifonov. Approaches to identify vulnerabilities in the security system of the social organization and computer resources, a refereed Journal Scientific and Applied Research (Licensed in EBSCO, USA), Konstantin Preslavsky University Press, ISSN 1314-6289, vol. 5, 2014, pp. 101-107.
- [9] A. Kolev, and P. Nikolova, Instrumental Equipment for Cyberattack Prevention, Information & Security: An International Journal 47, no. 3 (2020): 285-299. <https://doi.org/10.11610/isij.4720>
- [10] V. Tselkov, and N. Stoianov. E-net models of a software system for web pages security. Mathematics and mathematical education, Sofia, Bulgaria, BAS, 2003.
- [11] К. Александрова, Ив. П. Иванов, Архитектура на пасивна бистатична радарна система базирана на DVB-T сигнали и софтуерно-дефинирана платформа, "Сборник доклади от международна научна конференция "Хемус 2016", стр. III-193 – III-201, ISSN 1312-2916, 2016 г.
- [12] К. Александрова, Ив. П. Иванов, Перспективни радари срещу електронните заплахи на съвременното бойно поле. "Сборник доклади от международна научна конференция "Хемус 2016", стр. III-202 – III-210, ISSN 1312-2916, 2016 г.
- [13] Доктрина на въоръжените сили на Р България, 2017 г. https://www.mod.bg/bg/doc/strategicheski/20171211_Doktrina_V_S.pdf
- [14] М. Кочанков, Р. Илиев. Предизвикателства и направления за развитие на системата за командване и управление. Сборник доклади от международна научна конференция „Хемус 2020“, стр. 81 – 87 г. Пловдив, 2020 г.
- [15] Св. Спасов. Международни академични програми и модели за обучение по противодействие на корупцията и приложението им в УНСС. Научни трудове на УНСС, 69-95 стр., 2022 г.
- [16] Св. Спасов. Европейска архитектура за сигурност. Книга, Издателство на УНСС, ISBN: 978-954-644-340-3, 2012 г.
- [17] С. Р. Маринов, Иван П. Иванов, А. А. Колев, Моделиране на управляема комуникационна среда, Сборник доклади от Научна конференция „Съвременни тенденции в авиационното обучение“, НВУ „В. Левски“, Факултет „Авиационен“ – Долна Митрополия, 2017 г., ISBN 978-954-713-110-1

Innovative Trends in the Field of Modern Artificial Intelligence Methodology

Anatolii M. Yarovyi
department of Public Management
and Administration
Vinnytsia Mykhailo Kotsiubynskiy
State Pedagogical University)
Vinnytsia, Ukraine
anatolii.a.yarovyi@gmail.com

Andrii A. Yarovyi
department of Computer Sciences
Vinnytsia National Technical
University
Vinnytsia, Ukraine
a.yarovyy@vntu.edu.ua

Svitlana S. Kizim
department of innovative and
information technologies in
education
Vinnytsia Mykhailo Kotsiubynskiy
State Pedagogical University
Vinnytsia, Ukraine
skizim2012@gmail.com

Volodymyr S. Ozeranskyi
department of Computer Sciences
Vinnytsia National Technical
University
Vinnytsia, Ukraine
ozeranskyj@vntu.edu.ua

Abstract. The article justifies the necessity of introducing methodological innovations in the modern field of artificial intelligence (AI), which precede and actively determine technological innovations. The authors of the article analyse the existing AI conceptual structure and point out its insufficiency and introduce significant improvements, including the figurative component. This addition was not made arbitrarily but in accordance with the structure of human natural intelligence, where the rational (symbolic) is directly related to the figurative and interacts with it. The figurative is not identical to the rational (symbolic); there are significant differences in their epistemological content. This difference results from the epistemological differences in their basic (primary) structures - the concept and the image. This, accordingly, means that the figurative (image) is always a reflection of the singular (individual), which is always brought to the sensory-specific, while the rational (concept) is always a reflection of the general (typical), which reaches the level of the systematic. This analysis of the peculiarities of the epistemological and methodological content of figurative and rational thinking becomes important not only in terms of studying the essence of an individual's natural thinking. These features are of great methodological importance in the modeling of artificial intelligence, especially when the question is raised about the creation of a new generation of artificial intelligent systems. Considering all of the above, artificial intelligence combines rational (logical) and figurative components, with priority given to the figurative structure as more information-intensive and heuristically powerful. It is the figurative component of artificial intelligence that defines and ensures the object's multidimensional representation, while the rational component chooses one of the dimensions provided

by the figurative one and fills it with logical content. In the concept of functioning of a real artificial intelligence system, its figurative component initially functions, transforming into rational transformations, which, in turn, are later returned and included in more voluminous figurative architectures. The article proposes schemes that present new approaches to depicting the modern AI conceptual structure.

The suggested innovations are not implemented arbitrarily, they are determined and correspond to the real structure and functioning of human natural intelligence.

Keywords: artificial intelligence, methodology, artificial intelligence conceptual structure, modern model of artificial intelligence.

I. INTRODUCTION

The article justifies the necessity of introducing methodological innovations in the modern field of artificial intelligence (AI), which precede and actively determine technological innovations. The authors of the article analyse the existing AI conceptual structure and point out its insufficiency and introduce significant improvements, including the figurative component. This addition was not made arbitrarily but in accordance with the structure of human natural intelligence, where the rational (symbolic) is directly related to the figurative and interacts with it. The figurative is not identical to the rational (symbolic); there are significant differences in their epistemological content. This difference results from the epistemological differences in their basic (primary) structures - the concept and the image. This, accordingly,

Print ISSN 1691-5402
Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8065>

© 2024 Anatolii Yarovyi, Andrii Yarovyi, Svitlana Kizim, Volodymyr Ozeranskyi.
Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

means that the figurative (image) is always a reflection of the singular (individual), which is always brought to the sensory-specific, while the rational (concept) is always a reflection of the general (typical), which reaches the level of the systematic. This analysis of the peculiarities of the epistemological and methodological content of figurative and rational thinking becomes important not only in terms of studying the essence of an individual's natural thinking. These features are of great methodological importance in the modeling of artificial intelligence, especially when the question is raised about the creation of a new generation of artificial intelligent systems.

Considering all of the above, artificial intelligence combines rational (logical) and figurative components, with priority given to the figurative structure as more information-intensive and heuristically powerful. It is the figurative component of artificial intelligence that defines and ensures the object's multidimensional representation, while the rational component chooses one of the dimensions provided by the figurative one and fills it with logical content. In the concept of functioning of a real artificial intelligence system, its figurative component initially functions, transforming into rational transformations, which, in turn, are later returned and included in more voluminous figurative architectures. The article proposes schemes that present new approaches to depicting the modern AI conceptual structure.

The suggested innovations are not implemented arbitrarily, they are determined and correspond to the real structure and functioning of human natural intelligence.

If we analyse the history of the various sciences, we can identify one interesting pattern: the vast majority of them at some point (one way or another) reach the level of analysing the methodological issues of their science. This is no coincidence because it is precisely with the reaching of such a stage that we consider its accomplishment of scientific maturity.

Moreover, discussions on methodological issues in a particular science usually take place when certain contradictions (or difficulties) arise, when complex scientific problems accumulate, and when an active search for their solution is underway. It is these problems that become fundamental, as they relate to and reflect the deep and meaningful context of a given science. As the analysis shows, all these processes gain positive significance, as they ultimately lead to the formation of new scientific theories and, in general, to progressive transformations of this science.

At the same time, other, no less important, transformations associated with technological changes in the relevant fields of science are also noteworthy. In fact, we can clearly state the direct cause-and-effect relationship between the concepts of "methodology" and "technology". The history of science and technology directly confirms that certain changes in technology are preceded by corresponding innovations in methodology. Moreover, methodological transformations not only precede, but, accordingly, powerfully determine the implementation of fundamental technological transformations. In other words, to make significant changes in the field of technology, it is necessary to seriously tackle methodology and ensure its significant innovation at the beginning.

Similar processes are currently taking place in the field of artificial intelligence. Methodological issues are being actively included in the context of scientific discussions of artificial intelligence specialists.

II. MATERIALS AND METHODS

Speaking about the current state and prospects of development of the artificial intelligence industry, it is worth noting the research of the famous American expert George Luger,[1] who, along with the issues of engineering technologies, highlights the need to address important methodological issues. When analysing certain limitations and disadvantages of the industry development, he sees them not so much in the shortcomings of scientific directions and schools of artificial intelligence research as in the limitations of philosophical and methodological nature. George Luger clearly and frankly points out that these limitations are conditioned by and derive from the philosophy of rationalism. This philosophical rationalism limits the development of artificial intelligence at the present stage. And if earlier the rationalist concept of physical symbolic systems was considered sufficient in general to characterise intelligence, then later and especially at the present stage, researchers began to argue that, on the contrary, the most important aspects of intelligence, in principle, cannot be modelled by means of symbolic representation. [2,3,4,5,6,7] George Luger pays special attention to the alternative methodological approach of the non-rational character.

In general, supporting the position of the American expert, it should be noted that today the entire field of artificial intelligence is entering a stage of fundamental transformation. The issue of developing a new generation of artificial intelligent systems that would function on completely new principles is on the agenda.

The main aim of the article is to substantiate the need for methodological innovations in the field of artificial intelligence sciences, as well as to develop new conceptual approaches that would serve as powerful methodological determinants of the development of a new generation of artificial intelligence systems.

Supporting the position of the leading American expert, we would like to express our views and suggest a non-rational concept of the figurative type of cognition, which would serve as a methodological basis for further innovations in the system of artificial intelligence modelling.

The main statements of this concept are presented by one of the authors in a scientific monograph [8], where a whole range of problems is considered and solutions to some of their main ones are proposed. However, the central idea that is substantiated is the need to develop a new general logic and methodology of figurative structures. This idea is seen as a kind of innovation in the system of modern general philosophical logic and methodology of scientific knowledge. It should be noted here that at the general paradigmatic level, the modern system of rational thinking is mainly provided and operates on the basis of logical and methodological structures. Figurative thinking on the general paradigmatic level is not supported at all in terms of logic and methodology. The logic and methodology of figurative

structures do not exist as such, they need to be developed. That is why we argue that the entire modern field of general scientific methodology is at the stage of radical transformation. Although in this regard there is a certain paradox when in the aspect of the general methodology of scientific knowledge only the question of the need to develop such a methodology is raised, and in the reality of scientific research in some fields elements of such a methodology have already been developed and are functioning to obtain new practical results.

Introduction The development of a new general methodology of figurative structures should be carried out taking into account the peculiarities of the primary, basic structure of figurative thinking - the image. Here it is necessary to point out the following fundamental pattern when the peculiarity of methodological functions is directly determined by the peculiarity of the gnoseological content of a particular form of cognition. This means that, if the basic structure of rational thinking is the conceptual form (concept), then, accordingly, the peculiarities of the gnoseological content of the concept determine the peculiarities of the methodological functions of rational structures. Accordingly, in identifying the features of the figurative methodology, one should proceed from the peculiarities of the gnoseological content of the image as the basic structure of figurative thinking.

The monograph [8] analyses the gnoseological content of both the image and the concept and points out their fundamental difference. If one thesis expresses the essence and content of these differences, then (in the author's opinion) it is legitimate to assert:

1. The figurative is a methodology of penetration into the individually specific, through the disclosure of the particular.
2. The conceptual (rational) is a methodology that ensures the achievement of the general through the reflection of the consistent.

These methodological features of the figurative and rational directly result from the peculiarities of the gnoseological content of their basic structures, which are expressed in the fact that the figurative (image) is always a reflection of the unit (individual), which is always brought to the sensory-specific, while the conceptual (concept) is always a reflection of the general (typical) that reaches the level of the consistent.

III. RESULTS AND DISCUSSION

This analysis of the peculiarities of the gnoseological and methodological content of imaginative and rational thinking becomes important not only in terms of studying the essence of natural human thinking. These peculiarities are of great methodological importance in the field of artificial intelligence modelling, especially when it comes to creating a new generation of artificial intelligence systems.

Traditionally, artificial intelligent systems are based on the principle of inferential knowledge, when a person sets the machine's conceptual apparatus (forming its database) and provides the mathematical logic apparatus based on which one knowledge is derived from another. This is what we call the machine learning process. The

new generation of image-based intelligent systems operates in a fundamentally different way: a person provides the machine with the ability to perceive sensory and imaginative data ("artificial senses"), and then the machine itself (without a person) develops sensory and figurative data, based on which the machine independently forms its knowledge base and uses it for its intended purpose. And this is quite different from teaching, it is a process of self-learning.

Thus, it is fundamentally important to model artificial intelligence of the figurative type:

- Provide the machine with the ability to independently sense perception.
- Hardware and software should be adjusted and developed to such a level that it allows the machine to independently develop sensory-imaginative material.
- The process of integrating new sensory-imaginative data is essentially a self-learning process, as a result of which the machine independently (without a human) forms its database.

Our opponent may have questions as if everything is not as simple as it is portrayed here. Firstly, how we can provide a machine with the ability to sense, what modern technologies (and whether they exist today) to use. The answer is that such technologies already exist, such as modern neurotechnology. However, they need to be used differently. In this regard, we would like to refer to the same American specialist George Luger [1], as well as to the above monograph, where these issues are also discussed [8]. Secondly, concerning the status of sensory and imaginative data that the machine will generate in terms of its scientific value and correlation with rational knowledge. And, thirdly, there is the no less important question of the motivation for the machine's functioning to obtain sense-figurative knowledge. The machine does not possess true motivation as such. Such motivation is brought in from the external world by a human being, which is determined by the system of human needs and interests. Therefore, the so-called machine motivation will be determined by the goals (setting of relevant tasks) that humans will generate.

We would like to emphasise the importance of this stage since it is at this stage that the main problems are solved (in fact, it becomes clear why a user engages a machine to perform certain intellectual functions). Accordingly, the main challenging task of the machine is to use the independently developed information and figurative basis (self-learning) to direct it to find a solution to the task set by a human. At least, if the existing information and figurative basis are not sufficient, the machine can independently "refine" it by supplementing its basis with new sensory and figurative information, until it is sufficient.

By performing these intellectual operations, the machine can provide several options for solving the tasks set by a human, ultimately determining one of the most effective ones. And let the human assess and make the final decision. If a person is not satisfied with the results provided by the machine, then they act as follows. It's not the machine that makes the decision, but the machine's

task is to form (in response to a human request) a certain sensory and figurative environment and let the person in. And let the person make the decision, to allow them to independently process figurative information, to visit the world of images.

Why it is so fundamentally important to provide a machine with the ability to artificially "perceive". There is only one explanation: an objective assessment of the importance of the role of human feelings in the functioning of human natural intelligence. We are acting by analogy, and this should be emphasized: what is important for human natural intelligence should be important for artificial intelligence. At the same time, objectively assessing the real gnoseological situation, we state a certain paradox, which is expressed in the underestimation of the role of the sensory component not only in the process of cognition but also in human life support in general. We will dwell on what is meant by this in further detail. There are classical statements that human feelings are an objective source of knowledge, a direct form of reality reflection. That is, a person is directly connected with the objective world through their feelings. At the same time, feelings themselves do not seem to provide knowledge but are a kind of gnoseological background for this knowledge. After all, sensory data must be rationally processed, and only then can the transformation and formation of scientific knowledge itself take place.

All of the above statements relate to a purely rationalistic interpretation of the process of cognition, the main point of which is that without the rational there is no knowledge and no cognition itself. But let us critically review the above rationalist position and categorically state that in order to acquire the status of knowledge, the presence and function of rational structures of human thinking are not necessary. Even without the rational component at the level of sensory-figurative knowledge, knowledge can also be formed and not only formed but also actively heuristically function.

Therefore, we would like to point out the misconception of rationalism that sensory-imaginative data do not acquire the status of knowledge. We believe that it is legitimate to argue that sensory-imaginative knowledge also provides a level of scientific knowledge, but even more information-intensive and heuristically powerful. In this matter, there is an objective problem of revising the criteria of scientific knowledge, which need to be significantly enhanced, not limited to rationalistic criteria. It is this formulation of the issue that leads us to a more global problem, namely: what kind of science should be in the future, and what transformations it can undergo in the short and long term.

- However, we shall return to the initial problems concerning the acquisition of the scientific status of sensory and figurative knowledge and its relationship with rational knowledge. We have already considered such issues (in this particular formulation) in our previous research [8].
- Summarising this analysis, we believe it is reasonable to say that this refers to the functioning of natural human thinking:
- Rational and figurative knowledge should be considered as parity (equivalent). And most

importantly, in their interconnection and close integration.

- Sensory and figurative knowledge is the initial one, which sets a certain strategy for scientific research. This strategy is determined by the multidimensionality of sensory and imaginative knowledge, which reflects the limitless range of sensory and imaginative data obtained.
- The multidimensionality of sensory and figurative data is determined by the social coordinate, which reflects and functions on the principle of social expediency (based on human interests and needs). And since the interests (needs) of people differ, this, accordingly, determines a variety of social certainty, which is imposed as a matrix and sets the social request to which the sensory-imaginative should respond (and find an answer).
- The sensual and figurative then turns the baton over to the rational, which chooses one (the most reasonable choice at a given historical stage) from the many dimensions and fills it in based on the results of the preparatory work, guided by the logical component. As soon as this one-dimensional choice has been logically completed, the rational returns to the sensory-figurative to include its one-dimensional choice (already filled with logical content) in the sensually chosen multidimensional choice and to "show" its results in the context of social expediency.

However, the rational does not stop at this point, but again, interacting with the multidimensionality of the sensory and figurative chooses another new choice in order to repeat the gnoseological procedure (logical "filling" of this choice) and return to the original (sensory and figurative). And such a path of the rational is a demonstration of its higher purpose and sense of existence.

If these questions are brought to the level of paradigmatic assessments, then, to summarise, we will point out that the status of the figurative structures of natural human thinking is gaining special significance. That is why the essence of paradigm shifts is not so much in the modernisation of rationality itself as in the transformation of forms of rationality and their further inclusion in the basic structures of a more voluminous figurative world perception. We have already considered such a dialectic of the transition of the figurative to the rational in our previous research [8].

The mentioned mechanism, we emphasise once again, of functioning and interaction between rational thinking and figurative thinking is implemented in the system of human natural intelligence. At the same time, this should be emphasised again, in addressing the issues of artificial intelligence modelling, it is necessary to act by analogy and achieve similar results. This means that, based on the methodological approach to the analysis of the structure, content and functions of human natural intelligence, the solution to the problem of modelling artificial intelligence becomes somewhat multidimensional and complex. This problem cannot be solved (by and large) by creating a single character of an artificial intelligent system that would simply be capable of performing certain symbolic intellectual operations. Such artificial intelligent systems

of a singular character can be modelled infinitely (by adapting them to perform relevant practical tasks). Of course, this is also important in the local dimension. In principle, if we limit ourselves to this kind of modelling (in general), the problem of artificial intelligence may never be solved. The proposed above methodological representation and model of natural human intelligence in the form of a complex hierarchy of figurative and rational, especially and necessarily requires fundamentally different methodological approaches to solving the problem of modelling artificial intelligence and its structure. The main aspect of such new methodological approaches is expressed in the form of representing such an artificial intelligence structure as a single, complex, hierarchical artificial intelligence system (by analogy with natural intelligence). Accordingly, two structural levels can be distinguished here: the first (more voluminous), which is presented in the form of artificial sensory and figurative structures; and the second (of lesser content) - artificial symbolic structures of the intellectual system. We think that in the presentation and construction of the most complex structure of artificial intelligence, it is necessary to rely on and be guided by (and it is created for this purpose) the principles of the already existing technology of parallel-hierarchical networks. Where one level of the hierarchy represents, accordingly, the figurative structure as a single whole, which, at the same time, is differentiated into many corresponding (smaller) structural components, which are provided by many series of symbolic calculations. Accordingly, there can be several or many such levels (figurative structures), each of which is provided by a symbolic series according to its structure and content. At the same time, in turn, the identified levels can be integrated into a new (more voluminous) figurative architecture. Such integration (ultimately) is carried out according to the criteria of the target settings received by an artificial intelligent system from a human.

Therefore, having presented the structure of artificial intelligence as a complexly organised parallel-hierarchical system, the issues of developing the latest approaches to the element base and hardware of a new type of intelligent structures are consequently becoming relevant. In this case, we can appeal to another of the modern information technologies - neurotechnology, which allows us to solve the extremely difficult task (in our opinion) of modelling the sensory imagery component. Since (and here we will refer to the authority) it is the American specialist George Luger who claims that it is an artificial neural network that, if properly trained, reveals its ability to sensory perception [1].

Accordingly, it is justified to use other already existing and well-proven information technologies, such as parallel-hierarchical networks [9] and optical technologies, but with their prior re-profiling to perform fundamentally different tasks. Moreover, at the same time, actively begin to develop new technologies, taking into account their specifics for the functioning of a complex hierarchical intelligent system.

However, the main thing that needs to be pointed out here is that conducting such studies requires a fundamentally new approach to solving complex problems, especially in the context of studying such a

component as figurative thinking. In our opinion, here we need to turn to the already developed methods and technologies in the system of other modern sciences (in particular, optical science).

The proposed artificial intelligence architecture is presented in the form of a complex multi-level parallel hierarchical network with its priorities. Everything is carried out following the structure and functions of natural intelligence, where, by analogy, such priorities take the following form and are as follows:

1. The figurative and rational components of artificial intelligence are considered in their interrelation and mutual transition to each other.
2. The figurative components are presented in the form of certain levels (of a more voluminous nature), which are provided by the corresponding (smaller) series of symbolic structures.
3. Sensual and figurative components have one significant advantage - its social determination, it directly "glows" with the social. Whereas the rational has no direct connection with the social, but is related to it indirectly - through the sensual and figurative.
4. Therefore, the rational, in order not to lose its connection with the socially appropriate, needs (and it has no other option) to constantly connect with the sensual and figurative. Actually, not with the sensual and figurative in general, but with the socially expressed multidimensionality which it provides, in order to take one of these dimensions and (based on the results of the preparatory work) fill it with logical content. And then, without stopping at this, to return to the initial point (to the multidimensionality of the sensory-figurative) and to include this one dimension (but already filled, socially grounded) in a single sensory-figurative multi-dimension. Then (having fulfilled its relatively finite function), it repeats it, taking another (second) dimension as a basis. Thus, the social multidimensionality of the sensory and figurative component of artificial intelligence can be continued endlessly.
5. It is clear that human sensory-figurative natural thinking objectively directly reflects (and is filled with) social content. As for sensory-figurative artificial intelligence, the social is not given to it by itself but is introduced by the person himself in the form of certain social attitudes (specifically set tasks) that the person gives to the machine. As for the social coordinates for rationality, in any case (whether in natural or artificial intelligence), they are obtained indirectly and, necessarily, through the sensory-figurative.

Innovative model of artificial intelligence (AI) Common structure of artificial intelligence (AI) we have stated) the sensory and figurative are directly related to and reflect the components of the social and to what extent the components of the social are the dominant factor in the process of modelling artificial intelligence.

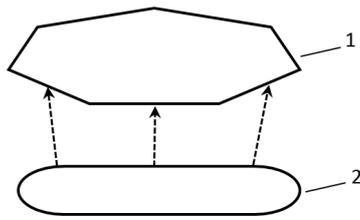


Fig. 1. Figurative structure of AI (figurative picture of the world)

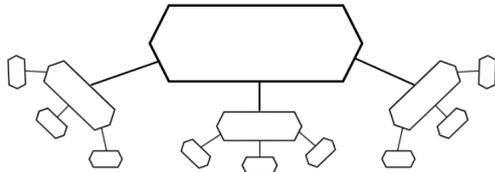


Fig. 2. Rational structure of AI (scientific picture of the world)

The answers to these questions stem from the general understanding that artificial intelligence development is not the goal itself (intelligence is not for the sake of intelligence), but the ultimate goal is its inclusion in the context of social practice (i.e., the human aspect). If social factors are conditionally removed, then, accordingly, any sense of modelling and functioning of artificial intelligence is lost.

However, why, it is in the sensory and figurative that the social dimension finds its greatest manifestation. Here we need to proceed from the general philosophical provisions about the sensual essence of a human being. A human being is first and foremost a sensual creature, and the sensual component is the first, and then the rational component is added. The sensual nature of man stems from his material nature (carnal basis). That is why social factors acquire, first of all, material and then (at the next stage) spiritual social needs, which are expressed and provided in sensory and figurative forms.

CONCLUSIONS

In general, it is true to say that no matter how high the level of artificial intelligence is, it is unable to reach or even replicate the level of natural human intelligence. Artificial intelligence is doomed to always be the "second" one. And this is not only in the context of artificial intelligence becoming helpless without humans, expecting appropriate social targets from them. Here, it is

necessary to point out another global, even more powerful (than the sensory-figurative and rational) component of human intelligence, namely intuitive thinking. So far, we have not mentioned intuition. However, it is with intuition that we associate the realisation of the highest level of human intelligence. However, (without revealing the content of this component yet) we point out that intuition is a component of human natural intelligence. Is artificial intelligence capable of acquiring the ability to think intuitively? Let's leave this question open for now.

Thus, summarising and generalising all the above material, it is fair to draw the following general conclusion. Methodological innovations in the structure of artificial intelligence are extremely necessary and important. They are a condition for and a significant factor in further technological innovations in the field of artificial intelligence. Shifting the emphasis on the structure of artificial intelligence towards the dominance of figurative components and their corresponding hardware and software content is a prerequisite for modelling a new generation of irrational artificial intelligence systems. All this allows the entire field of artificial intelligence to reach a higher level.

REFERENCES

- [1] George, F. Luger. (2009). Artificial Intelligence: Structures and strategies for complex problem solving. [6th ed.]. Pearson.
- [2] Nikolskyi, Yu. V., Pasichnyk, V. V., & Shcherbina, Yu. M. (2015). Artificial Intelligence Systems. Lviv: Magnolia.
- [3] Lytvyn, V. V. (2012). Metody ta sredni inzhenerii dani ta znani [Methods and means of data and knowledge engineering]. Helps. Lviv: Magnolia.
- [4] Shakhovska, N. B., Kaminskyi, R. M., & Vovk, O. B. (2018). Systems of Artificial Intelligence. Lviv: Lviv Polytechnic Publishing House.
- [5] Trotsko, V. V. (2020). Methods of Artificial Intelligence: Method. Helps. Kyiv: KROK University.
- [6] Stuart Russell, P. (2020). Norvig Artificial Intelligence: A Modern Approach. [4th ed.]. Pearson.
- [7] Kaplan, J. (2016). Artificial Intelligence: What Everyone Needs to Know. [1st ed.]. Oxford University Press.
- [8] Yarovyii, A. M. (2023). Visualization as a Unique Information Technology and Socio-Cultural Phenomenon: Monograph. Vinnytsia: VSPU. Retrieved from <https://dspace.vspu.edu.ua/handle/123456789/11110>
- [9] N. Dmitrenko, O. Voloshyna, S. Kizim, K. Mnyshenko, S. Nahorniak. Smart Education in the Prospective Teachers' Training. (2023) CEUR Workshop Proceedingsthis link is disabled, 3364, pp. 38–53 <https://doi.org/10.55056/cte.568>

Skills and attitudes towards using AI based chatbots

Radoslav Yoshinov

Laboratory of Telematics
Bulgarian Academy of Sciences
Sofia, Bulgaria
yoshinov@cc.bas.bg

Monka Kotseva

Laboratory of Telematics
Bulgarian Academy of Sciences
Sofia, Bulgaria
mkotseva@cc.bas.bg

Anastas Madzharov

Institute of Robotics "St. Ap. and
Gospeller Matthew"
Bulgarian Academy of Sciences
Sofia, Bulgaria
a.madzharov@ir.bas.bg

Neda Chehlarova

Institute of Robotics "St. Ap. and
Gospeller Matthew"
Bulgarian Academy of Sciences
Sofia, Bulgaria
nedachehlarova@ir.bas.bg

Abstract. The results of a survey conducted in 2023 on skills and attitudes towards the use of Artificial Intelligence are presented. The study included employees working in the public administration in the Republic of Bulgaria and students from the Cybersecurity specialty. The aim was to find out to what extent and area of interest the two target groups work with or are willing to start using ChatGPT or similar chatbots. The questions asked in chatbots, as well as the listed by both groups advantages and disadvantages can be used as one of the indicators when creating the teaching materials for school or university courses, as well as for the updating of already ongoing training programs.

Keywords: Artificial Intelligence, ChatGPT, digital competence, public administration, employees, students

I. INTRODUCTION

One of the five specific goals of the "Digital Europe" program for the period 2021-2027 is goal No. 2. Artificial intelligence, Art. 5, b) "the provision of these resources to all enterprises and public administrations" [1]. The need for measures to help the transition to new technological knowledge and skills, as a result of the economic changes from the introduction of AI, is also reflected in [2] - [5]. According to [6], the network of IPA lecturers note "Digitalization, Artificial Intelligence, Cybersecurity" as one of the "most important problems, areas, changes/trends that justify the need for training civil servants on them". The need for support for work with AI is also key for other sectors in the country [7] - [9]. As of 02.2024, the Ministry of Education and Science has prepared a document with examples and key terms to support the use of AI in education [10].

Here, the results of a survey conducted on the skills and attitudes towards the use of AI among public

administration employees and learners in the field of cyber security will be considered. The aim was to find out to what extent and area the two target groups work with or are willing to start using ChatGPT or similar chatbots.

II. MATERIALS AND METHODS

The survey was conducted in the period 01.10-31.12.2023. The research involved 59 employees of the public administration in the Republic of Bulgaria and 18 students of the OCS "Bachelor", part-time study, motivational course, first semester, first year. The survey was voluntary and anonymous, available online through Google Forms. The survey included the next questions:

- You are: Male; Female; I prefer not to specify.
- Your age is: up to 25; from 26 to 30; from 31 to 35; from 36 to 40; from 41 to 45; from 46 to 50; from 51 to 55; from 55 to 60; over 60.
- You work in: Sofia; Regional centre; Municipal center; Small town; A village; other.
- How many times have you logged into your ChatGPT or similar chatbot?: I don't have a profile; 0; 1-10; 11-20; 21-30; over 30.
- Do you need help using ChatGPT or similar chatbot?: Yes; No.
- Write down questions you've asked ChatGPT or a similar chatbot: Long answer text.
- Write down benefits (opportunities) when using ChatGPT: Long answer text.
- Write down disadvantages (dangers) of using ChatGPT: Long answer text.

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8064>

© 2024 Radoslav Yoshinov, Monka Kotseva, Anastas Madzharov, Neda Chehlarova.

Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

The analysis based on the received answers is presented according to the sequence of the asked questions.

III. RESULTS AND DISCUSSION

The gender distribution of the respondents from the public administration includes 65% female and 33% male. The students' data are opposite - 33% are female and 67% male "Fig. 1".

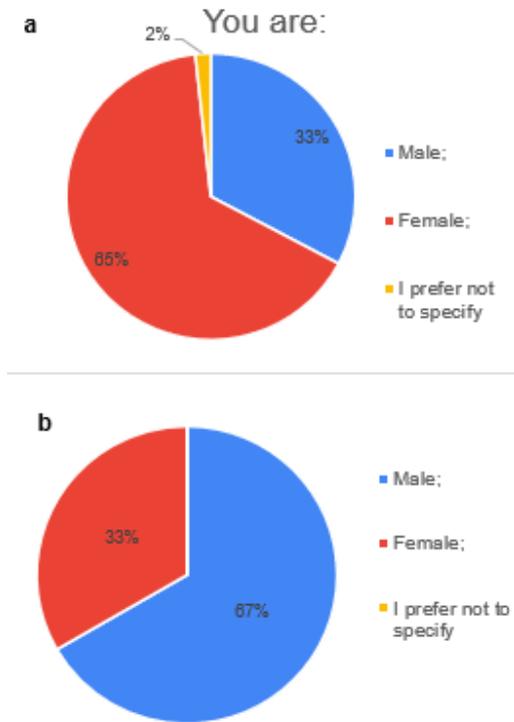


Fig. 1 Gender distribution of participants from public administration (a) and students (b).

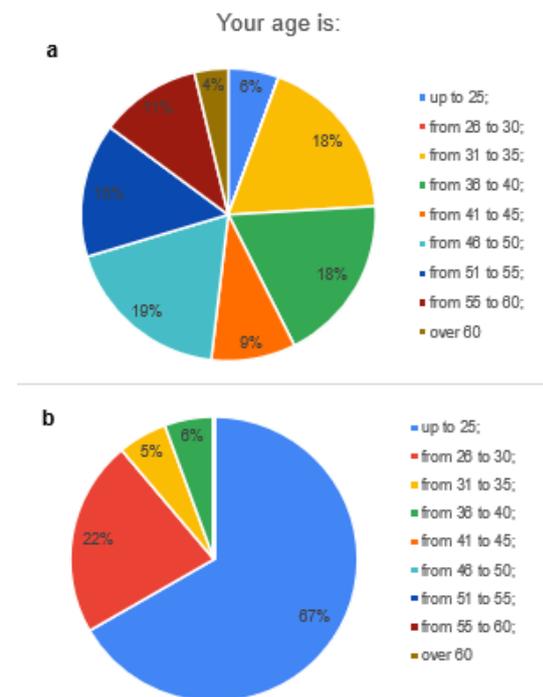


Fig. 2 Age distribution of participants from public administration (a) and students (b).

There is a diversity in the age of respondents from the public administration "Fig. 2". The largest group is the "from 46 to 50" year olds, which are 19% of the participants. 18% are the persons from the next two most covered groups - "from 35 to 40" and "from 31 to 35" years old. Of those working in public administration, representatives are missing only in the "from 26 to 30" range, while 22% of the surveyed students were in this range. On the part of students, 67% are under 25 years of age, and of the remaining 5% are persons "from 31 to 35" and 6% are "from 36 to 40" years old.

The workplace of 78% of the persons in the public administration is in Sofia city. Of the students, 88% also specify that their employment is in the capital. In both groups, there are no representatives from villages. The representatives from small towns are 2% from public administration and 5% from students "Fig. 3".

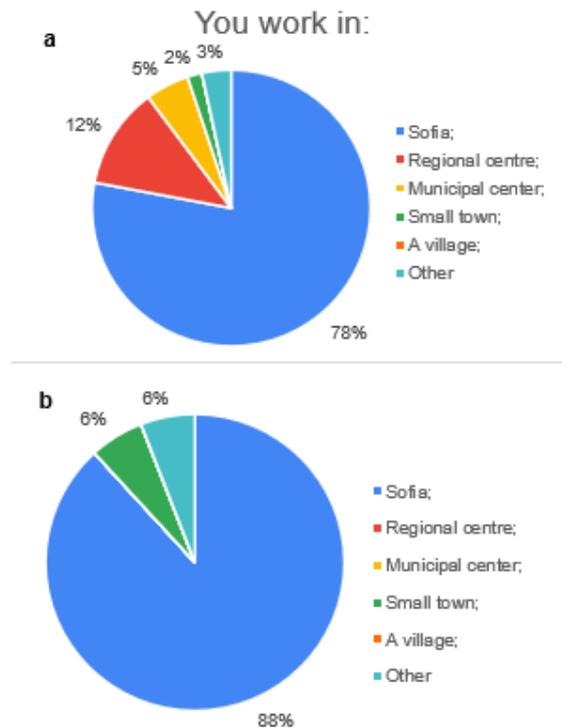


Fig. 3 Workplace of participants from public administration (a) and students (b).

Over 50% of the respondents in both target groups said that they do not have a ChatGPT profile or in a similar chatbot "Fig. 4".

Adding to this data and the percentage of those who answered "0" number of logins to such chatbots, in summary 64% of those working in public administration and 55% of students have not used such AI based systems. Looking at participants who did use AI, the most reported logins were 1 to 10 times. Presented in percentages, the frequency of entries "1-10" times for public administration is 25%, and for students - 28%. 17% of students and 5% of those working in public administration scored more than 30 logins.

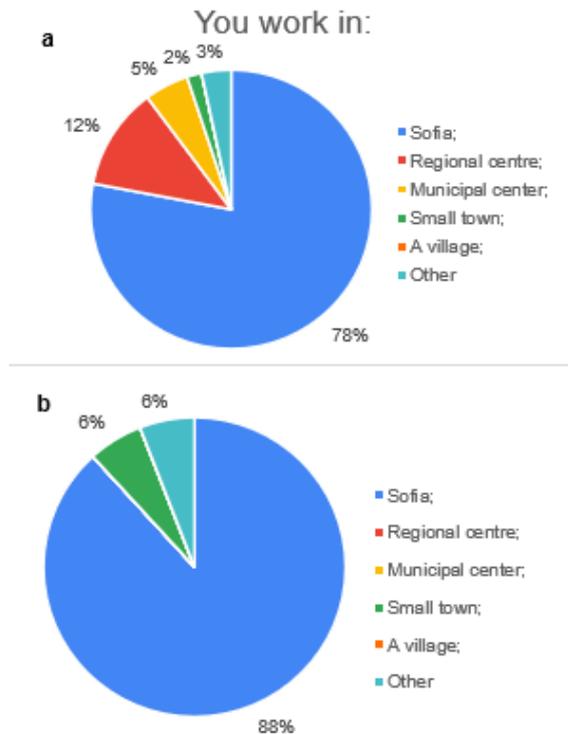


Fig. 4 How many times have you logged into your ChatGPT or similar chatbot? Public administration (a) and students (b).

Total of 33% of public employees need help using ChatGPT or a similar chatbot, of which only two have used such chatbots so far, "1-10" and "11-20" times, respectively, 27% of students also need assistance, and all of them specified that they do not have a profile in similar spaces according to the same data "Fig. 5"

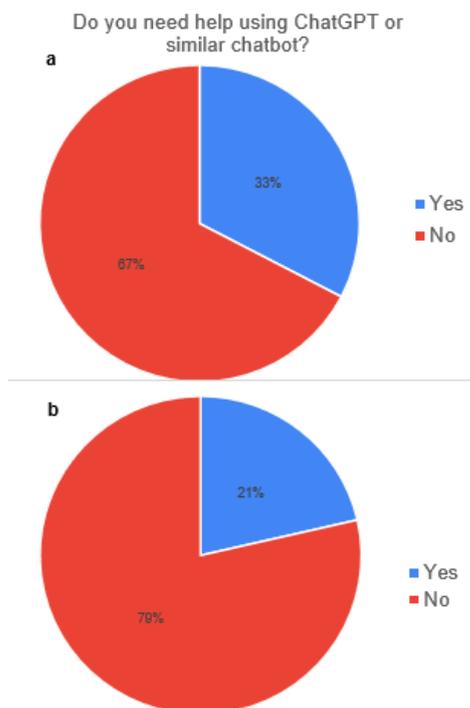


Fig. 5 Do you need help using ChatGPT or similar chatbot? Public administration (a) and students (b).

For the purposes of the study, participants listed the type of questions they asked ChatGPT or a similar chatbot and what they thought were the advantages and disadvantages of such type of AI based systems.

Of the nine responding students, six listed topics of questions asked about specific digital processes that are directly related to their professional direction at the university: "Questions related to my work in software development", "Primarily for help with programming, mathematical formulas, summaries of major topics", "Questions related to writing scripts, solving mathematical equations, creating a network topology with set parameters and requirements, writing greeting cards, etc.", "What are the 2 types of VPN? What is the CISCO way of subnetting? Convert hex code into decimal and show me how", "Debugging code", "Questions related to the implementation of software with a clearly described purpose as well as for a set of information".

The questions described by two other students are based on personal interests, requiring a narrative response or scenario: "English literature, German literature"; "Issues related to communism and world history in general. Space, various quantum physics issues and the like. To create some kind of scenarios or story". One student shared that he "Have not" ask questions, while also sharing that he didn't have a profile on such chatbots.

Creating a text on a given topic is also part of the questions asked among the representatives of the public administration. Five of the sixteen respondents listed the following questions: "Write an essay on a different topic," "Make a story about a mysterious ship and a lonely man on an island. Summarize the following document", "Too much, social media content creation, historical facts, astrology, etc", "Scripts, drawing", "Who is the actress who plays in LP video; Can you write me a short synopsis for an episode of Love, Logic, Revenge, a question about a sample script, and a question about transportation to get to another city."

Another four of the respondents from the public administration asked questions related to digital skills and their work processes: "Questions related to the functions of the Excel program. For example, which formula should I apply", "What is artificial intelligence", "Questions were related to solving math problems from competitions. Questions related to programming in any language. Questions related to sample laws. Get me a program code at assigning tasks. To write me a children's story. To suggest a program for viewing medical information", "Questions related to programming".

The questions of a free nature asked by three representatives of the public administration are the following: "What is the purpose of life?", "Compare models of electric cars", "Reliability tests". One respondent specified "Classified" as the answer.

Students share the advantages of using ChatGPT as the speed of synthesis and access to information of a different nature: "Quick, easy and convenient", "It has an interesting approach to problems and gives interesting analogies and many possible solutions", "Summarizing texts, structuring topics, easy access to any kind of specific information", "Access to information", "As long

as it is used wisely, ChatGPT can be a powerful learning time saver. ChatGPT can be our 24/7 mentor/teacher/professor", "Extremely good search engine as well as translator considering the way ChatGPT works", "Accessibility", "Saves time searching for information".

Similar advantages were described by the representatives of the public administration: "Technical assistance", "Processing vast amounts of information in a short time", "Gives concrete steps how to perform the action", "quickly creates narrative texts to be the basis for further expansion. Summarizes large texts quickly", "To prepare theses on a given subject", "Synthesizes information quickly. Search in many different sources. The answers are synthesized, but can be expanded. It also handles asking questions in Bulgarian", "It is fast and accurate for mathematical and logical questions", "Shows a summary of characteristics of compared products, which would take a lot of time to search and compare", "Ability to add things, that you already know, speed of systematizing information that you would spend hours searching for", "Fast and complex".

TABLE I DISADVANTAGES (DANGERS) WHEN USING CHATGPT ACCORDING TO RESPONDENTS FROM PUBLIC ADMINISTRATION AND STUDENTS

	Public administration	Students
Credibility of information	"Incorrect information"	"May give false information"
Accuracy of information	"The summary doesn't always get the point across." The questions must be asked very precisely. It may return incorrect or unverified information"; "Expresses it quite incorrectly"	"Many times he gives inaccurate answers and one needs to specify the question in several ways and still have an adequate judgment"
Timeliness of information	"The date to which its database is updated is not frequently updated and accordingly responses may not be relevant at the date of the question"; "No data before 2020. Avoids providing subjective opinions"	
AI vs human	"It is not particularly creative and flexible like the human brain, yet there is a set framework that the human mind can overcome"; "Interferes with people's thought process"; "Using non-original ideas"	"With us learners, there is a danger of increased laziness in the analysis of information"
Trust. Privacy of personal data and search history	"Users should not trust each other, it is not yet developed enough"; "Unidentified Opportunities"	"Threat to privacy (by registering with personal data)"; "Every request we've had to the language model is kept in a history, which may contain information critical to us (personal/corporate). Such information, when hacking our profile, becomes easily accessible"

The ability to use AI based chatbots as a vehicle for ideas and creativity was noted by public administration respondents: "facilitates with ideas", "Initially offers basic things, but subsequently gives creative ideas", "Gives answers/opportunities for which it may not you got it", "Creating content. Giving ideas".

Only one respondent from the public administration said that he could not yet distinguish specific advantages - "Not yet discovered".

As disadvantages, the students and respondents from the public administration indicated similar disadvantages, which are summarized in Table 1.

Both surveyed groups use AI with great criticality. From the indicated shortcomings, it is clear that all respondents are aware of the possibility that the credibility, accuracy and timeliness of the information received is not reliable. Trust in the overall access and maintenance of profiles in AI based chatbots is also important to them. This includes the privacy of the "search" history.

CONCLUSION

Different strategies at European and national levels are used to combine high-quality digital infrastructure with strengths in science and technology [11] - [12]. To achieve this goal, significant efforts are being made to promote an inclusive digital transformation in each Member State. This requires an emphasis on investment in human capital training, starting with the public administration. Knowledge of technology not only includes the skills to use it, but also requires an understanding of the potential dilemmas associated with technology and how they can be effectively managed.

In recent weeks and months, artificial intelligence has occupied an important place on the public agenda. The implementation of artificial intelligence represents radical innovation that covers not only the technological aspect, but also aspects such as culture, processes and workforce. The presented research shows an understanding on the part of both survey groups that AI type systems continue to develop, therefore they apply great criticality when using such chatbots. Although the use of artificial intelligence provides significant benefits, the risks of its impact on society impose the need for evaluation, critical approach and development of reliable, honest and responsible approaches.

The results from the research showed that even though half of the participants don't have profile in ChatGPT, or similar chatbots, they are aware of the credibility and accuracy of the information in a given answers form those kind of spaces. The amount of surveyed people needing help with AI based chatbots, the listed advantages and disadvantages, can be used for the creating of school or university courses as well as the updating of already ongoing training programs. The questions asked in chatbots from both groups indicate that is appropriate to separate individual consumer groups, as well as ones based on professional employment when creating the teaching materials.

ACKNOWLEDGEMENT

This work was supported by the NSP DS program, which has received funding from the Ministry of Education and Science of the Republic of Bulgaria under the grant agreement no. Д01-74/19.05.2022.

REFERENCES

- [1] Regulation of the European Parliament and of the Council on the establishment of the "Digital Europe" program for the period 2021-2027. Brussels, 6.6.2018. COM(2018) 434 final, 2018/0227(COD). [Online]. Available: <https://eur-lex.europa.eu/legal-content/BG/TXT/?uri=CELEX%3A52018PC0434> [Accessed: Feb. 22, 2024].
- [2] National strategic document "Digital transformation of Bulgaria for the period 2020-2030", adopted by Decision No. 493 of the Council of Ministers of 21.07.2020. [Online]. Available: <https://www.strategy.bg/StrategicDocuments/View.aspx?lang=bg-BG&Id=1318> [Accessed: Feb. 22, 2024].
- [3] D. Borissova, Z. Dimitrova, N. Naidenov and R. Yoshinov, "Integrated approach to assessing the progress of digital transformation by using multiple objective and subjective indicators." Research Challenges in Information Science. RCIS 2022. Lecture Notes in Business Information Processing, 446, 2022, p. 626-634, https://doi.org/10.1007/978-3-031-05760-1_37
- [4] Z. Minchev, "On the growing transformational role of ai technologies for the future cyber diplomacy in the post-information age," International Journal of Cyber Diplomacy, 2023, pp. 29-41.
- [5] Z. Minchev, "Malicious future of AI: transcendentals in the digital age," The 12th International Conference on Business Information Security (BISEC-2021), 2021, pp. 18-22.
- [6] IPA. Analysis of training needs in the state administration of the Republic of Bulgaria for the period 2022 - 2024. [Online]. Available: https://www.ipa.government.bg/sites/default/files/apo_2022_2024_ipa.pdf [Accessed: Feb. 22, 2024].
- [7] Concept for the development of artificial intelligence in Bulgaria until 2030, adopted by Protocol No. 72.4 of the Council of Ministers of 16.12.2020. [Online]. Available: <https://www.strategy.bg/StrategicDocuments/View.aspx?lang=bg-BG&Id=1338> [Accessed: Feb. 22, 2024].
- [8] R. Trifonov, S. Manolov, R. Yoshinov, G. Tsochev, S. Nedev and G. Pavlova, "Operational syber-threat intelligane supported by artificial intelligence methods," Proceedings of the International Conference on Information Technologies (InfoTech-2018), 20-21 September, 2018, pp 1-9.
- [9] D. Gotseva, R. Trifonov and P. Stoynov, "Artificial intelligence and advanced technologies-some case studies from European research space." JFAMM-6-2018, 2018, pp. 13-19.
- [10] MES. MES with guidelines for more awareness of teachers in the use of artificial intelligence. [Online]. Available: <https://web.mon.bg/bg/news/5839> [Accessed: Feb. 22, 2024].
- [11] A. Zorins and P. Grabusts, "Ethical Development and Implementation of Artificial Intelligence. Environment," Technology. Resources. Rezekne, Latvia Proceedings of the 13th International Scientific and Practical Conference. Volume 2, 2021, pp. 214-218 <https://doi.org/10.17770/etr2021vol2.6549>
- [12] I. Šukjurovs, R. Zvirgzdiņa and S. Jeromanova-Maura, "Artificial intelligence in workplaces and how it will affect employment in latvia", Environment. Technology. Resources. vol. 2, 2019, pp. 154–158. doi:10.17770/etr2019vol2.4151.

On special finite difference approximations for solving second order differential equations

Ilmars Kangro
Faculty of Engineering
Rezekne Academy of Technologies
Rezekne, Latvia
ilmars.kangro@rta.lv

Harijs Kalis
Institute of Mathematics and
computer sciences
University of Latvia
Riga, Latvia
harijs.kalis@lu.lv

Abstract. The described special methods are applicable for various mathematical physics problems with second-order differential equations involving periodic boundary conditions (PBCs) and first-order homogenous boundary conditions (FBCs). Solutions of some linear and nonlinear problems for parabolic type partial differential equations (PDEs) with FBCs are obtained, using the method of lines (MOL) to approach the PDEs in the time and the discretization in space applying the finite difference scheme with exact spectrum (FDSES). For PBCs we use the finite difference scheme (FDS) for locally approximating periodic function's derivatives in a $2n+1$, $n \geq 1$ -point stencil, obtaining higher order accuracy approximation. This method in the uniform grid with N mesh points is used to approximate the differential operator of the second and the first-order derivatives in the space. In this paper, we show that the approximation using the FDSES method is equivalent to the spectral differentiation matrix method based on trigonometric (Fourier) interpolant.

Considering, that the solutions obtained in solving nonlinear problems can be very significantly different from classical solutions, for example, mathematical modelling of processes where temperature or energy is concentrated in a very narrow interval or around a point, again causes increased interest in such areas of application as laser technology, military sphere, etc.

In this regard, also in the given publication, the solution of the "blow-up" phenomenon of the boundary problem of the nonlinear heat conduction equation has been studied and obtained with the above-mentioned high-accuracy solving methods.

Keywords: "Blow-up" phenomenon, differentiation matrices, finite difference scheme with exact spectrum, multi-points stencil, trigonometric interpolant.

1. INTRODUCTION

In the last three decades, the concept of a differentiation matrix (DM) to be a very useful tool in the numerical solution of differential equations is developed. DMs are derived from the spectral collocation or pseudo-

spectral method for solving differential equations of boundary value type [5], [7], [6], [4], [10]. In the spectral collocation method, the unknown solution is expanded as a global interpolant, such as a trigonometric or polynomial interpolant. The DMs are based on Chebyshev, Fourier, Hermite, and other interpolants.

Spectral DMs for problems with PBCs are based on Fourier interpolant. In other methods, such as finite elements or finite differences, the expansion involves local interpolants such as a piecewise polynomial.

In practice the accuracy of the spectral method is superior- for problems with smooth solutions convergence rates of $O(e^{-cN})$ are achieved ($c = const > 0$) in [6], [3], [4]. In contrast, finite elements or finite differences on 3-point stencil yield convergence rates that are only algebraic in N , typically $O(N^{-2})$. The spectral collocation method for solving differential equations is based on weighted interpolants of the form [7]:

$$f(x) \approx P_{N-1} = \sum_{j=1}^N \frac{\alpha(x)}{\alpha(x_j)} \Phi_j(x) f(x_j).$$

Here $\{x_j\}_{j=1}^N$ is set of distinct interpolation nodes (grid points), $\alpha(x) > 0$ is a weight function and the set of interpolation functions $\Phi_j(x_k) = \delta_{jk}$ satisfies $\Phi_j(x_k) = \delta_{jk}$ (the Kronecker delta), $f(x_k) = P_{N-1}(x_k)$, $k = \overline{1, N}$.

For Chebyshev, Hermite and other interpolant the interpolating functions $\Phi_j(x)$ are polynomials of degree $N - 1$.

For nonpolynomial cases there are trigonometric interpolants. The collocation derivative operator is generated by taking m - order derivatives of the interpolants and evaluating the result at the nodes $\{x_k\}$.

The derivative operator may be represented by matrix $D^{(m)}$ (DM) with entries $D_{kj}^{(m)} = \frac{d^m}{dx^m} \left[\frac{\alpha(x)\Phi_j(x)}{\alpha(x_j)} \right]_{x=x_k}$.

Print ISSN 1691-5402
Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8020>

© 2024 Ilmārs Kangro, Harijs Kalis. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

The numerical differentiation process may therefore be performed as the matrix-vector product $F^{(m)} = D^{(m)}F$, where $F, F^{(m)}$ are the vectors of function values at the nodes. When solving differential equations, the derivatives are approximated by these discrete derivative operators.

For boundary value problems with the PBCs the DMs $D^{(m)}$ are circulant and there can be given with the first row.

For such matrices it is easy to do arithmetic operations in shorter computation time. Also, it is possible to get the inverse matrix analytically. Orthonormal eigenvectors w_k, w_k^* with the elements

$$w_{k,j} = \sqrt{N^{-1}} \exp(2\pi ijk/N),$$

$$w_{k,j}^* = \sqrt{N^{-1}} \exp(-2\pi ijk/N), i = \sqrt{-1}, k; j = \overline{1, N} \text{ do not depend on the elements of circulant matrix.}$$

PBCs allows to freely increase approximation order by increasing the stencil of grid points.

For, example, $2n + 1$ points stencil needs to use additional discrete conditions of periodicity

$$u_k = u_{N+k}, k = \overline{-n, n}.$$

Thus, can be obtained algorithms with higher order precision (different order FDS).

By solving the discrete spectral problem, we can express the matrix $A_{m,n}$ in the form $A_{m,n} = WD_{m,n}W^*$, where W is the complex matrix which consists of the eigenvectors in its columns, W^* is the conjugate transpose of W and $D_{m,n}$ - diagonal matrix with the eigenvalues $\mu_{m,n}$ of matrix $A_{m,n}$ on the diagonal, $m = 1; 2, n = \overline{1, N}$.

Eigenvalues are obtained analytically for every multi-point stencil [8], [10].

Finite difference methods are important for approximating differential operators and solving various ordinary and partial differential equations numerically.

Probably, the most casual is the second-order accurate FDS for approximation of the first and second-order derivatives in a uniform 3-point stencil.

2. MATERIALS AND METHODS

In this chapter, we will consider special difference schemas for solving ordinary and partial differential equations, and special numerical methods (to find the solution of the discrete problem by choosing a suitable transformation or Fourier series elements for finding the components of the discrete problem).

2.1 Special difference schemes for solving differential equations

In this paper, more accurate methods for approximation of the first and second order derivatives in a uniform multi-point $2n + 1, n \geq 1$ stencil are investigated. The algebraic convergence rate is $O(N^{-n})$.

We define the FDSES [1], [9] where the finite difference matrix A is represented in the form $A = WDW^*$, W, W^* are the complex and conjugate-complex matrices of finite difference eigenvectors, D is diagonal matrix of the discrete eigenvalues and the elements of diagonal matrix D are replaced with the first N eigenvalues from the differential operator.

In the first publication about FDSES [2] the finite differences with the second order of approximation in the uniform grid are used for the approximation of the second order derivative in the space segment $x \in [0, L]$ with the FBCs.

Special numerical algorithms are developed for solving 1D and 2D problems of the second order ordinary (ODE) and partial differential (PDE) equations with PBCs.

The linear heat transfer equations with variable coefficients can be written in the following form:

$$u_t(x, t) = k(x)(u(x, t))_{xx} + p(x)(u(x, t))_x + q(x)u(x, t) + f(x), u(x, 0) = u_0(x), \quad (1)$$

where $k(x), p(x), q(x), u_0(x)$ are real functions, $x \in (0, L), t > 0$ are the space and time variables, L is the period for PBCs or the length of the segment, $u = u(x, t)$ is the unknown function. For the similar system of PDEs k, p, q are matrices, u is column-vector.

The heat transfer problem is solved numerically using the method of lines and two ways of finite difference methods for the approximation of spatial derivatives - local approximation with finite differences in uniform grid (FDS, FDSES) and global approximation with differentiation matrices.

For local approximation we have the discrete equations ($x_j = jh, Nh = L, j = \overline{1, N}$) as a system of ODEs in following form:

$$\dot{U} = (KA_{2,n})(U) + (PA_{1,n})(U) + Q(U) + F, U(0) = U_0,$$

where $A_{1,n}, A_{2,n}$ are N -th order circulant matrices, $U = U(t), F = F(t), \dot{U} = \dot{U}(t), U_0$

are column-vectors of the N -th order with elements $u_j(t), f(x_j(t)), u_t(x_j, t), u_0(x_j),$

K, P, Q are N -th order diagonal matrices with elements $k(x_j), p(x_j), q(x_j)$ (in the case of the constant matrices k, p, q we have Kronecker tensor products $k \otimes A_{2,n}, p \otimes A_{1,n}, q \otimes I$, I is N -order unit matrix).

2.2 Special numerical methods for approximations of derivatives

To determine the special numerical methods the solution of the discrete problem can be obtained with:

- a) the transformation $V = WU^*$ by reducing the vector problem to scalar-separated problem with the discrete eigenvalues,
- b) the complex discrete Fourier series for vector components $u_j = u(x_j), f_j = f(x_j)$ using the discrete orthonormal eigenvectors w_k, w_k^* and eigenvalues $\mu_{m,k}$ of matrix $A_{m,n}, m = 1, 2, k = \overline{1, N}$,
- c) the real discrete Fourier series for vector components u_j, f_j using trigonometrical functions $\sin(2\pi kj/N), \cos(2\pi kj/N), k = \overline{1, N/2}$ (in this case the real discrete Fourier expression from matrix $A_{m,n}$ spectral representation is obtained).

For forming complex eigenvalues of FDSES method in the diagonal matrices $D_{m,n}$ elements d_k , the discrete

eigenvalues $\mu_{m,k}$ are replaced with the first N eigenvalues $\lambda_{m,k}, m = 1; 2$ in special way (N - even):

1) $d_k = \lambda_{2,k}, k = \overline{1, N/2}, d_{k+N/2} = \lambda_{2, N/2-k}, k = \overline{1, N/2 - 1}, d_N = 0$ (see Fig. 1.),

2) $d_k = \lambda_{1,k}, k = \overline{1, N/2 - 1}, d_{k+N/2} = -\lambda_{1, N/2-k}, k = \overline{1, N/2 - 1}, d_{N/2} = 0, d_N = 0$ (see Fig. 2.)

In Fig. 1., Fig. 2. by $N = 80, L = 1$ there are represented discrete eigenvalues for $(-u'')$, imaginary parts of the discrete eigenvalues for u' by different values of $n = 1; 2; 3; 4; 30$ and corresponding, first $N = 80$ modified continuous values for the FDSSES method.

For N - odd we obtain:

1) $d_k = \lambda_{2,k}, k = \overline{1, (N-1)/2}, d_{k+(N-1)/2} = \lambda_{2, (N-1)/2-k+1}, k = \overline{1, (N-1)/2}, d_N = 0,$

2) $d_k = \lambda_{1,k}, k = \overline{1, (N-1)/2}, d_{k+(N-1)/2} = -\lambda_{1, (N-1)/2-k+1}, k = \overline{1, (N-1)/2}, d_N = 0.$

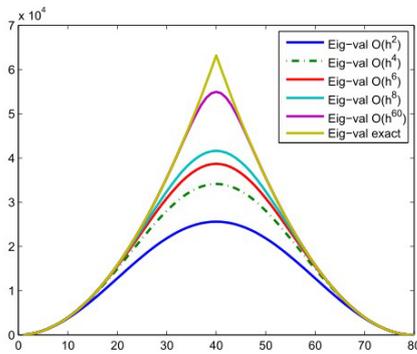


Fig. 1. Eigenvalues for $-u''(x)$ depending on x at $N = 80, L = 1, n = 1; 2; 3; 4; 30$.

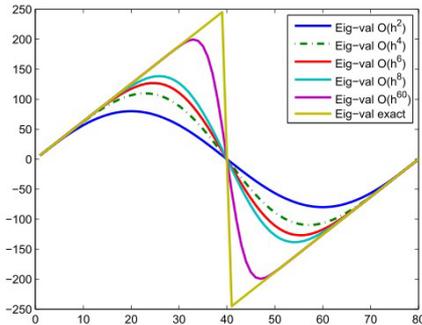


Fig. 2. Imaginary part of eigenvalues for $u'(x)$ depending on x at $N = 80, L = 1, n = 1; 2; 3; 4; 30$.

For variable coefficients k, p, q numerical solutions of the discrete heat transfer problems are obtained with MATLAB ODEs solver "ode15s", using the spectral representation of matrices $A_{m,n}, m = 1; 2$ (methods FDS, FDSSES and versions of differentiation matrices).

3. RESULTS AND DISCUSSION

The previously described methods of derivative approximation, like other finite difference approximation, can be applied in this chapter to estimate function's derivatives by solving ordinary and partial difference equations with variable coefficients, solving linear heat

transfer equations with the homogenous boundary conditions of the first kind and solving nonlinear heat transfer equation with the boundary conditions of the first kind.

3.1 Ordinary differential equations (ODEs) with variable coefficients

The described finite differences can be used to solve numerically ODEs in the form:

$$\begin{cases} k \cdot u''(x) + p \cdot u'(x) + q \cdot u(x) = f(x), x \in (0, L), \\ u(0) = u(L), u'(0) = u'(L). \end{cases} \quad (2)$$

For functions $k = 1, p = p(x), q = q(x)$ the finite difference equation (the linear system of algebraic equations) is $A_{2,n}U + (P * A_{1,n})U + QU = F$, where U, F are the column-vectors of N order, P, Q are N - order diagonal matrices with corresponding elements

$$p_j = p(x_j), q_j = q(x_j).$$

The matrices $A_{2,n}, A_{1,n}$ we can form using the spectral decomposition

$$A_{2,n} = WD_{2,n}W^*, A_{1,n} = WD_{1,n}W^* \text{ in two way:}$$

- 1) for the multi-point stencil FDS diagonal matrices $D_{2,n}, D_{1,n}$ with elements $\mu_{2,k}, \mu_{1,k}$,
- 2) for the FDSSES diagonal matrices $D_{2,n}, D_{1,n}$ with elements $\lambda_{2,k}, \lambda_{1,k}, k = \overline{1, N}$ in special way.

We can find the vector U in the form $U = A^{-1}F$ or in MATLAB $U = A \setminus F$, where $A = A_{2,n} + P * A_{1,n} + Q$.

Special test-examples (Example 1, Example 2 and Example 3) were created with the aim of evaluating the accuracy of the FDS and FDSSES methods.

Example 1.

The boundary value problem (2) was solved for constant coefficients: $p = 3, q = -1, f(x) = \cos(4\pi x) - 3 \sin(28\pi x), L = 1$. The exact solution is $u(x) = u_1(x) + 3u_2(x)$, where

$$u_1(x) = \frac{-(16\pi^2+1) \cos(4\pi x) + 12\pi \sin(4\pi x)}{(16\pi^2+1)^2 + (12\pi)^2},$$

$$u_2(x) = \frac{84\pi \cos(28\pi x) + (784\pi^2 + 1) \sin(28\pi x)}{(784\pi^2 + 1)^2 + (84\pi)^2}.$$

Several maximal errors of solutions were computed corresponding to different n values, namely $n = 1$ (the standard FDS in 3-point stencil), $n = 7, n = 15$ and FDSSES. For $N = 35$ we have $5.3e - 04 (n = 1), 4.57e - 06 (n = 15), 1.5e - 15$ (FDSSES).

The spectral method for $N \geq 28$ is exact, because of the given linear combination for functions $\sin(p\pi x), \cos(p\pi x), p \leq 28$.

Example 2.

The boundary value problem (2) was solved for $p(x) = 4k_0\pi \cos(2k_0\pi x), q(x) = -(2k_0\pi)^2(\sin(2k_0\pi x) - \cos^2(2k_0\pi x)), f(x) = f_1(x)f_0(x), f_0(x) = \exp(-\sin(2k_0\pi x)), f_1(x) = \cos(4\pi x)$. We can see, that function $v(x) = u(x)/f_0(x)$ is the solution for

ODEs of constant coefficients $v''(x) = f_1(x), x \in (0,1)$ with periodic BCs.

This solution is in the following form: $v(x) = -\frac{\cos(4\pi x)}{16\pi^2} + C$, where C is an arbitrary constant.

The exact solution is $u(x) = -\frac{\cos(4\pi x)}{16\pi^2} f_0(x) + C f_0(x)$, where from $u(0) = 0$ follows that $C = \frac{1}{16\pi^2}$.

In the TABLE 1 there are represented the maximal errors of solutions by $N = 20, 40, 80, 100, 160; k_0 = 2, 8, 14$, obtained with global (FDSES= DM) and local approximations for different n (1;2;10).

TABLE 1 THE MAXIMAL ERRORS OBTAINED WITH GLOBAL (FDSES= DMS) AND LOCAL APPROXIMATIONS FOR DIFFERENT N

k_0	N	(FDSES)	n=1	n=2	n=10
2	20	4.5e-6	1.1e-2	2.1e-3	3.3e-5
2	40	2.2e-11	2.5e-3	1.6e-4	1.1e-8
8	80	2.6e-6	7.1e-3	1.5e-3	4.1e-5
8	100	4.7e-8	7.0e-2	9.4e-3	1.0e-5
14	140	3.0e-7	1.4e-2	3.0e-3	7.7e-7

The solutions by $N = 80, k_0 = 8, n = 1; 2$ are represented in Fig. 3., Fig. 4.

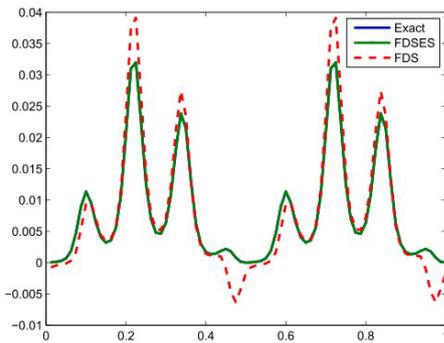


Fig. 3. $u=u(x)$ – solution with the exact method, with FDS ($n=1$, error = $7.11e-03$) and FDSES (error = $2.61e-06$) methods, $k_0 = 8, N = 80$.

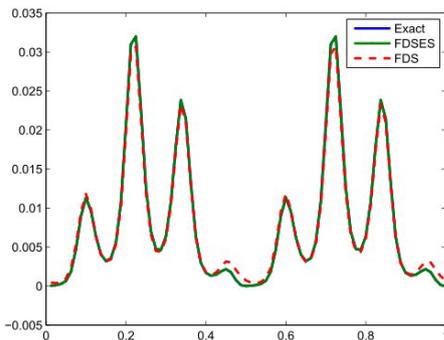


Fig. 4. $u=u(x)$ – solution with the exact method, with FDS ($n=2$, error = $1.30e-03$) and FDSES (error = $2.61e-06$) methods, $k_0 = 8, N = 80$.

3.2 Solving linear partial differential equations (PDEs) with variable coefficients

For the heat transfer equation (1) using method of lines (MOL) we obtain the linear discrete system of ODEs:

$$\dot{U}(t) = (K * A_{2,n})U(t) + (P * A_{1,n})U(t) + QU(t) + F(t), U(0) = U_0,$$

where U, F, U_0 are N-order column-vectors with the elements $u_j(t) \approx u(x_j, t), f_j(t) = f(x_j, t), u_j(0) = u_0(x_j), K, P, Q$ are N-order diagonal matrices with the elements $k(x_j), p(x_j), q(x_j), j = 1, N$.

Formed the matrices with the spectral decomposition we obtain FDS and FDSES approximations for the linear system of ODEs. If the coefficients k, p, q are constants, then solution we can obtain analytically, using Fourier methods.

In the case of variable coefficients MATLAB solver "ode15s" was used.

Example 3. Solving an example 2 with $k(x) = 1, f(x, t) = -f_1(x)f_0(x), L = 1, u_0(x) = \frac{1}{16\pi^2} f_0(x), k_0 = 2, N = 20$ we obtain the stationary solution by $t = 0.1$ with 42 times step for FDSES (max. error $4.0 e - 06$), FDS ($n \geq 7$) (max. error $2.0 e - 05$) and with 45 times step for FDS ($n = 1$), (max. error $3.0 e - 03$).

In Fig. 5., Fig. 6. there are represented the stationary solutions by $k_0 = 14, n = 1; 2, N = 160$ obtaining with FDS and FDSES ($t=0.1$).

In Fig. 7., Fig. 8. there are represented solutions $u = u(x, t)$ by $k_0 = 8; 14, N = 80; 160$ obtaining with FDSES ($t=0.04$).

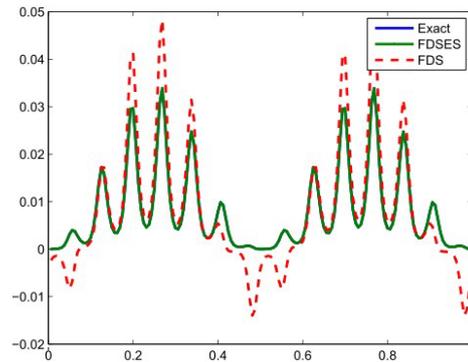


Fig. 5. $u=u(x)$ – solution with the exact method, with FDS ($n=1$, error = $1.44e-02$) and FDSES (error = $3.10e-07$) methods, $k_0 = 14, N = 160$.

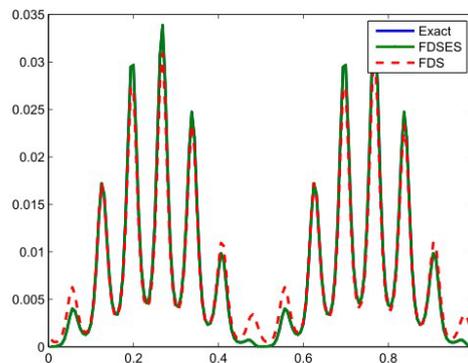


Fig. 6. $u=u(x)$ – solution with the exact method, with FDS ($n=2$, error = $2.95e-03$) and FDSES (error = $3.10e-07$) methods, $k_0 = 14, N = 160$.

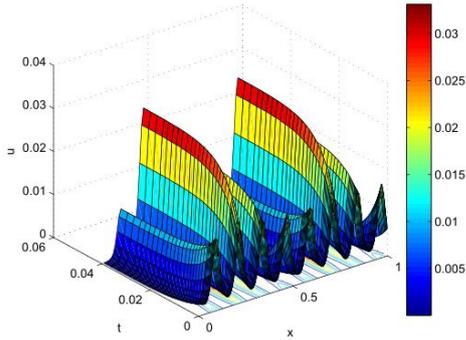


Fig. 7. $u(x,t)$ – solutions with the FDSSES method, $k_0 = 8, N = 80$.

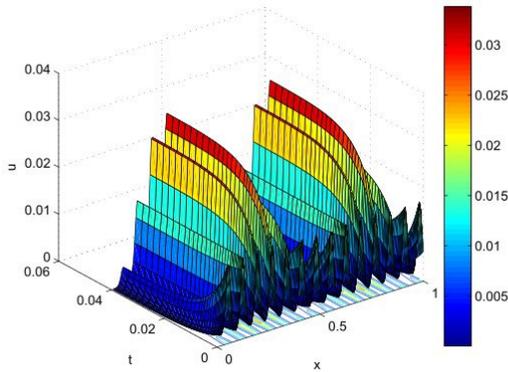


Fig. 8. $u(x,t)$ – solutions with the FDSSES method, $k_0 = 14, N = 160$.

The function $v(x,t) = u(x,t)/f_0(x)$ is solution from the heat transfer equation $v(x,t)_t = v(x,t)_{xx} - f_1(x)$ with periodic BCs. the exact solution by $v(x,0) = \frac{1}{16\pi^2}$ is $v(x,t) = f_1(x)(\exp(-16\pi^2 t) - 1)/(16\pi^2) + \frac{1}{16\pi^2} \rightarrow \frac{1-f_1(x)}{16\pi^2}$ if $t \rightarrow \infty$.

3.3 Linear heat transfer equation with the homogenous boundary conditions (BC) of the first kind (FBCs)

We consider the linear initial - boundary heat transfer problem in following form:

$$\begin{cases} \frac{\partial T(x,t)}{\partial t} = \frac{\partial}{\partial x} \left(\bar{k} \frac{\partial T(x,t)}{\partial x} \right) + f(x,t), \\ T(0,t) = 0, T(L,t) = 0, t \in (0, t_f), \\ T(x,0) = T_0(x), x \in (0, L), \end{cases} \quad (3)$$

where $\bar{k} > 0$ is the constant parameter, t_f is the final time, T_0, f are given functions. We consider uniform grid in the space $x_j = jh, j = \overline{0, N}, Nh = L$. Using the finite differences of second order approximation we obtain from (3) the initial value problem for system of ordinary differential equations (ODEs) in the following matrix form

$$\begin{cases} \dot{U}(t) + \bar{k}AU(t) = F(t), \\ U(0) = U_0, \end{cases} \quad (4)$$

where $A = A_{2,n}$ is the 3-diagonal matrix of $N - 1$ order, $U(t), \dot{U}(t), U_0, F(t)$ are the column-vectors of $N - 1$ order with elements $u_j(t) \approx T(x_j, t)$, We can consider the analytical solutions of (3) using the spectral representation of matrix $A = WDW^T$. The corresponding discrete spectral problem $Aw^k = \mu_k w^k, k = \overline{1, N-1}$ have following solution $\mu_k = \frac{4}{h^2} \sin^2 \frac{k\pi}{2N}$ (elements of the diagonal matrix D), $w_{i,j} = \sqrt{\frac{2}{N}} \sin \frac{\pi ij}{N}, i, j = \overline{1, N-1}$ (elements of the symmetric matrix W). From transformation $V = W^T U (U = WV)$ follows the separate system of ODEs

$$\begin{cases} \dot{V}(t) + \bar{k}DV(t) = G(t), \\ V(0) = W^T U_0, \end{cases} \quad (5)$$

where $V(t), \dot{V}(t), V(0), G(t) = W^T F(t)$ are the column-vectors of $N - 1$ order with elements $v_k(t), \dot{v}_k(t), v_k(0), g_k(t), k = \overline{1, N-1}$. The solution of this system is the function

$$v_k(t) = v_k(0) \exp(-\kappa_k t) + \int_0^t \exp(-\kappa_k(t - \tau)) g_k(\tau) d\tau, \quad (6)$$

where $\kappa_k = \bar{k}\mu_k$.

The analytical solution of heat transfer problem (3) by $\bar{k} = L = 1, f = 0, T_0 = 1$ with discontinuous initial and boundary data can obtained from following Fourier series:

$$T(x,t) = \frac{4}{\pi} \sum_{i=0}^{\infty} \frac{1}{2i+1} \exp(-(2i+1)^2 \pi^2 t) \sin((2i+1)\pi x).$$

The corresponding solution with FDS (4) is in the following form:

$$U(t) = W \exp(Dt) W U_0,$$

where U_0 is the column vector with ones, the diagonal matrix D contain the discrete eigenvalues $\mu_k = \frac{4}{h^2} \sin^2 \left(\frac{k\pi h}{2L} \right), k = \overline{1, N-1}$.

For the FDSSES the elements of matrix D are replaced with the first $N - 1$ continuous eigenvalues $\lambda_k = \frac{k^2 \pi^2}{L^2}$. The maximal error by $t = 0.02, N = 10$ is 0.089 for FDS and 0.0102 for FDSSES. The results obtained with Fourier series contain on $x = 0, x = L$ oscillations (Gibbs phenomenon). For FDSSES method these oscillations disappear. The maximal error by $t = 0.9, N = 10$ is 0.000012 for FDS and 0.000001 for FDSSES.

From Fourier series $T(x,t) = \sum_{k=1}^{\infty} a_k(t) w_k(x), f(x,t) = \sum_{k=1}^{\infty} b_k(t) w_k(x), b_k(t) = (f, w_k)_*$

follows ODEs $\dot{a}_k(t) = -\bar{k}\lambda_k a_k(t) + b_k(t)$ with $a_k(0) = (T_0, w_k)_*, \lambda_k = \left(\frac{\pi k}{L} \right)^2$.

We have following solutions

$$a_k(t) = \exp(-\bar{k}\lambda_k t) a_k(0) + \int_0^t \exp(-\bar{k}\lambda_k(t - \xi)) b_k(\xi) d\xi.$$

From the discrete case (FDS) the solution of the matrix equation (4) is

$$U(t) = \exp(-\bar{k}tA) U(0) + \int_0^t \exp(-\bar{k}A(t - \xi)) F(\xi) d\xi.$$

Using the matrix A representation $A = WDW$ and transformation $V = WU$, follows (that for every matrix function $f(A) = Wf(D)W$)

$$V = \exp(-\bar{k}tD) V(0) + \int_0^t \exp(-\bar{k}D(t - \xi)) G(\xi) d\xi.$$

Therefore, we have the solution in the same integral form (6).

3.4 Nonlinear heat transfer equation with the boundary conditions (BC) of the first kind

We shall consider the dimensionless initial - boundary value problem (IBVP) of the first kind for solving the following nonlinear heat transfer equation in:

$$\frac{\partial T}{\partial t} = \frac{\partial^2(g(T))}{\partial x^2} + f(T), T(0, t) = 0, T(L, t) = 0, T(x, 0) = T_0(x), \quad (7)$$

where $T = T(x, t)$ is the solution of IBVP, $g(T)$ is nonlinear continuously differentiable power function with $\frac{\partial g}{\partial T} = g'(T) > 0$, $f(T)$ is nonlinear continuous source function.

For the power functions

$$g(T) = T^{\sigma+1}, g'(T) = (\sigma + 1)T^\sigma, f(T) = aT^\beta, \quad a > 0, \beta \geq 1, \sigma \geq 0, \quad T_0(x) \geq 0 \text{ follows } T(x, t) \geq 0 \text{ for all } t \geq 0.$$

From $T(0, t) = T(L, t) = 0$ follows that $T'(u) = 0$ by $x = 0$; $x = L$ and the solution of the problem (7) is not a classical.

In paper [12], [13] it is proved that

- 1) by $\beta < \sigma + 1$ exists a global bounded solution for all t ,
- 2) by $\beta \geq \sigma + 1$ exists a global bounded solution for sufficient small $\|T_0\|$ ($\|T_0\|$ - the norm of the function $T_0(x)$, $\|T_0\| = \max T_0(x)$ for $x \in (0,1)$), but for larger $\|T_0\|$ there exists the finite value T_* when $T(x, t) \rightarrow \infty$ if $t \rightarrow T_*$ ("blow up" solutions).

The IBVP (7) in the vector form is represented in the following way

$$\dot{U} + AG = F, U(0) = U_0, \quad (8)$$

where $A = PDP$ is the standard 3-diagonal matrix of $N - 1$ order with elements $\frac{1}{h^2} \{-1; 2; -1\}$, G, F are the vectors-column of $N - 1$ order with elements $g_k = g(u(x_k, t)), f_k = af(u(x_k, t)), k = \overline{1, N - 1}$, $U(t), \dot{U}(t), U_0, F(t)$ are the column-vectors of $N - 1$ order with elements $u_j(t) \approx T(x_j, t)$,

$$\dot{u}_j(t) \approx \frac{\partial T(x_j, t)}{\partial t}, \quad u_j(0) = U_0(x_j), f_j(t) = f(x_j, t), j = \overline{1, N - 1}.$$

The numerical experiment with $L = 1$ and $T_0(x) = x(1 - x) \geq 0$ was produced by MATLAB solver "ode23s" for different values of σ and β [11].

For, example, by $a = 5, \sigma = \beta = 3, (\beta < \sigma + 1), t = 10, N = 6, 10, 20$ there were obtained following maximal errors with FDS and FDSES methods:

- 1) $N = 5 - 0,0125$ (FDS), $0,0011$ (FDSES);
- 2) $N = 10 - 0,0046$ (FDS), $0,0003$ (FDSES);
- 3) $N = 20 - 0,0013$ (FDS), $0,0001$ (FDSES).

In the Fig. 9., Fig. 10. we can see two type of solutions for three-time moments ($t = 0, t = T_1, t = T_2 > T_1$) by $\sigma = 3$ depending on the parameters β, a , obtained with the FDSES method ($N = 80$):

- 1) $\beta = 4 (\beta = \sigma + 1), a = 12$, three-timepoints of the numerical experiment - $(0, 17.800, 17.813000)$, the solution $u(x, t) \rightarrow \infty$ globally for all $x \in (0,1)$, when $t \rightarrow T_* < \infty$ ($T_* = 17.813001$ is finite value of time, this is the global "blow up" solution), (Fig. 9.).
- 2) $\beta = 5 (\beta > \sigma + 1), a = 50$, three-time points of the numerical experiment - $(0, 16.018700, 16.018780)$, the solution $u(x, t) \rightarrow \infty$ locally neighbourhood of point $x = 0.5$, when $t \rightarrow T_* < \infty$ (for finite value of $T_* = 16.018781$, this is the local "blow up" solution), (Fig. 10.).

It should be noted that when performing numerical experiments directly at the time values $T_* = 17.813001$ and $T_* = 16.018781$, the MATLAB solver "ode15s" stopped working.

The maximum value of the function $u(x, t)$ ($\max(u) = 2060.6247$) is shown in Fig. 11., Fig. 12., calculated at the parameter values $\beta = 5, \sigma = 3, a = 15$ at the time moment $t = 0.0278000$. In this case, the local "blow up" solution constant is $T_* = 0.0278588$.

The numerical experiments presented in the given publication were performed with the MATLAB solver "ode15s".

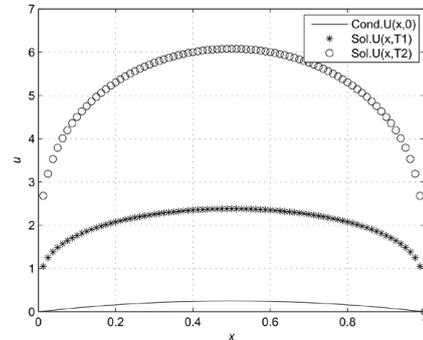


Fig. 9. $u(x, t)$ - solutions for fixed t at $(0, 17.800, 17.813)$ and for $x \in (0,1)$, $\beta = 4, \sigma = 3, a = 12$.

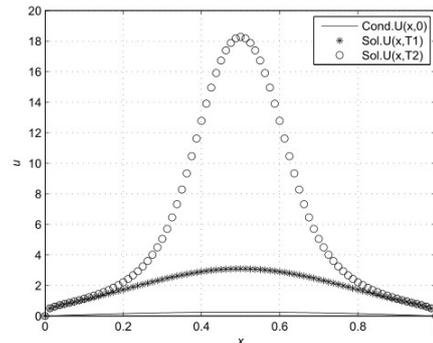


Fig. 10. $u(x, t)$ - solutions for fixed t at $(0, 16.01870, 16.01878)$ and for $x = 0.5$, $\beta = 5, \sigma = 3, a = 50$.

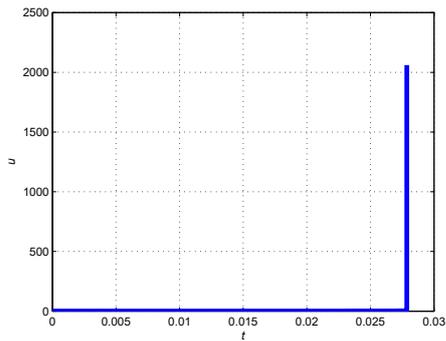


Fig. 11. $u(x, t)$ - solution depending on t at fixed $x=0.5$, its maximal value $\max(u)=2060.6247$ at $t=0.0278$, $\beta = 5, \sigma = 3, a = 15$.

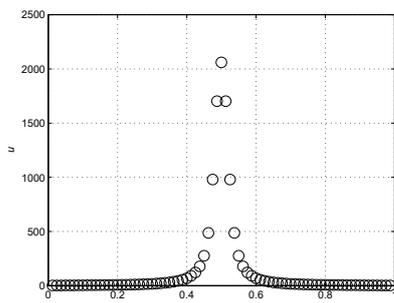


Fig. 12. $u(x, t)$ - solution depending on x at fixed $t=0.0278$, its maximal value $\max(u)=2060.6247$ at $x=0.5$, $\beta = 5, \sigma = 3, a = 15$.

In the monograph [13] there are collected all methods used in the study of “blow-up” of solutions to mathematical models of realistic physical phenomena. The “blow-up” effect occurs, for example, when a computer breaks down as a result of an electrical breakdown, or when a nuclear bomb explodes, and in several other interesting physical phenomena. Here exist several well-known methods of the study of the “blow-up” effect of solutions to nonlinear equations.

CONCLUSIONS

1. It was found that the FDSES method and the trigonometric interpolation method were equivalent methods in terms of accuracy.
2. All eigenvalues and eigenvectors for finite difference operators have been obtained. In the case of the homogenous first-kind boundary conditions, the FDSES method provided a solution with any desired accuracy.
3. The algorithm of the discrete Fourier method has been formed in different wise - using the special transformation by reducing the vector problem to scalar separated problem with the discrete eigenvalues, using the complex discrete Fourier series and the real discrete Fourier series for the respective vector components.
4. The advantages of the FDSES method for solving the problems of ODEs with periodical boundary conditions have been demonstrated in comparison with local FDS methods. In solving the partial differential equations for

the linear heat conduction equation using the method of lines, exact algorithms in space were obtained. The FDSES method proved to be useful in solving boundary value problems both with periodic boundary conditions and also with homogenous boundary conditions of the first type.

5. Linear and nonlinear partial differential equations have been solved using the FDSES method due to the MATLAB solvers “ode15s”, and “ode23s”.

6. By the theoretical positions, the solution of the nonlinear problem “blow-up” has been studied and obtained in connection with different characteristic-parameter values of the nonlinear heat conduction equation with the above-mentioned high-accuracy solving methods, especially, the FDSES method.

7. Numerical experiments showed that obtaining the solution of the “blow-up” phenomena and its graphic visualization is possible only with high-precision numerical methods - the values of time moments in the process of mathematical modelling had to be chosen with an accuracy of no less than $1.e^{-5}$ or $1.e^{-6}$.

REFERENCES

- [1] H. Kalis and A. Buikis, “Method of lines and finite difference schemes with exact spectrum for solution the hyperbolic heat conduction equation,” *Mathematical Modelling and Analysis*, vol. 16, No 2, 2011, pp. 220-232.
- [2] V. L. Makarov and I. P. Gavriljuk, “On constructing the best net circuits with the exact spectrum,” *Dopov. Akad. Nauk Ukr. RSR*, Ser. A, 1975, pp. 1077-1080.
- [3] L. N. Trefethen, *Spectral methods in Matlab*. Oxford - Pres, 2000.
- [4] J. A. C. Weideman and S. C. Reddy, “A Matlab differentiation matrix suite,” *ACM Transactions on Mathematical Software*, vol. 26, No 4, 2000, pp. 465-519.
- [5] D. Gottlieb, M. Y. Hussaini and S.A. Orszag, “Theory and applications of spectral methods”, *Spectral methods for partial differential equations*, 1984, pp. 1-54.
- [6] E. Tadmor “The exponential accuracy of Fourier and Chebyshev differencing methods”, *SIAM J. Numer. Anal.*, vol 23, No. 1, 1986, pp. 1-10.
- [7] C. Canuto, M. Y. Hussaini, A. Quarteroni T. A. Zang, *Spectral methods in fluid dynamics*. Berlin: Springer-Verlag, 1988.
- [8] M. Kokainis and H. Kalis, “Matrix representation of the finite difference method in a multi-point stencil for periodic boundary conditions”, *MMA2013 and MOE2013, May 27-30, 2013, Tartu, Estonia*, Tartu, p. 62., 2013.
- [9] H. Kalis and I. Kangro, *Effective finite difference and Conservative Averaging methods for solving problems of mathematical physics*, Monography. Rezekne: Rezekne Academy of Technologies, 2021.
- [10] A. Kalis I. Kangro and A. Aboltins, “Numerical analysis for system of parabolic equations with periodical functions”, *Engineering for Rural development, Jelgava 24.-26. 05. 2023*, Jelgava, 2023, pp.796-809.
- [11] H. Kalis I. Kangro and A. Gedroics, “Numerical methods of solving some nonlinear heat transfer problems”, *Int. Journ. of Pure and Applied Mathematics*, vol. 57, No. 4, 2009, pp. 467-484.
- [12] A. A. Samarskij, V. A. Galaktinov, S. P. and Kudrjumov, *Blow-up solutions in the problems of quasilinear parabolic equations*. Moscow: Nauka, 1987.
L. M. O. Korpusov, V. A. Ovchinnikov, A. G. Sveshnikov etc., *Blow-up in nonlinear equations of Mathematical Physics, Theory and methods*. Berlin, Boston: De Gruyter, 2018.

Ensuring Information Security in the Intelligent Scientific and Technical Information Systems

Komil Kerimov

Department of System and Applied
Programming
Tashkent University of Information
Technologies named after
Muhammad al-Khwarizmi
Tashkent, Uzbekistan
kamil@kerimov.uz

Zarina Azizova

Department of Information Security
Tashkent University of Information
Technologies named after
Muhammad al-Khwarizmi
Tashkent, Uzbekistan
z.i.azizova18@gmail.com

Fayzi Bekkamov

Department of Library information
systems
Tashkent University of Information
Technologies named after
Muhammad al-Khwarizmi
Tashkent, Uzbekistan
bfayzi93@gmail.com

Mekhriddin Rakhimov

Department of Computer Systems
Tashkent University of Information
Technologies named after
Muhammad al-Khwarizmi
Tashkent, Uzbekistan
raximov022@gmail.com

Mannon Ochilov

Department of Computer Systems
Tashkent University of Information
Technologies named after
Muhammad al-Khwarizmi
Tashkent, Uzbekistan
ochilov.mannon@mail.ru

Abstract. Scientific and scientific-technical information is a valuable tool for the development of education, technology and society as a whole. The increase in the volume of information and the development of information networks of data exchange requires special means to ensure information protection of data. Methods, means and systems for information security of scientific, technical and scientific-educational resources in intellectual information systems are of particular importance. The purpose of the research is to develop methods and software tools to ensure information security of valuable scientific and technical information resources in intelligent information systems.

The proposed solution for intrusion detection in intelligent system is a web application firewall, which is used for enhanced security, detecting and preventing attacks before they reach the web application. It will protect the system from a whole range of attacks while allowing HTTP traffic monitoring and analyzing small changes or persistent state online. The Web Application Firewall (WAF) has the following features: logging of all HTTP protocol transactions, including request termination permissions and logging of the response; HTTP traffic can be examined in real time to detect attacks; preventing attacks before they reach the web application.

This work is performed within the framework of the project on creation of an integrated intelligent system "SMART TUIT", which includes several subsystems (Information Retrieval, Voice Recognition, Pattern Recognition, Scientific Information Assessment, Geoinformation System).

Keywords: information security, intelligent system, scientific and technical information, information retrieval, behavioural analysis.

I. THE CREDIBILITY OF SCIENTIFIC AND TECHNICAL INFORMATION SOURCES

In recent times, significant scientific and technical discoveries stemming from diverse research endeavors have become increasingly valuable. Simultaneously, this body of knowledge plays a pivotal role as a primary resource for conducting further research. Hence, the ability to fully utilize such information during research endeavors is paramount. However, it is important to note that not all scientific and technical resources are readily accessible, and their utilization is governed by the owners or publishers of these resources. Presently, a plethora of international publishers and scientific databases, including Web of Science, Scopus, Ebsco, Springer, and ProQuest, alongside libraries, scientific laboratories, and research centers, offer access to these invaluable resources.

Various methods and tools have been proposed in previous studies for evaluating information, considering factors like accuracy, completeness, reliability, compatibility, usability, objectivity, and novelty. However, the complexity arises from factors such as the user is knowledge level, the research field, the information

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8042>

© 2024 Komil Kerimov, Zarina Azizova, Fayzi Bekkamov, Mekhriddin Rakhimov, Mannon Ochilov.

Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

acquisition purpose, and the continuous evolution of science, leading to new information and changing the value of existing information over time. The evaluation of scientific and technical information sources is influenced by the evaluator's goals, interests, knowledge level, and timing of evaluation. Although evaluation often becomes subjective, there is a need for occasional objective assessments regarding the information's significance in advancing society and science [1].

In an era marked by the exponential growth of digital data, numerous search engines have emerged to cater to users' information requirements. These search systems are designed for various purposes, including accessing electronic libraries, archives, and educational databases, particularly for scientific and technical information retrieval. However, the majority of these search engines operate by retrieving information based on user queries. Consequently, it is crucial for scientific and technical database search systems to analyze user information needs before presenting relevant resources. Addressing this challenge, recommendation systems offer a viable solution, leveraging a knowledge base and machine learning algorithms. They have become integral to artificial intelligence and are widely employed across different organizations and services. For instance, Amazon has implemented a personalized recommendation system to suggest e-books to its customers effectively [2].

Research has commenced on implementing artificial intelligence within library systems [3]. This involves utilizing artificial intelligence in scientific and technical databases to analyze user data such as age, interests, expertise in specific fields, and past queries. By doing so, the system can suggest relevant information sources tailored to the user's needs, ultimately streamlining the librarian's tasks, enhancing the speed and precision of information retrieval, and improving overall management efficiency while better meeting the populace's informational requirements.

II. SECURITY OF THE INTEGRATED INTELLIGENT SYSTEM "SMART TUIT"

In integrated intelligent systems, user data stored in the database, such as personal data, their requests for information searches, preferences, search history and other types of confidential information may be used by attackers implementing attacks such as URL interpretation, data entry validation attacks, SQL-injections and others for the purpose of stealing personal information, fraud or violating confidentiality.

Among the scientific works devoted to the protection of information systems from security threats the following ones: a comparative study of various web-application vulnerability tools and scanners to determine their effectiveness and accuracy in vulnerability detection [4], rationalization of security measures against SQL injections [5], increasing the security level of web-applications by using firewalls [6], study of various filtering techniques to prevent SQL injection attacks [7], and others.

Our solution for intrusion detection in an integrated intelligent system, "SMART TUIT", is a web application firewall that is used for enhanced security, detecting and preventing attacks before they reach the web application. It will protect your system from a whole range of attacks,

while allowing you to monitor HTTP traffic and analyze small changes or persistent state online. The Web Application Firewall (WAF) has the following features:

- Logging of all HTTP protocol transactions, including permissions to terminate the request and log the response,
- HTTP traffic can be inspected in real time to detect attacks,
- Prevention of the attacks before they reach the web application.

A web application firewall can be part of a web server structure or a reverse proxy server on a network. Figure 1 illustrates a detailed scheme of web-application firewall functionality. To create an effective protective tool, sets of rules have been developed that detect HTTP protocol violations, detect typical attacks on web application security, protect against automated activity (bots, worms, scanners and other malicious programs), detect access to Trojan horses, and distort error messages sent to the server.

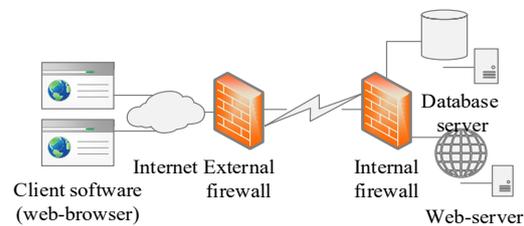


Fig. 1. Scheme of functioning of the web application firewall.

Consider in more detail the architecture of the proposed web application firewall shown in Figure 2.

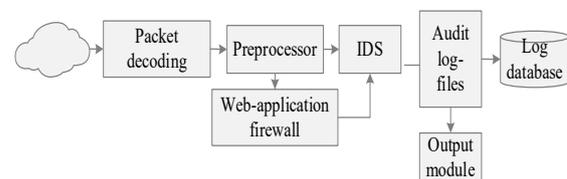


Fig. 2. Architecture of the proposed web application firewall.

a) *Packet Decoding*. The library used to capture packets transmitted over the network that contain the capture time, packet length, and link type (e.g., Ethernet, FDDI). A pointer is created to point to each packet for performance analysis. The firewall in built-in mode has additional features such as packet transmission, packet modification, specific packet return, and packet deletion.

b) *Preprocessor*. After packets are captured, they are passed to the preprocessor for packet extraction and normalization using the formats of each protocol. The preprocessor also analyzes statistics of network traffic usage and identifies unwanted attacks such as worms.

c) *IDS (Intrusion Detection System)* is the core of the proposed system. With proper settings to detect network attacks effectively. If the captured packet contains any signature pattern, the system will alert about the attack and write the data to the log files.

d) *Audit log-files*. When the system recognizes attacks, log-files are generated and messages are displayed that

contains attack-related information for the administrator to remove the attack.

e) *Output module.* A module that allows to output errors in the desired format.

As we research XSS, SQL injection vulnerabilities, we wrote filters to protect against them. The following code used to prevent SQL injection attacks:

```
$blackfile = 'blacklist.txt';
$admin_email = 'your@gmail.com';
$bad_words = "UNION SELECT INSERT FROM";
//Пример ключевых слов
$user_ip = $_SERVER['REMOTE_ADDR'];
if (file_exists($blackfile)) {
    $blacklist = file_get_contents($blackfile);
    if (preg_match("/".preg_quote($user_ip)."/is",
    $blacklist)) {
        exit("You are banned. Go fuck yourself
        :");
    }
}
$bad_list = explode(' ', $bad_words);
$line = $_POST?implode(" ",
$_POST):$_SERVER['QUERY_STRING'];
foreach ($bad_list as $re) {
    if (preg_match("/$re/i", $line)) {
        $fp = fopen($blackfile, 'a+');
        fputs($fp, "$user_ip\n");
        fclose($fp);
    }
}
```

Fig. 3. Filtering rule to prevent SQL injection

The following code used to prevent XSS attacks:

```
function xss ($str) {
    $r_str = str_replace(
    array('<','>','"',"'",','), '('),
    array('&lt;','&gt;','&apos;','&#x22;','&#x29;',
    '&#x28;','), $input_str );
    $r_str = str_ireplace( '%3Cscript',
    '', $return_str );
}
```

Fig. 4. Filtering rule to prevent XSS attacks.

In this section of the article, we presented an intrusion detection mechanism using web application firewall. The Web application firewall reduces the level of activity or blocks common attacks by using filters with the right set of rules. It should be noted, however, the need for the administrator to filter all incoming data from users.

III. PATTERN RECOGNITION SUBSYSTEM IN “SMART TUIT”

Recognition technologies applied in accordance with the specifics of the systems in which they are used. Among the most relevant today are bar codes, fingerprints, NFC and face recognition. Digital image processing allows devices to recognize an object, make a decision regarding the distribution and access control of the object in question, and act in accordance with the set access control rules in the system.

This allowed using the capabilities of computers in different spheres of activity, as devices today can see objects in the same representation as people do [8]. The development of deep learning technology has allowed bringing to a new level the process of image detection, by convolutional neural network (CNN) and R-CNN. The authors of [9] investigated the learning approaches for face recognition in integrated information systems, in addition, different neural network architectures such as convolutional neural networks and recurrent neural networks (RNN) and their applications are discussed. In turn, in [10], the authors present a hybrid computing platform based on a graphics processing unit (GPU) and a programmable gate array (FPGA) for processing machine

learning tasks. They investigate the application of this platform in the context of pattern detection and recognition. The combination of the power of the GPU and the flexibility of the FPGA enables high performance and efficiency in complex pattern recognition tasks.

This section of the paper presents a model of image recognition, namely the faces of users of the integrated intelligent system “SMART TUIT”. The integration of the pattern recognition module in “SMART TUIT” led to the automation of the process of image capture, its analysis, subsequent search, as well as the definition of tasks. The CNN detector used in the module is a method of recognizing facial images of the system users. The module consists of four main parts: image (face) formation module, training module, camera module, and image identity verification module.

The implementation of the pattern recognition module consists of initially recording information about each user (library visitor), then initiating the training process (Figure 5 illustrates the process of creating and training the neural network) and subsequent testing with basic functions in the CNN library.

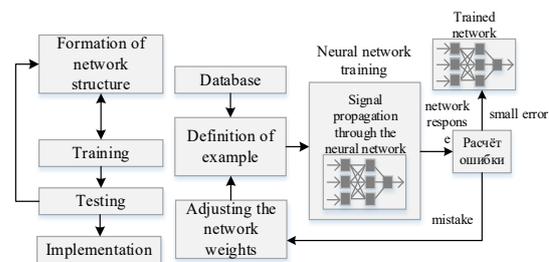


Fig. 5. Architecture of the proposed web application firewall.

Storage of recognition objects provides the primary process of recording the faces of the system users. All these objects are stored in a single library. The greater the number of images stored in the database, the more accurately the image recognition module in the “SMART TUIT” system will function. The next step is the learning process represented by the algorithm associated with the data stored in the library. The code compiled in the training module provides step-by-step instructions on the processes performed in the system.

One part of the presented image retrieval logic is shown in Figure 6.

```
img = imread(student_face_file);
[img, face] = cropface(img);
%face value is 1 when it detects face in image or 0
if face == 1
    img = imresize (img, [300 400]);
    predict = classify (newnet, img);
end
```

Fig. 6. Program code of the logic of functioning of the pattern recognition software module.

First, the image is stored in memory, image identification based on faces by cropping the desired object from the total image. Next, the camera module recognizes the image and compares the available image with the images stored in the database according to the previously trained sample. The main process of functioning of this module (Figure 7) is to recognize an object based on the shape of the face, after which the image captured for the

purpose of subsequent comparison and determination of the identity of the images.



Fig. 7. Interrelation of pattern recognition modules in the "SMART TUIT" system.

The architecture of the image recognition module in the "SMART TUIT" system (shown in Figure 8) includes a logical level responsible for data maintenance and management, as well as a storage level including databases with visit information, a knowledge base and a database with user information. The interaction of these components allows the system to effectively recognize user facial images, manage information, and provide security and access control.

A. Logical level:

- Image Recognition. At this level, the main process of recognizing user face images takes place. The image captured by the camera is stored in memory and is subjected to identification by cropping the desired object from the overall picture. The camera module then recognizes this image and compares it with the images stored in the database. The basic process of this module is to recognize an object based on the shape of the face and then capture the image to determine its identity.
- Data management. This component is responsible for managing all necessary information in the system. This level contains data on users, staff, request management and statistics. Information about each user, visitor of the library, is recorded and stored in a database. The knowledge base contains information about the processes and rules of the system, and the user information database contains additional data about users, such as their personal data, visit history and other useful information.

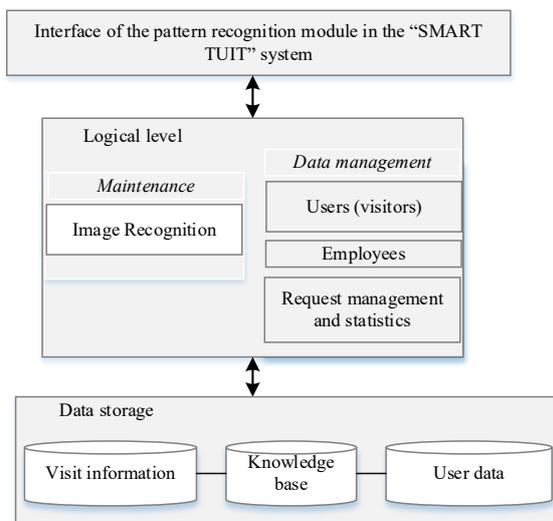


Fig. 8. Architecture of the pattern recognition module in the "SMART TUIT" system.

Each component of the architecture will be discussed in more detail:

B. Storage level:

- Attendance database. This database contains information about each visit by users of the "SMART TUIT" system. It stores records of the date and time of the visit, user ID and other related data. This information can be used for analyzing and statistics of visits, as well as for security and access control purposes.
- Knowledge base. The knowledge base contains information about the processes and rules of the "SMART TUIT" system. It includes instructions and manuals for using the system, pattern recognition algorithms, and other relevant knowledge necessary for the correct functioning of the pattern recognition module.
- Database with user information. This database stores additional data about users of the "SMART TUIT" system. This may include personal data such as names, photos, contact information, as well as visit history, preferences, and other useful information that can be used to personalize and better serve users.

The architecture of the image recognition module in the "SMART TUIT" system includes a logical level responsible for data maintenance and management, as well as a storage level including databases with visit information, a knowledge base and a database with user information. The interaction of these components allows the system to effectively recognize user facial images, manage information, and provide security and access control.

Presented a pattern recognition model based on user face recognition in the integrated intelligent system "SMART TUIT". The use of pattern recognition technologies, such as CNN and R-CNN, combined with digital image processing capabilities allowed to automate the process of capturing, analyzing and searching user faces, as well as determining the tasks. The process of implementing the module includes recording information about each user, training the neural network and testing the basic functions. One of the important components of the module is the storage of recognition objects in the database. The more images will be stored in the database, the more accurately will function the module of pattern recognition in the system "SMART TUIT". The use of the module in the "SMART TUIT" system provides automation of the processes of image capture, analysis and search, as well as reliability and security in the access control system.

IV. CONCLUSION

In our article, we proposed the concept of protecting the integrated intelligent system "SMART TUIT". One of the solutions we presented is a web application-based approach with a Web Application Firewall functionality, which enhances security by detecting and preventing attacks before they reach the web application. The primary focus is on using input data filtering to protect against common attacks such as SQL injections and cross-site scripting (XSS).

The image recognition subsystem in "SMART TUIT" is based on the application of CNN. The system automates the process of capturing, analyzing, and searching user

faces. The facial recognition module consists of several key components: the image formation module, training module, camera module, and image authentication module. It enables automation of the processes of capturing, analyzing, and searching user faces, providing reliability, security, and access control in the system.

The architecture of the "SMART TUIT" system includes not only the intrusion detection module and image recognition module but also other components such as a knowledge base, user information database, and visit information database. The interaction among these components allows for effective information management, security, and access control. Overall, the scientific research and development in the field of intrusion detection and image recognition in the integrated intelligent system "SMART TUIT," along with the proposed solutions, contribute to enhancing system security and efficiency.

REFERENCES

- [1] M. Rakhmatullaev, Sh. Normatov and F. Bekkamov, Fuzzy model for determining the information needs of library users, 14th international scientific and practical conference: Environment. Technology. Resources, June 15-16, 2023, Rezekne. Rezekne Academy Of Technologies.
- [2] M. Bendecheche, N. Limaye and R. Brennan, "Towards an Automatic Data Value Analysis Method for Relational Databases," presented at the 22nd International Conference on Enterprise Information Systems, 2020.
- [3] I. M. Omame and J. C. Alex-Nmecha, "Artificial Intelligence in Libraries," presented at the 22nd International Conference on Enterprise Information Systems, vol.2: ICEIS, 2020, pp. 833-840.
- [4] J. J. Shahid, M.K. Hameed, I.T. Javed, K.N. Qureshi, M. Ali and N. Crespi, "A Comparative Study of Web Application Security Parameters: Current Trends and Future Directions, ", Applied Sciences, vol. 12, no. 8: 4077, 2022.
- [5] J. Clarke, SQL Injection Attacks and Defense, 2nd ed., MA: Syngress, 2012. [E-book] Available: StudyLib, <https://studylib.net/doc/26304630/sql-injection-attacks-and-defense.pdf---pdfdrive-->.
- [6] G. Betarte, E. Gimenez, R. Martinez and A. Pardo, "Improving Web Application Firewalls through Anomaly Detection," 17th IEEE International Conference on Machine Learning and Applications (ICMLA), Orlando, FL, USA, 2018, pp. 779-784.
- [7] R. J. Dubey and H. Gupta, "SQL filtering: An effective technique to prevent SQL injection attack," 5th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO), Noida, India, 2016, pp. 312-317.
- [8] K. Kim and S. Oh, "Edge Computing System applying Integrated Object Recognition based on Deep Learning," 24th International Conference on Advanced Communication Technology (ICACT), PyeongChang Kwangwoon_Do, Republic of Korea, 2022, pp. 415-419.
- [9] G. Yolcu et al., "Deep learning-based facial expression recognition for monitoring neurological disorders," IEEE International Conference on Bioinformatics and Biomedicine (BIBM), Kansas City, MO, USA, 2017, pp. 1652-1657.
- [10] X. Liu, H. A. Ounifi, A. Gherbi, W. Li and M. Cheriet, " A hybrid GPU-FPGA based design methodology for enhancing machine learning applications performance ," Journal of Ambient Intelligence and Humanized Computing, vol.6, 2020, pp. 2309-2323.

Methodology of Information Security Risk Assessment of Electronic Resources under Unauthorized Access Threats

Komil Kerimov

Department of System and Applied
Programming
Tashkent University of Information
Technologies named after
Muhammad al-Khwarizmi
Tashkent, Uzbekistan
kamil@kerimov.uz

Zarina Azizova

Department of Information Security
Tashkent University of Information
Technologies named after
Muhammad al-Khwarizmi
Tashkent, Uzbekistan
z.i.azizova18@gmail.com

Abstract. The article proposes a methodology for assessing the risk of information security of a computer network based on the results of the analysis of vulnerability attributes and protection attributes of information system elements, as well as security attributes of information system elements. According to the results of the research the space of information protection signs is formed. The results of the analysis of possible variants of threats of unauthorized access to electronic resources of the computer network, as well as solutions to reduce the risks of information security are given. Quantitative indicators of the results of the application of the proposed methodology to assess the risk of threats of unauthorized access to electronic resources of the computer network confirm the effectiveness of the proposed methodology, which can be used to improve the level of protection of electronic resources in organizations

Keywords: computer network, vulnerability, risks, information security, artifacts, testing

I. INTRODUCTION.

Rapid growth rates of information technologies contribute to the expansion of business relations of a person in all spheres of his activity through the Internet. With the development of means of communication, such as computer networks, WEB sites, problems of protection of information (business, scientific) electronic resources of systems from encroachment on it by individuals have arisen.

Information security (IS) risk in the general sense is a certain probability of occurrence of an adverse event leading to some damage or loss in relation to the assets of the organization.

Information security risk of electronic resources (ER) on the Internet remains high if they are not adequately protected from unauthorized access. In this regard, the development of effective means of protecting ER information from unauthorized access remains relevant. Unauthorized access to a computer network, as a rule, is carried out through vulnerabilities in the ER, therefore, to reduce the risk of penetration to the system information, effective methods of vulnerability detection, their assessment and their exclusion are required. Nowadays the internet has become an integral part of our daily lives, with web applications serving as the backbone of various online services. However, this increased reliance on web applications has also made them attractive targets for malicious actors seeking to exploit vulnerabilities and compromise user data. Among the various attack vectors, Cross-Site Scripting (XSS) attacks have emerged as a significant security concern.

The analysis of scientific works of researchers dealing with this problem has shown that a significant part of the applied methods of risk assessment from threats of unauthorized access to the organization's assets are aimed at qualitative assessment of the threat under study. The risk arises when there is insufficient information about the consequences when making a decision, or in its absence in general. The complexity of the IS risk assessment process also depends on it. J.Bhattacharjee, A.Sengupta and K.Mazumdar proposed a formal risk assessment methodology that considers asset dependency and vulnerability dependency during risk calculation while determining the factors that affect the risk [1]. It should also be noted that in [2] the authors propose a new taxonomy of approaches to risk assessment based on qualitative, quantitative and hybrid (semi-quantitative) criteria. In

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8043>

© 2024 Komil Kerimov, Zarina Azizova. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

quantitative assessment of IS risks, the degree of influence of each individual scenario is considered from the point of view of the expected damage from the impact on assets of this scenario. Qualitative assessment of IS risks takes into account the measure of vulnerability and the measure of threat probability, expressed on a scale from one to five. This simplifies the stage of calculating the probability and impact of scenarios, but due to the fact that the input data are mostly the knowledge of experts, it leads to possible inaccuracies and subjectivity of the assessment. In turn, the authors [3] point out ways of applying fuzzy theory in order to reduce subjectivity.

It should be taken into account that the IS of a computer network depends largely on the competent implementation of a number of organizational and design works [4], and a significant problem for modern corporate networks are data leaks [5] - [9], which occur as a result of unauthorized influence of intruders. The proposed methodology of IS risk assessment on the example of an organization's computer network is based on the identification of threats to the security of ES and is aimed at obtaining quantitative results in the assessment of IS risks.

II. METHODOLOGY OF INFORMATION SECURITY RISK ASSESSMENT OF ELECTRONIC RESOURCES.

The most important requirements for a computer network design to meet modern information security include:

- 1) *Selection of the required computer network architecture.* The logical structure of the network should not depend on the physical structure. That is, the topology of the network at the link layer is built independently of the geographical location of the organizational structure network components;
- 2) *Effective password protection of switches, routers and servers,* providing computer network monitoring for prompt diagnostics and troubleshooting;
- 3) *Development of the system of notification of various events and incidents,* related to unauthorized access.

Figure 1 shows a computer network of an organizational structure in which its two subnets are geographically separated but connected by the same logical topology.

Notation: gw - gate way, dsw - distribution switch, asw - access switch.

The network is configured with six local virtual networks of Vlan type [6]:

- vlan 2 (switches for device management: dsw1,asw1,asw1,asw2, asw3, asw 4)
- vlan 3 (servers: web, file, mail);
- vlan 4 (computers of production and technical department (PTD)) ;
- vlan 5 (computers of financial and economic department (FEO));
- vlan 6 (computers of accounting department (AD));
- vlan 7 (computers - other users (U)).

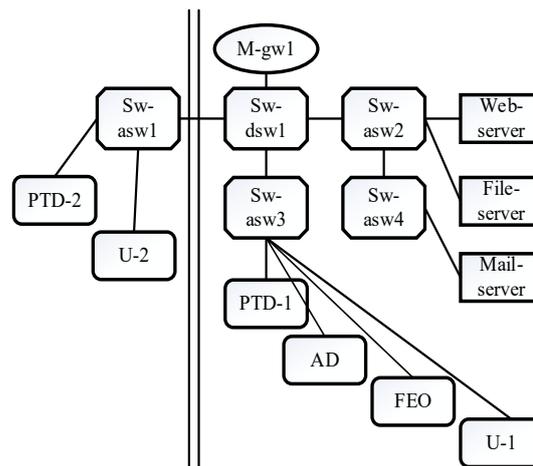


Fig. 1. Simplified diagram of the organization's computer network.

Vlans form a group of network nodes in which all traffic of a Vlan, including broadcast traffic, is completely isolated from other Vlans. Frame transmission between nodes of one Vlan occurs at the second (link) layer. Vlans communicate with each other through a router at the third (network) layer.

The computer network included:

- router *M-gw1*- for transferring data from one Vlan to another Vlan;
- switch *Sw-dsw1* for the distribution layer, where all subnets are aggregated into a common trunk;
- switches *Sw-asw1*, *Sw-asw2*, *Sw-asw3*, *Sw-asw4* are used as access devices. End-user computers and servers connected to them.

To assess risk, the following steps should be performed:

- a) *Form the space of protection and vulnerability attributes of the project;*
- b) *Build a table of project artifacts with protection and vulnerability attributes;*
- c) *Develop a database of vulnerabilities;*
- d) *Build a scheme of threat detection in case of unauthorized access to the project objects by protection and vulnerability attributes;*
- e) *Prepare data for assessment of information security risks of the ER;*
- f) *Assess IS risks in case of unauthorized access using this methodology.*

III. FORMATION OF THE SPACE OF INFORMATION PROTECTION ATTRIBUTES

Let's represent the attributes of the computer network project as artifacts of the information security risk management process of the object with the corresponding attributes of protection and vulnerability (Tables 1-3).

TABLE 1 ARTIFACTS OF CONTROL WITH APPROPRIATE SIGNS OF PROTECTION AND SIGNS OF VULNERABILITY

№	Control artifacts	Protection feature code	Vulnerability code
1	Web server	X1	Y1
2	File server	X2	Y2
3	Mail server	X3	Y3
4	Router M-gw1	X4	Y4
5	Switch Sw-dsw1	X5	Y5
6	Switch Sw-asw1	X6	Y6
7	Switch Sw-asw2	X7	Y7
8	Switch Sw-asw3	X8	Y8
9	Switch Sw- asw4	X9	Y9
10	Computer PTD-1	X10	Y10
11	Computer PTD-2	X11	Y11
12	Computer FEO	X12	Y12
13	Computer AD	X13	Y13
14	Computer U-1	X14	Y14
15	Computer U-2	X15	Y15

TABLE 2 EQUIPMENT PROTECTION CHARACTERISTICS

№	Protection characteristic and description	Protection code index
<i>Characteristics of server protection</i>		
1.	Digest Authentication program that allows you to encrypt the username and password in a request.	1
2.	HTTPS protocol, which allows encryption of all data transmitted between the browser and the server, not just usernames and passwords.	2
3.	Authentication and authorization via RADIUS server protocol. Verification of user credentials (including encrypted credentials) at the request of the served system.	3
<i>Switch protection characteristics</i>		
4.	A network screen in the form of a hardware and software module filters routed and/or broadcast packets	4
5.	Packet-type firewall. Packet filters function at the network layer and control the passage of traffic based on the information contained in the packet header.	5
6.	Port security. The switch function is used to prevent unauthorized change of the MAC address of a network device.	6
7.	Port security is used to prevent overflow attacks.	7
8.	DHCP snooping. Switch function to protect against server attacks on the network or DHCP spoofing attacks.	8
9.	Dynamic ARP Inspection (Protection) - A switch feature to protect against attacks using the ARP protocol.	9
<i>Characteristics of computer protection</i>		
10.	Personal firewall - software that controls the computer's network activity and filters traffic. It is installed directly on the protected computer.	10
11.	MAC authentication. An authentication method that grants access to a network by authenticating the computer rather than the user.	11
12.	Web Authentication provides access to the network by authenticating the user through a web interface. An effective method of combating IP spoofing.	12
13.	Cryptographic two-factor authentication using one-time passwords. An effective method of combating IP spoofing.	13

TABLE 3 CHARACTERISTICS OF EQUIPMENT VULNERABILITIES

№	Vulnerability characteristic and description	Vulnerability code index
<i>Characteristics of server vulnerability</i>		
1.	The username and password in the request are not encrypted, (Digest Authentication is not configured).	1
2.	Data transmitted between the browser and the server and usernames and passwords are not encrypted (HTTPS protocol does not work).	2
3.	User credentials (including encrypted credentials) are not verified at the request of the served system, (RADIUS server protocol is not implemented).	3
4.	Insecure password recovery. A vulnerability occurs when a Web server allows an attacker to unauthorized obtain, modify, or recover other users' passwords.	4
5.	Inadequate authentication. A Web server allows an attacker to access sensitive information or server functions without proper authentication.	5
6.	Insufficient authorization. With insufficient authorization, the Web server allows an attacker to access sensitive information or features that should be restricted.	6
<i>Characteristics of switch and router vulnerabilities</i>		
7.	Network shield in the form of a hardware and software module is not installed (or configured). Routed and/or broadcast packets are not filtered.	7
8.	Packet-type firewall is not installed (or configured). The network layer does not filter and control traffic flow based on packet header information.	8
9.	The switch's Port security feature is not configured. The MAC address on the switch's network card has changed, causing packets to be sent to the port to which the attacker is connected.	9
10.	The switch's Port security feature is not configured. The switching table is full. After the table is full, the switch does not learn new MAC addresses and starts working as a network hub, sending traffic to all ports.	10
11.	DHCP Snooping server is not used. An attack involving the spoofing of a DHCP server on a network or a DHCP starvation attack forces the DHCP server to give out all existing addresses on the server to the attacker.	11
12.	Dynamic ARP Inspection (Protection) - The switch feature to protect against attacks using the ARP protocol is not used.	12
<i>Characteristics of computer vulnerabilities</i>		
13.	The computer's network activity is not monitored and traffic is not filtered according to the specified rules. Personal firewall is not installed directly on the protected computer.	13
14.	MAC authentication is not properly configured. Unauthorized access to the computer's network is open while connected to the switch.	14
15.	Unauthorized access to the network is opened during user authentication via the Web interface (Web authentication is not properly configured).	15
16.	Weak authentication.	16

IV. DATABASE FOR INFORMATION SECURITY RISK ASSESSMENT.

The database project includes the following data sets:

- 1) *Artifacts of security feature codes.*
- 2) *Artifacts of vulnerability feature codes.*

- 3) Characteristics of server security features.
- 4) Characteristics of router security features.
- 5) Characteristics of switch security features.
- 6) Characteristics of signs of vulnerability of servers.
- 7) Characteristics of signs of vulnerability of the router.
- 8) Characteristics of switch vulnerability signs.
- 9) Characteristics of computer vulnerability indicators.
- 10) Temporal array about the operational state of the computer's ER.
- 11) Temporary array of artifacts, with corresponding codes of protection and vulnerability attributes.

Formation of stages of information security risk assessment of a computer network. IS risk assessment carried out according to the following stages:

- a) Readings on the operating state of the protection elements are taken (array 10).
- b) Using arrays 1, 2, and 10, an array of artifacts is generated, with corresponding threat and vulnerability feature codes (array 11).
- c) Using arrays 3,4,5,6 and 11, the presence of a threat to the computer network ER is determined.
- d) Information security risk assessment is performed.
- e) A decision is made to reduce information security risks.

V. RISK ASSESSMENT OF UNAUTHORIZED ACCESS THREATS TO ELECTRONIC RESOURCES OF A COMPUTER NETWORK

Let the testing of defence elements result in an array of 10 (Table 4).

Note: In Table 4, the value of the protection code index in the third column of Tables 2-3 corresponds to the protection or vulnerability characteristic of the artifact. For example, X10 (protection code index), U11 (vulnerability code index).

TABLE 4 RESULTS OF TESTING THE ELEMENTS OF PROTECTION

№	Control artifacts	State of the protection element
1.	Web server	Y1(4)
2.	File server	X2(3)
3.	Mail server	X3(2), X3(3)
4.	Router M-gw1	X4(1), X4(2)
5.	Switch Sw-dsw1	X5(1), X(2)
6.	Switch Sw-asw1	X6(5), X6(6), Y6(9), X6(7)
7.	Switch Sw-asw2	X7(5), X7(6), X7(7), X7(9)
8.	Switch Sw-asw3	X8(5), X8(6), X8(7), X8(9)
9.	Switch Sw- asw4	X7(5), X7(6), X7(7), X7(9)
10.	Computer PTD-1	X10(13), X10(14), X10(15), X10(16)
11.	Computer PTD-2	X11(13), Y11(14), Y11(15), Y11(16)
12.	Computer FEO	X12(13), X12(24), X12(15), X12(16), X12(17)
13.	Computer AD	X13(13), X13(24), X13(15), X13(16), X13(17)
14.	Computer U-1	X14(13), X14(24), X14(15), X14(16), X14(17)
15.	Computer U-2	X15(13), X15(24), X15(15), X15(16), X15(17)

With the help of arrays 1,2,10, array 11 - an array of artifacts with the corresponding codes of threat and vulnerability features (Table 5) formed.

TABLE 5 RESULTS OF TESTING FOR THE FORMATION OF AN ARRAY OF ARTIFACTS

№	Control artifacts	State of the protection element
1.	Web server	Y1(4)
2.	File server	Y1
3.	Mail server	x2
4.	Router M-gw1	x3
5.	Switch Sw-dsw1	x4
6.	Switch Sw-asw1	Y5
7.	Switch Sw-asw2	Y6
8.	Switch Sw-asw3	x7
9.	Switch Sw- asw4	x8
10.	Computer PTD-1	x9
11.	Computer PTD-2	x10
12.	Computer FEO	Y11
13.	Computer AD	x12
14.	Computer U-1	x13
15.	Computer U-2	x14

VI. ANALYSIS OF POSSIBLE VARIANTS OF UNAUTHORIZED ACCESS THREATS TO ELECTRONIC RESOURCES OF A COMPUTER NETWORK.

The results of data analysis, using arrays 3, 4, 5, 6 and 11, summarized in Table 6.

Let's consider possible variants of threats of unauthorized access to the computer network ER, according to the results of testing to form an array of artifacts:

A. "Insecure Password Recovery" vulnerability, where the Web server allows an attacker to unauthorized obtain, modify, or recover the password of a PTD-2 computer user.

Possible Threats:

- Denial of Service (DoS - attack) - an attack on some system resource to bring it to failure.

B. Switch Sw-asw1 Vulnerability "The switch Port security feature is not configured correctly".

Possible Threats:

- MAC-spoofing attack, which changes the MAC address on a switch's network card, causing packets to be sent to the port to which the attacker is connected.

C. PTD-2 Computer vulnerability "MAC authentication not properly configured" opens unauthorized access to the network when it connects to the switch.

Possible Threats:

- Man in the middle (MitM) - The attacker is between two victims, either listening to the traffic that is passed between them or intercepting it and spoofing it. At the same time, for the victims of the attack, there are no visible signs of the attack;
- Denial of Service (DoS attack) - an attack on a system resource to bring it to failure.

TABLE 6 RESULTS OF TESTING FOR THE FORMATION OF AN ARRAY OF ARTIFACTS

№	Control artifacts	Vulnerable electronic resources			Possible attacks on vulnerabilities of electronic resources
		Y1(4)	Y6(9)	Y11(14)	
1.	M-gw1				
2.	Web server	yes			“Denial of service”, attack on Y1(4)
3.	File server				
4.	Mail-server				
5.	Sw-dsw1				
6.	Sw-asw1		yes		“MAC spoofing” attack on Y6(9)
7.	Sw-asw2				
8.	Sw-asw3				
9.	Sw-asw4				
10.	PTD-1				
11.	PTD-2			yes	“Man in the middle” attack on Y11(14) “Denial of service” attack on Y11(14)
12.	FEO				
13.	AD				
14.	U-1				
15.	U-2				

sw-asw3	D8=0
sw- asw4	D9=0
PTD-1	D10=0
PTD-2	D11=1
FEO	D12=0
AD	D13=0
U-1	D14=0
U-2	D15=0

The threat characteristic U_j is defined as the sum of the characteristics [10] of the ER threats on the interaction path of two end-users.

Let us index the parameter D_t by index j (1,2,...,m). We define U_j using the data for threat characteristics from the following expression:

$$j = \begin{cases} \sum_1^q Dq, & 0 < \sum_1^q Dq < Lj \\ 0, & \sum_1^q Dq = 0 \end{cases},$$

where the index q , is defined by the number of vulnerable ERs on the path with index j . The results of the U_j calculations summarized in Table 7.

VII. INFORMATION SECURITY RISK ASSESSMENT IN CASE OF UNAUTHORIZED ACCESS

Assessment of IS risk from unauthorized access threats is based on the data in Table 7. Let us introduce notations for the following parameters [4]:

- Pg – threat attribute of one ER vulnerability;
- D_t – threat characteristic of an ER threat as a sum of threat attributes;
- U_j – characteristic of the set of ER threats on the path with index j . The line of information interaction between the end user of one Vlan and the end user of another Vlan taken as the path with index j .
- V_j – IS risk of the path with index j from one end-user to another end-user;
- V – IS risk of the computer network

To estimate D_t , we index Pg by the index t ($t=1,2,...,15$). In this case, the sign Pgt at the intersection of the vulnerability column g and row t of the ER of Table 7 takes the value 1 if vulnerability occurs, otherwise 0. The value of D_t is determined by the following expression:

$$D_t = \begin{cases} 0, & \sum_{g=1}^4 Pgt = 0 \\ \sum_{g=1}^4 Pgt, & \sum_{g=1}^4 Pgt > 0 \end{cases},$$

According to the results of calculations, the following values for threat characteristics D_t , ($t = 1,2, \dots, 15$) are obtained:

M-gw1	D1=0
Web-server	D2=1
File-server	D3=0
Mail-server	D4=0
sw-dsw1	D5=0
sw-asw1	D6=0
sw-asw2	D7=0

TABLE 7 RESULTS OF THE DATA ANALYSIS

№	Information paths in the graph of a computer network							U_j	U_j
1	a1	a10	a8	a5	a7	a2		1	1
2	a1	a10	a8	a5	a7	a3		0	0
3	a1	a10	a8	a5	a7	a4		0	0
4	a1	a12	a8	a5	a7	a2		1	1
5	a1	a12	a8	a5	a7	a3		0	0
6	a1	a12	a8	a5	a7	a9	a4	0	0
7	a1	a13	a8	a5	a7	a2		1	1
8	a1	a13	a8	a5	a7	a3		0	0
9	a1	a13	a8	a5	a7	a9	a4	0	0
10	a1	a14	a8	a5	a7	a2		1	1
11	a1	a14	a8	a5	a7	a3		0	0
12	a1	a14	a8	a5	a7	a9	a4	0	0
13	a1	a11	a6	a7		a2		3	1
14	a1	a11	a6	a5	a7	a3		2	1
15	a1	a11	a6	a5	a7	a9	a4	2	1
16	a1	a15	a6	a5	a7	a2		2	1
17	a1	a15	a6	a5	a7	a3		1	1
18	a1	a15	a6	a5	a7	a9	a4	1	1
19	a1	a11	a6	a5	a8	a12		2	1
20	a1	a11	a6	a5	a8	a13		2	1
21	a1	a11	a6	a5	a8	a14		2	1
22	a1	a15	a6	a5	a8	a1		1	1
23	a1	a15	a6	a5	a8	a12		1	1
24	a1	a15	a6	a5	a8	a13		1	1
25	a15	a6	a5	a8	a14			1	1
26	a11	a6	a5	a8	a10			2	1

The IS risk of end-user ER information interaction on the path V_j , ($j= 1,2,...,15$) is determined from the expression:

$$V_j = \begin{cases} 1, & 0 < U_j \\ 0, & U_j = 0 \end{cases}$$

The results of IS risk on the path V_j are summarized in Table 7. The vertices of the graph are identified with the corresponding ERs of the network and labeled with symbols ak , ($k = 1, 2, \dots, 15$).

To assess the IS risk, let us represent the computer network (Figure 2) as a finite graph (Figure 3). In Figure 2, the shaded nodes of the graph simulate the vulnerabilities of the electronic resources of the computer network. With the help of the graph, using Table 7, it is possible to identify a subgraph of the part of the computer network exposed to IS risk (Figure 3), as well as the part not exposed to IS risk (Figure 4).

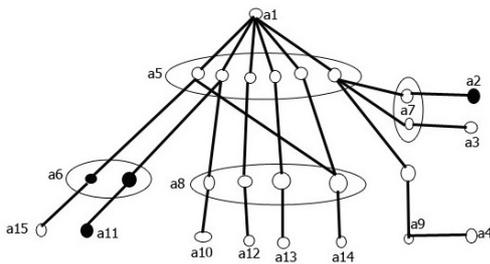


Fig. 2. Simplified diagram of the organization's computer network.

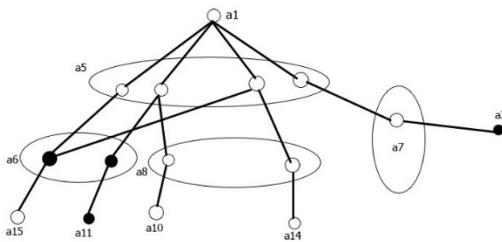


Fig. 3. Subgraph of the part of computer network exposed to information security risk.

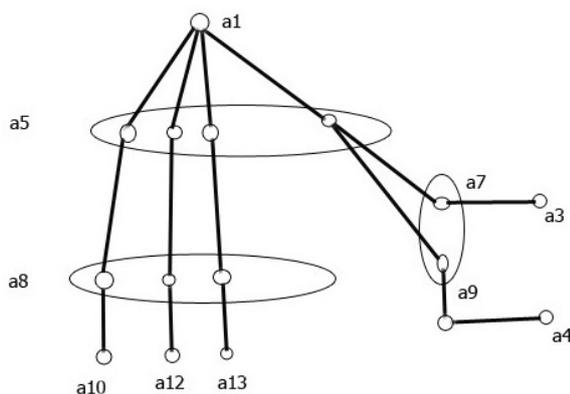


Fig. 4. Subgraph of the part of computer network not exposed to information security risk.

Table 7 shows that the total number of end-user ER interaction paths is 26 and the number of exposed paths is 18. The IS risk value of a computer network is calculated by the following expression:

$$V = f(x) = \begin{cases} \sum_1^n V_j, & \sum_1^n V_j > 0 \\ 0, & \sum_1^n V_j = 0 \end{cases},$$

where $n = 26$ is the total number of end-user interaction paths. Calculating the risk of IS, computer network, by the above expression, show that the percentage of V is: $V = (18/26) \times 100 = 70\%$.

The risk of information security of a computer network with identified vulnerabilities is high. Mitigation measures are required.

Information Security Risk Mitigation Solutions. The following actions are required to reduce IS risk in case of threats that disrupt the computer network:

- selection of the optimal mode of secure operation of the information system for the current situation;
- selection of the optimal service discipline for local and remote users communicating with the information system;
- switching on the reserve ERs of the system in case of their overloaded state;
- blocking of some nodes of the computer network for some time or until a new situation occurs;
- blocking of service requests for a certain category of information system users;
- blocking of some modes of operation of the information system, etc.

Depending on the situation, the minimum IS risk is achieved by performing one or more of the above actions.

VIII. CONCLUSION

Information security risk assessment is an important part of a comprehensive approach to information security. In this regard, a prerequisite for protecting electronic resources is the process of analyzing and then assessing IS risks for their subsequent identification as a possible threat and taking appropriate countermeasures to manage them.

In the paper we proposed the principles of IS risk assessment in case of threats of unauthorized access to the computer network ER, and developed a methodology for determining the IS risk, which is based on the recognition of signs of threats of unauthorized access to ER. The effectiveness of the proposed methodology is considered on a specific example of application of the methodology of IS risk assessment at possible threats of unauthorized access to the computer network ER. The study has shown that to assess the IS risk to the network requires information about vulnerabilities that open unauthorized access to its ER, as well as knowledge about the ways of interaction of end users of the network.

REFERENCES

- [1] J. Bhattacharjee, A. Sengupta and C. Mazumdar, "A formal methodology for Enterprise Information Security risk assessment," presented at 2013 International Conference on Risks and Security of Internet and Systems (CRISIS), La Rochelle, France, 2013.
- [2] A. Shameli-Sendi, R. Aghababaei-Barzegar and M. Cheriet, "Taxonomy of Information Security Risk Assessment (ISRA)," *Computers & Security*, vol. 57, pp. 14-30, 2016.

- [3] Y. Ye, W. Lin, S. Deng and T. Zhang, "A Practical Solution to the Information Security Risk Evaluation Problems in Power Systems," presented at 2014 International Conference on Future Computer and Communication Engineering, Tianjin, China, 2014.
- [4] R. Khamdamov, K. Kerimov and J. Ibrahimov, "Method of Developing a Web-Application Firewall", Journal of Automation and Information Sciences, vol. 51, pp. 61-65, 2019.
- [5] S. Bezzateev, T. Elina, V. Mylnikov and I. Livshits, "Methodology of information systems risk assessment based on the analysis of user behavior and information security incidents," Scientific and Technical Bulletin of Information Technologies, Mechanics and Optics, vol. 21, pp. 553-561, 2021.
- [6] F. Krachten , Introduction to Rational Unified Process - 2.ed.: Williams, 2002.
- [7] A. Astakhov, The Art of Information Risk Management. M: DMK Press, 2010.
- [8] P. Khorev, Methods and means of information protection in computer systems. M: Helios, 2006.
- [9] S. Zapechnikov, Information security of open systems. In 2 vol. Vol. 1 Threats, vulnerabilities, attacks and approaches to defense. M: GLT, 2017.
- [10] V. Opanasenko, S. Kryvyi, "Synthesis of Adaptive Logical Networks on the Basis of Zhegalkin Polynomials", Cybernetics and Systems Analysis, vol. 51, pp. 969-977, 2015.

Applying the Python Programming Language and Arduino Robotics Kits in the Process of Training Future Teachers of Computer Science

Vitalii Kyslitsyn

Vinnytsia Mykhailo Kotsiubynskyy
State Pedagogical University
Vinnytsia, Ukraine
v.kyslitsyn@vspu.edu.ua

Lyudmila Shevchenko

Vinnytsia Mykhailo Kotsiubynskyy
State Pedagogical University
Vinnytsia, Ukraine
l.shevchenko@vspu.edu.ua

Volodymyr Umanets

Vinnytsia Mykhailo Kotsiubynskyy
State Pedagogical University
Vinnytsia, Ukraine
umanets@vspu.edu.ua

Lina Sikoraka

Zhytomyr Medical Institute of the
Zhytomyr Regional Council
Zhytomyr, Ukraine
sikoraka@ukr.net

Yaroslav Angelov

Vinnytsia Mykhailo Kotsiubynskyy
State Pedagogical University
Vinnytsia, Ukraine
angelovyaroslav@gmail.com

Abstract. The article explores the possibilities and advantages of applying the Python programming language for using Arduino robotics kits in the process of training future computer science teachers in pedagogical institutions of education. Considerable emphasis is placed on analyzing the principles of operation of simple programs and devices. This analysis visualizes the possibilities of using the Arduino platform and Python libraries to create robots that can be implemented in education and everyday life. The authors have presented a working model of a robot built and programmed on the basis of Arduino components to measure humidity in computer laboratories and develop automatic plant irrigation systems to maintain appropriate conditions in classrooms. They also provide an example of integrating the learning of the Python programming language with the use of Arduino robotics kits. This method aims to enhance the quality of training for future computer science teachers, broaden their methodological toolkit, and equip them with the ability to teach students using innovative methods. The study's results and the developed teaching materials aim to increase students' interest in STEM education and prepare a new generation of computer science teachers for the challenges of the modern technological world. This will expand their methodological arsenal and develop their ability to use integrated technical, engineering, and mathematical solutions to solve theoretical and practical problems. This study can serve as a guide for popularizing the use of Arduino and Python in educational institutions. It may encourage future computer science teachers to introduce STEM and practical teaching methods, which can contribute to better student learning and improve the quality of professional education in the field of information technology. The study

presents opportunities for utilizing modern digital technologies in vocational education and encourages interest in STEM education among computer science teachers and students. This contributes to the development of a new generation of engineers and technology leaders. Further research could focus on developing targeted training courses and methods for integrating the Python programming language and Arduino robotics kits into STEM education. It is crucial to create interdisciplinary STEM courses with the involvement of computer science, physics, mathematics, and vocational education teachers in the IT industry.

Keywords: *Arduino; Python; STEM education; Arduino programming; computer science teacher.*

I. INTRODUCTION

Problem statement. Nowadays, robotics and programming are becoming increasingly popular and integrated into education. Robots are becoming ubiquitous in our daily lives and education. For example, we use them to process Bigdata or to observe phenomena that require round-the-clock monitoring.

This also applies to education, as the inclusion of robotics in educational programs guides us to understand the principles of using robots and programming to train computer science teachers. This study also takes into account the importance of integrating STEM (Science, Technology, Engineering, Mathematics) technologies into the educational process.

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8026>

© 2024 Vitalii Kyslitsyn, Lyudmyla Shevchenko, Volodymyr Umanets, Lina Sikoraka, Yaroslav Angelov.

Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

After all, STEM is an approach to education that combines different sciences, technologies, engineering creativity and mathematical thinking. Interdisciplinarity is an important concept in STEM education and is considered a pedagogical innovation. The main challenge in developing STEM curricula is integrating related yet independent disciplines. This requires careful consideration of established ontologies. Science as a way of knowing that helps to understand the world around us:

- "Technology as a way to improve the world, which is sensitive to social changes;
- Engineering as a way to create and improve devices for to solve real-world problems;
- Mathematics as a way of describing the world (analyzing the world and real problems with the help of numbers)" [1].

STEM is a suitable field for learning scientific knowledge and engineering skills, promoting the development of critical thinking and innovative solutions in technology and science. Integrating STEM technologies creates a practical learning environment that supports the development of creativity and technical abilities for both students and teachers. STEM is an educational paradigm that emphasises scientific, technological, engineering, and mathematical aspects of learning. The approach aims to develop critical thinking, problem-solving, creativity, and practical skills among students, creating the basis for future scientific and technological innovation. STEM education not only trains a new generation of science and technology professionals but also enhances the intellectual level of society and promotes the development of engineering solutions to various global challenges. This approach is widely used in modern educational programs and fosters creative and innovative approaches to solving complex problems in all spheres of life. The level of development of educational systems achieved today in the developed countries of the world is a significant factor in their intellectual, economic, social, scientific, technical, innovative, technological and cultural development, which largely ensures the stability and evolutionary nature of development in these countries, allows to improve the life structure, deepen democratic processes, gradually increase the spiritual and material level of peaceful, creative life of the population - the main goal of the progressive development of man and society [2].

According to scientists Bykov V., Boichuk V., Morse N., Umanets V., teachers of the State Vocational School Vinnytsia Interregional Higher Vocational School, Higher Vocational School No. 11, and the State Vocational School Vinnytsia Higher Vocational School of Services, teachers are not fully capable of implementing this type of program in the educational process. However, STEM education is gradually spreading in the Ukrainian educational space, which to some extent compensates for this issue. Because STEM technology is an important part of modern education, as it helps to develop the relevant competencies of teachers and students in science, technology, engineering and mathematics [3].

One of the areas of application of STEM education is robotics. This is an applied science that deals with the development of automated technical systems. Robotics in the educational process takes the form of variable modules

that, with the help of ICT and educational tools, give students the skills to design robots and write programs to control them. Research and publications show that using Python to control Arduino robots has great potential. This was considered by such scientists as: Dayal Vanambathina V. Krushynskyi, Y. Lebedieva, Lee E, V. Loshak, Sikora O. V., D. Montefusco, Morze V., E. Chorny, E. Myronenko, O. Lysenko.

Python is a widely used programming language that simplifies project development. It has a large user base and numerous libraries that can be used to program Arduino robots. Many publications provide code examples and explain how Python and Arduino interact, which can extend robot functionality and create new programs.

Additionally, using Python to control Arduino robots has great potential in STEM education. Python is a programming language that is accessible to beginners, making it easy to learn how to code and program robots. Python is widely used in educational projects and programs to program robots, demonstrating its popularity in this field.

Arduino is a popular platform for developing electronic projects, and using Python in conjunction with it simplifies and improves the development of these projects. The Python programming language is known for its simplicity and accessibility, making it an ideal choice for both beginners and experienced developers. Additionally, the large community of Python users and feature-rich libraries make it easy to interact with Arduino, expand the capabilities of robots, and create new programs. A plethora of publications and code examples are available, making the process of learning and developing for Arduino using Python accessible and informative.

II. MATERIALS AND METHODS

The aim of this study is to investigate the potential advantages of using Python programming language with the Arduino platform in STEM education. The study will explore how this combination of tools can benefit computer science teachers and create interactive and practical learning environments for students.

The study of using Python and Arduino in STEM education is an urgent task. Today, the level of digital competence among teachers does not fully meet the demands of the modern technological era. Introducing programming and robotics in schools creates the preconditions for training qualified engineering and technical personnel in the future. STEM education enables the organic integration of natural science, technology, engineering, and mathematical knowledge to solve practical problems. This contributes to the development of skills in applying the acquired competence in practice, stimulates interest in natural sciences and develops logical thinking. In particular, in the training of future skilled workers in such specialties as: 4113.7241 Information and Software Processing Operator and Electromechanic for the Repair and Maintenance of Computing Machines (based on 9th grade), 7241 Electromechanic for the Repair and Maintenance of Computing Machines (based on 11th grade), 7242 Installer of information and communication equipment, which are provided by such vocational schools as the State Vocational School "Vinnytsia Interregional

Vocational School", Higher Vocational School No. 11 and Vinnytsia Higher Vocational School of Services. The higher education institution where the authors work has existing cooperation agreements with the above-mentioned vocational education institutions (<https://vspu.edu.ua/?p=first>). In particular, the authors cooperate with the STEM Laboratory of the State Vocational Educational Institution "Vinnytsia Interregional Higher Vocational School".

The Arduino platform is an ideal tool for STEM education due to its accessibility, simplicity, and versatility. Arduino boards can interact with a variety of sensors and devices to collect environmental data and control motors,

lights, pumps, and more. Programming these devices using Python provides ample opportunities for interactive and project-based learning. Students can create weather stations, smart home systems, robots, and more.

The study aims to analyze the application of Arduino and Python in educational projects, specifically in creating a system for measuring humidity and an automated irrigation system. The study will focus on the principles of collecting sensor data, processing them in Python, and controlling actuators to enhance the understanding of software and hardware interactions. This text demonstrates the potential of using Arduino and Python to create solutions for real-life tasks.

The study's results will serve as methodological guidelines for teachers on the use of programming and robotics in STEM education. The proposed projects can be modified and adapted to different age categories and used to teach computer science, physics, mathematics, engineering, and technology. Involving schoolchildren in the creation of such solutions can increase motivation and develop logical and computational thinking, as well as skills in the exact sciences and engineering. Therefore, studying the use of Python and Arduino has significant practical significance for improving the quality of STEM education, developing effective teaching methods, and training IT teachers.

III. RESULTS AND DISCUSSION

The Research Laboratory on the use of information technologies in education at Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University (VSPU), which includes, one of the authors, who is the responsible person for occupational health and safety at the Educational and Research Institute of Pedagogy, Psychology, and Training of Higher Education, members of the laboratory work closely with the departments of biophysics at Vinnytsia Pirogov National Medical University and the Institute of Digitalization of Education at the National Academy of Sciences of Ukraine. During our research, we concluded that the Arduino platform is suitable for developing control systems for switches and sensors. These systems can control a range of indicators, motors, and other devices. Arduino-based modules are autonomous and can interact with computer software. Python is a suitable software for implementing various projects that benefit society. To work with Arduino, you can use the Python libraries that are designed to program robots, which are listed below:

- PySerial is a library that enables communication between Python and Arduino via the Serial port. It provides functions to open, close, and configure the Serial port, as well as transfer data between Python and Arduino.
- Firmata is a library that enables communication between Python and Arduino using the standard Firmata protocol. It provides functions to control pin outputs and read data from sensors using common Firmata commands.
- PyMata is a Python wrapper for the Firmata library. PyMata is a library that provides a simpler and more convenient interface for interacting with Arduino. It enables control of pins, sensor data reading, servo control, and more.
- The Arduino library allows for direct code writing in the Python environment and the ability to rewrite Arduino sketches in Python for robot control.
- Johnny-Five is a JavaScript library that facilitates interaction with Arduino and other boards. It is capable of supporting a wide range of sensors and devices, and features a user-friendly and straightforward interface for interacting with them.

An example of using Python libraries and Arduino sensors is to collect data on indoor humidity and save it in a text file.

The main component for collecting indoor humidity data is a humidity sensor, such as the DHT11. By connecting this sensor to an Arduino and using PySerial, we can collect and write data to a text file.

This requires only a minimum set of components. For this project, we utilized either an Arduino UNO, Arduino Nano, or Arduino Mega, along with a DHT11 or DHT22 temperature sensor module. In our specific case, we opted for the DHT11 temperature sensor module, a breadboard, and connecting wires.

The DHT11 is a digital sensor that measures both temperature and humidity, and allows for calibration of the digital output signal. It is composed of a capacitive humidity sensor and a thermistor. The sensor includes an ADC for converting analog humidity and temperature values. These are the characteristics of the ADC:

- Power supply and I/O 3.5-5.5 V
 - Determination of humidity 20-95% with 5% accuracy
 - Temperature detection 0-50 deg. with an accuracy of 2 deg.
 - Polling frequency no more than 1 Hz (no more than once every 1 sec.)
 - Dimensions 15.5mm x 12mm x 5.5mm
 - 4 pins with a leg spacing of 2.54mm
- Conclusions:
- Vcc (3-5V power supply)
 - Data out - Data output
 - Not used
 - General.

After selecting the components, the next step is to connect to the Arduino (Fig. 1.). Let's describe the main

points. The module is equipped with a three-pin connector of the 2.54mm standard, to G - connect to GND, V - connect to the +5V pin, S - connect to the digital pin (in the example D4).

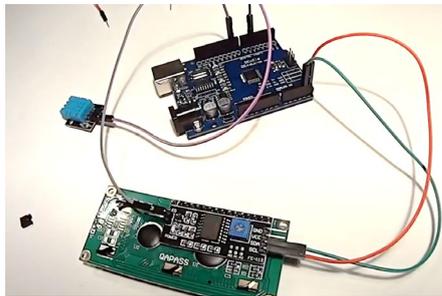


Fig. 1. Mounting the Arduino unit with the DHT11 sensor

After connecting the appropriate sensor (in our case, DHT11), you need to "fill" (download) the sketch for operation. For the DHT11 module to work, you need to download the library (Fig. 2.) and add it to the "libraries" folder in the Arduino IDE folder.

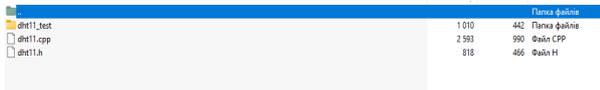


Fig. 2. Contents of the library for the DHT11 module

We recommend restarting the environment if it was running when you added the library.

Below is a sample sketch in which we will measure and send temperature and humidity data to the PC serial port (Listing.1.).

```

//Tested on Arduino IDE 1.0.5
#include // Add the DHT11 library
dht11 DHT; // declare a variable of
class dht11
#define DHT11_PIN 4 // The DHT11 sensor
is connected to digital pin number 4

void setup(){
Serial.begin(9600); // port speed
Serial.println("DHT TEST PROGRAM ");
// Print the text
Serial.print("LIBRARY VERSION: "); //
Print the text
Serial.println(DHT11LIB_VERSION);
Serial.println(); // Empty string
}

void loop(){
int chk;
;
// error monitoring
chk = DHT.read(DHT11_PIN); // reading
data
switch (chk){
case DHTLIB_OK:
break;
case DHTLIB_ERROR_CHECKSUM:
Serial.println("Checksum error, \t");
break;
case DHTLIB_ERROR_TIMEOUT:
Serial.println("Time out error, \t");
break;
default:

```

```

Serial.println("Unknown error, \t");
break;
}
// display the humidity and
temperature values
Serial.print("Humidity = ");
Serial.print(DHT.humidity, 1);
Serial.print(", Temp = ");
Serial.println(DHT.temperature,1);
delay(1000);
}

```

Listing.1. An example sketch in which temperature and humidity data are measured and sent to a PC serial port.

Below is the code to collect humidity data with the DHT11 sensor and save the data to a text file. (Listing.2)

```

import serial
import time
ser=serial.Serial('COM3',9600) #
підключення Arduino
while True:
try:
data=ser.readline().decode().strip()
if data:
humidity, temperature =
data.split(',')
# збереження даных у
текстовий файл
with
open('humidity_data.txt','a') as file:
file.write('f' {time.time()} ,
{humidity}, {temperature}\n')
except KeyboardInterrupt:
ser.close()
break

```

Listing.2. Code for collecting indoor humidity data

Thus, when you start the program and our robot, the process of data processing takes place. Our library connects to the Arduino board and starts a loop to process the data received from the DHT11 sensor and the end result is a file in which we will have data on time, humidity and temperature. The principle of Arduino operation using the DHT11 module under the control of the PySerial library is shown schematically on (Fig. 3.)

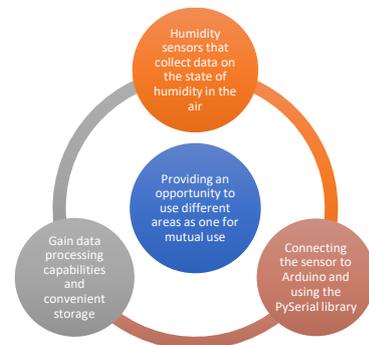


Fig. 3. Arduino and Python interaction diagram for robot control

Another example is an automatic garden irrigation system using Arduino, soil moisture sensors, and pumps. (Listing. 3.)

```
import serial
import time
ser=serial.Serial('COM3',9600) #
підключення Arduino
def pump_on():
    ser.write(b'H')
    print('Pump ON')

def pump_off():
    ser.write(b'L')
    print('Pump OFF')
while True:

moisture_data=ser.readline().decode().strip()
    moisture=int(moisture_data)
    if moisture < 400:
        pump_on()
    else:
        pump_off()
    time.sleep(1)
```

Listing. 3. Code for an automatic irrigation system

An automatic garden irrigation system uses a variety of elements and components. The main components for this are:

- Arduino - a microcontroller that is responsible for controlling the system and collecting data from the sensors.
- Soil moisture sensors - they measure the moisture level in the soil and transmit the data to the Arduino.

Soil moisture sensors are used to measure soil moisture, which are capable of determining moisture based on measuring the resistance between two electrodes installed in the soil. Soil moisture sensors can have different moisture measurement ranges, accuracy, and response speeds.

The most popular soil moisture sensors are:

Capacitive Soil Moisture Sensor

Resistance Soil Moisture Sensor

Frequency Domain Reflectometry Soil Moisture Sensor

Any of these soil moisture sensors can be used for an automatic garden irrigation system, depending on specific needs and requirements. The system includes pumps, which are controlled by the Arduino, and relays that turn the pumps on and off based on soil moisture levels.

Additionally, power supplies are used for the Arduino, sensors, and pumps.

Communication: To provide communication between the Arduino and a computer, USB cables and Bluetooth modules can be used, as well as to program the microcontroller.

Materials:

A variety of materials such as plastic, metal, and wood can be used to create an irrigation system, as well as tools and small parts to assemble and configure the system.

To develop professional competencies, numerous resources are available on the internet for creating various projects based on the Arduino platform.

<https://www.arduino.cc/en/software> - official website with software

<https://all3dp.com/2/most-useful-arduino-projects/> - Arduino projects

<https://projecthub.arduino.cc/> - Arduino projects on official website

The use of these innovative and informational [5-6] technologies in order to provide future skilled workers with constant access to educational materials makes it possible to work independently at a convenient time and in a convenient mode, allows you to free up time in the classroom for the educational process of high-quality professional training of future skilled workers in the service sector [4].

IV. CONCLUSIONS

This study examines the possibilities and benefits of using the Python programming language in combination with the Arduino platform to train computer science teachers and create interactive learning environments in the context of STEM education. The study analyzes the principles of Python libraries, such as PySerial, Firmata, and PyMata, which facilitate communication between Python and Arduino, control of outputs, and reading of data from sensors. The text provides specific examples of projects that use Arduino and Python, such as a humidity measurement system that uses a DHT11 sensor and stores data in a text file, and an automatic garden irrigation system that uses soil moisture sensors. The study emphasizes the importance of integrating STEM technologies into the educational process, as it contributes to the development of critical thinking, creative and practical skills, and the creation of innovative approaches to problem solving. The study concludes that the combination of the Python programming language and the Arduino platform meets the principles of STEM education.

It is promising both for the educational process and for creating useful inventions and projects for the benefit of society. These technolo

gies are simple and accessible, which allows for the development of innovative approaches in education and encourages interest in STEM among teachers and students.

The study's results indicate that educational materials created with Arduino and Python can enhance the skills of vocational teachers, broaden their methodological toolkit, and cultivate their capacity to teach with innovative technologies [7-9].

Future research could concentrate on designing specialized training courses and techniques for incorporating Python, Arduino, and STEM into educational programs for both teachers and students. The development of interdisciplinary STEM courses that involve teachers

from computer science, physics, mathematics, and other related disciplines is essential. These courses can aid in the preparation of well-rounded professionals for the future.

REFERENCES

- [1] L. M. Hrynevych, N. V. Morze, V. P. Vember, and M. A. Boyko, "The role of digital technologies in the development of the STEM education ecosystem", *ITZN*, 83, is. 3, pp. 1–25, June 2021.
- [2] T. P. Kobylnyk, O. V. Sikora, V. B. Zhydyk, and O. V. Sharan, "Python as a means for teaching the basics of algorithmization in general secretary education institutions", *Information Technologies and Learning Tools*, 89(3), pp. 16–32, 2022, <https://doi.org/10.33407/itlt.v89i3.4896>
- [3] STEM education: preparing for the work of the future: report. April 2012. [Online]. Available: http://www.jec.senate.gov/public/_cache/files/6aaa7e1f-9586-47be-82e7-326f47658320/stem-education---preparing-for-the-jobs-of-the-future-.pdf.
- [4] V. Boychuk, V. Umanets, and O. Boychuk, "Innovative technologies for training future skilled workers in the service sector in a vocational education institution", *Modern Information Technologies and Innovation Methodologies of Education in Professional Training Methodology Theory Experience Problems*, pp.140–146, 2020.
- [5] B. Rozputnia, L. Shevchenko, and V. Umanetz, "Creating a "Smart" computer science classroom at university", *Automation of Technological and Business Processes*, 15(2), pp. 72-75, 2023.
- [6] L. S. Shevchenko, V. O. Umanets, and B. M. Rozputnia, "The use of the ARDUINO platform in the training of computer science teachers on the principles of STEM learning". Electronic scientific professional publication "Open Educational E-SETTING of the Modern University", 15, pp. 130–138, 2023.
- [7] K. Zachariadou, K. Yiasemides, and N. Trougakos, "A low-cost computer-controlled Arduino-based educational laboratory system for teaching the fundamentals of photovoltaic cells", *European Journal of Physics*, vol. 3, № 6, 2012. <https://doi.org/10.1088/0143-0807/33/6/1599>
- [8] H. K. Kondaveeti, N. K. Kumaravelu, S. D. Vanambathina, S. E. Mathe, and S. Vappangi. A systematic literature review on prototyping with Arduino: applications, challenges, advantages, and limitations. *Comput. Sci. Rev.*40, May 2021. <https://doi.org/10.1016/j.cosrev.2021.100364>
- [9] E. Lee. "A meta-analysis of the effects of Arduino-based education in Korean primary and secondary schools in engineering education", *European Journal of Educational Research*, 9(4), pp.1503–1512, 2020. <https://doi.org/10.12973/eujer.9.4.1503>

Digital transformation of higher education: integrating multimedia systems into the study process

Evija Klave

Faculty of Business Administration
Turība University
Riga, Latvia
evija.klave@turiba.lv

Renate Cane

Faculty of Business Administration
Turība University
Riga, Latvia
renate.cane@gmail.com

Abstract. Higher education and digital transformation are two essential areas that interact and influence each other today. The rapid development of technology requires higher education institutions to provide students with the digital skills needed in the labor market and everyday life. At the same time, educational institutions are embracing digital solutions to improve the efficiency of the learning process and offer new opportunities for students and lecturers.

The digital transformation of higher education covers many areas, including integrating multimedia systems in the study process. This process refers to the use of digital technologies to enhance the learning experience by making it more interactive, accessible and effective. The integration of multimedia systems can include several aspects, including interactive classes, seminars and lectures on various collaborative platforms, interactive learning materials (e.g., interactive e-books, videos with 3D animations or simulations, virtual or augmented reality solutions), e-assignments and tests, automated assessment systems (data analysis and learning analytics). Also, multimedia systems can help universities to automate study administrative processes.

The aim of the study is to analyse the solutions for integrating multimedia systems in higher education, their potential for digital transformation of study courses and for increasing the efficiency of the study process.

The study used both qualitative and quantitative methods for data extraction and analysis. The study uses a case study approach - it evaluates the digitisation initiative of 12 distance and face-to-face bachelor level study courses of Turība University, integrating multimedia system solutions for asynchronous learning process into the course content and form. The case study analysis includes a student evaluation survey of the study courses through an online questionnaire, semi-structured interviews with course developers and lecturers, as well as document analysis.

As a result of the research, the authors conclude that the integration of multimedia systems in studying study courses provides additional support to students in strengthening their self-directed learning skills. At the same time, under the

influence of the digitalization of the study process, the space for both asynchronous and direct communication between lecturers and students, for the development of soft skills of students, as well as for the formation of practical knowledge and competences, increases the efficiency of the study process and the quality of education.

Keywords: digital transformation, higher education, interactive study process, multimedia systems.

I. INTRODUCTION

Analyzing economic development processes and the main factors influencing them, the works of economic analysts of the second half of the 20th century refer to the knowledge economy, which has already become a generally accepted term for this period. However, nowadays, with the rapid and even revolutionary development of various technologies (and this is especially true of the digital environment), to adapt to fast changes, ensure competitiveness, and promote sustainable development, comprehensive or in-depth knowledge is no longer enough. At a time when new technologies are constantly being developed in various fields, which often have a very short life cycle, because more technological solutions are constantly being sought, previously acquired knowledge and skills to use them become obsolete rather quickly or become irrelevant. Therefore, to achieve greater efficiency, the ability to apply or interpret knowledge innovatively and creatively becomes more and more essential. Because of these processes, the economy of the 21st century is called the economy of innovation, thus emphasizing a new approach to the acquisition or use of knowledge. Although these two economic models often interact and are interrelated, their main difference is their emphasis on resources and activities, which are considered the main drivers of the economy. A knowledge economy views knowledge as a central element of economic development, while an innovation economy places more

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8017>

© 2024 Evija Klave, Renāte Cane. Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

emphasis on the creation of new ideas and techniques and their commercialization to create economic value.

One of the most important concepts directly related to the innovation economy is digital transformation, whose impact is growing rapidly from year to year. As a concept, digital transformation envisages a significant transformation of an organization's operations and processes to create value by continuously implementing technologies on a large scale and thus creating competitive advantages, including reducing costs and improving the customer experience [1]. Researcher Gregory Vial also includes other processes in the definition of digital transformation: "Digital technologies create disruptions, triggering strategic responses from organizations that seek to alter their value creation paths while managing the structural changes and organizational barriers that affect the positive and negative outcomes of this process" [2].

Universities have traditionally been places where people acquire knowledge and develop themselves. However, digital transformation is changing this picture, offering new opportunities for both students and educational institutions themselves. This transformation process not only transforms teaching methodologies but also changes the way universities operate, making them more flexible, accessible, and efficient. The ever-increasing development of technology, the availability of the Internet, and the latest digital platforms have created new opportunities in the learning process. In addition, it should be taken into account that today's students are representatives of the digital generation, which is using technology on a daily basis. Thus, higher education institutions have to adapt to these new realities to maintain their importance and competitiveness in the educational market, and the main approach is the transformation of the learning process using the opportunities provided by digital technologies and the development of the digital learning space [3].

Digital transformation involves significant structural changes in four areas: organizational structure, organizational culture, leadership, and employee roles and skills. The digital transformation of higher education requires university leaders to create new and thoughtful partnerships throughout the institution to implement the transformation and involve all persons involved in the educational process to meet the needs of the university as a business unit, to quickly make informed decisions, balance risks and benefits, and broadly and rapidly implement innovations and improvements. Such an organizational culture should be aimed at all groups involved in the educational process that come into contact with each other—students, researchers, teaching staff, and other university employees—based on their knowledge and experience [4].

The implementation of digital transformation in universities brings many benefits. One of the most important is improving accessibility. With digital learning platforms and distance learning resources, students no longer need to be in person to participate in classes. This allows students to plan their time more flexibly and adapt their studies to their circumstances. In addition, digital technologies offer new teaching methods and tools that make learning more interactive and engaging; for example, virtual reality and simulations can help students better

understand complex issues or learn practice-oriented skills. However, digital transformation is not without its challenges. Even though new technologies offer opportunities for creativity and growth, one of the main problems is the need for significant financial investments to create and maintain modern digital infrastructures in universities or to integrate them into existing technologies. In addition, data security and privacy issues also need to be addressed, especially given that digital platforms can store large amounts of sensitive data and information about students. Likewise, resistance of staff and teaching staff to changes can be observed in practice, which can make it difficult to successfully integrate technology into the educational process [5].

One of the ways that organically fits into the digital transformation of the universities is the development of a multimedia environment and the use of its various channels and tools. They help adapt to the demands of today's technology, offer diverse learning experiences, and encourage student engagement. The role of multimedia in online course development has become a key factor in creating an engaging and effective learning experience. Positive factors associated with the use of multimedia in higher education:

- Enhanced Engagement and Retention: multimedia elements, such as videos, graphics, and interactive content, have a profound impact on student engagement and information retention. The combination of visual and auditory stimuli not only captures attention but also facilitates a deeper understanding of complex concepts. Engaged students are more likely to retain information and actively participate in discussions, creating a vibrant online learning community;

- Accessibility and Inclusivity: multimedia in online course design goes beyond text-based content, making educational materials accessible to diverse learners. Visual aids, for instance, benefit those with different learning preferences, and captioned videos ensure content accessibility for individuals with hearing impairments. Embracing multimedia promotes inclusivity and accommodates a wide range of learning styles, fostering an environment where every student can thrive;

- Real-world Applications: Integrating multimedia elements allows educators to bridge the gap between theoretical knowledge and real-world application. Videos, simulations, and case studies provide students with practical insights, enabling them to see how the concepts they learn in class are applied in professional settings. This approach not only enhances the relevance of the content but also prepares students for the challenges they may encounter in their future careers;

- Global Collaboration and Connectivity: Multimedia facilitates global collaboration by breaking down geographical barriers. Video conferencing, collaborative online projects, and multimedia-rich discussions enable students to connect with peers and experts from around the world. This interconnectedness not only broadens perspectives but also prepares students for a globalized workforce where effective communication and collaboration are essential skills;

- Adaptability and Personalization: multimedia supports the creation of adaptive and personalized learning

experiences. Through interactive quizzes, multimedia presentations, and self-paced modules, students can tailor their learning journey to their individual needs and preferences. This flexibility accommodates diverse learning paces and styles, empowering students to take control of their education [6].

Today, the inclusion of multimedia in the development of online courses in higher education is not only a trend but also a necessity, creating a dynamic, engaging, and inclusive learning environment. As educational institutions continue to embrace the digital environment, the transformative power of multimedia will play a central role in shaping the future of online education, facilitating rich and interactive educational experiences for students worldwide. It significantly changes the landscape of education, and keeping abreast of the current events of digital transformation helps higher education institutions operate efficiently, remain increasingly competitive in the digital world, and prepare students for the digital workplace.

II. MATERIALS AND METHODS

This study is approached from the methodology of evaluation research. It is a research approach that integrates into the design of action research. Action research can be defined as collaborative critical inquiry by reflexive practitioners who are both evaluating their practice and engaged in problem solving and continuous professional development related to the research environment and its object [7]. One of the types of action research is evaluation research that involves assessing the effectiveness and achievement of a specific programme, policy, intervention, or project. It aims to determine whether the intended objectives have been successfully attained and identifies areas requiring enhancement. The data obtained through evaluation research provides valuable insights into the overall value of the initiative. These findings inform decisions regarding the continuation, modification, discontinuation, or enhancement of future interventions.

The evaluation study combines qualitative and quantitative research methods [7]. Qualitative interviews aim not only to obtain data on the implemented activities, but also on the actors' assessment of the intervention and its possible further development, modification and improvement [8]. The research participants are directly involved in the reflection on the evaluation. Consequently, the analysis of the data, in line with the nature of the action research, takes place in continuous interaction with the study participants. The design of the evaluation research is characterised by the involvement of potential users of the research output, with implications on the way in which findings are articulated and presented [9]. Quantitative methods can be used for baseline measurements to capture the situation before an intervention, such as the introduction of a new study course design, and after an intervention, to assess the impact of the implemented actions on the direct target groups, draw conclusions and make decisions on future actions.

The object of the authors' study is 12 bachelor level study courses and their digitisation process, which was implemented as a wider activity of the European Social Fund project "Digitisation initiatives for improving the

quality of studies in the areas of strategic specialisation of universities" (No 8.2.3.0/22/A/005). The digital transformation of study courses is evaluated as a key intervention in the framework of this study. The research environment is Turība University (Latvia) and the university's distance learning digital platform, the main target groups are lecturers and students of the specific study courses, as well as strategic experts in methodology and use of information technologies involved in the planning and implementation of the intervention. The study uses both qualitative and quantitative research methods in parallel: the analysis of secondary data from student surveys (n=87; n=46) before and after the intervention, qualitative interviews of lecturers involved in the project (n=8) and document analysis, analysing documents on the process of developing the digitisation methodology, guidelines for the structure, form and content of the developed study courses, documentation on the project implementation, which reflects the process of the intervention under study. The questions of the qualitative interviews with lecturers covered the following thematic blocks: evaluation of the course digitalisation process, use of methods in the digitised study process, impact on students' performance and lecturers' professional competence. Descriptive statistical methods were used in the analysis of quantitative data, while qualitative data and documents were analysed using thematic analysis.

III. RESULTS AND DISCUSSION

The intervention involved the digital transformation of 10 distance learning courses of the Professional Bachelor's degree programme and the development of two new courses, which were planned to be developed both as face-to-face courses and as distance learning courses on the university's distance learning platform. The objectives of the digital transformation of study courses (defined as an intervention in the context of this study) were: first, to create model courses by developing guidelines and support materials for creating courses in a digital environment; second, to promote the use of interactive tools and multimedia systems in the creation of courses; third, to find technical and study process organisation solutions in order to introduce practices for the maximum use of these courses in the implementation of face-to-face study programmes; fourth, to develop and strengthen students' digital competences through the digitisation of the study process.

The 10 distance learning courses evaluated in this study had already been developed and implemented in the distance learning environment of the university before the intervention, but their design and the methods used in the asynchronous learning process were not appropriate for a modern learning process characterised by a shift from lecturer-facilitated learning to self-regulated and further to self-directed learning. Self-directed learning cuts across all domains of learning and has a significant potential in shaping transformational learning experiences. The students learn on their initiative and have primary responsibility for planning, implementing, and evaluating the effort. The content needs to be delivered through a teacher or a facilitator who communicates with the learner through face-to-face discussion, virtual online, or email posts. On the other hand, self-paced learning needs the learner to be motivated, oriented towards learning, and

competent to choose suitable resources for the required content [10].

To ensure that the study process in the digital environment can take place and that the goals and objectives of each study programme are achieved, the digital competences of students are an essential prerequisite. Prior to the implementation of the intervention, an initial assessment of students' digital competences in five categories – information and data literacy, communication and collaboration, digital content creation, digital safety and problem solving – was carried out. Within each category, several sub-categories were identified, making a total of 21 competences covered by the digital competences assessment. The questionnaire was uploaded to the university information system for those groups of students whose study programmes included one of the courses under development in the relevant semester (the questionnaire was distributed in September 2023). The survey was completed by students of the undergraduate programmes in Business Administration, Business Logistics Management and Marketing and Sales Management. The results obtained are not generalisable, as they are applicable to the survey population, given the method of conducting the survey (online questionnaire, voluntary). The results of the survey are presented in Figure 1. In all categories of digital competences, the level of the majority of students is average.

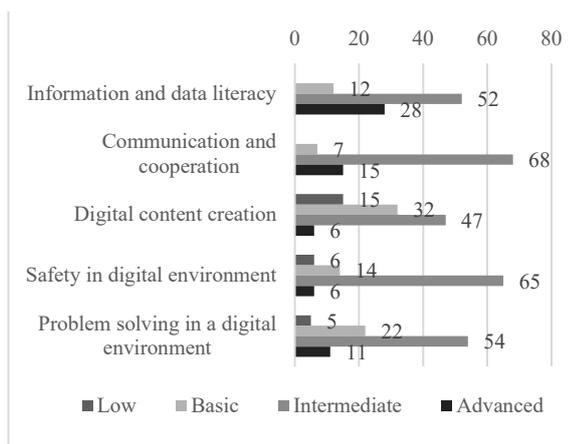


Fig. 1. Level of students' digital competences (n=87, %)

The intervention process was carried out in a series of sequential steps – preparation, development, implementation and initial impact assessment. The initial guidelines for course development were developed during the preparation phase, which included, firstly, guidance on the structure of the course content outline, secondly, methodological recommendations for the student assessment process both during the course and at the end of the course, thirdly, requirements for the inclusion of interactive tools and multimedia systems, fourthly, guidance on the development of digital competences for students. During the preparatory phase, lecturers' training sessions were also held, during which the thematic structure of the study courses, technical design, possibilities of using multimedia systems were jointly discussed. The data obtained from the interviews of the lecturers during the preparatory phase show that they had the greatest difficulty integrating interactive tools into the course content in order to ensure asynchronous communication with the students. To this end, training was

organised for lecturers on the Html-5-Package (H5P) tool and its possibilities of use. H5P is a plug-in tool designed for the creation of a wide variety of interactive content.

During the course development phase, lecturers reviewed the existing course content and updated the reading material, supplementing it with visual material, prepared video lecture presentations following a common design, filmed and then technically processed and edited video lectures, integrating interactive tasks, developed self-assessment tasks and tests to be carried out during the study course, using interactive tools and methods where possible, instructions for taking the tests, as well as references for additional resources to be used. The material prepared by the lecturers was passed on to the technical staff, who uploaded the material to the university's moodle environment. Throughout the course development phase, both methodological and technical support was provided to the lecturers. The most support was needed for the inclusion of H5P tools in the course of study, which was new for most of the lecturers and created a need to acquire new digital and methodological competences. The final activity of the development phase was to carry out a quality check of each study course at two levels. This was first carried out by the lecturer and then by a strategic expert in course development. For the purpose of the quality check, a course development checklist was prepared covering all components of the course.

The structure of the distance learning courses was the same for all courses - introduction, course content outlined in thematic blocks, self-testing tasks, current and final examinations. As already indicated above, the outline of each topic required the integration of H5P tools, with the aim of ensuring as interactive as possible asynchronous study process on the one hand and creating favourable conditions for an effective self-directed study process in a digital environment on the other hand. In the introductory part of the study course, the lecturer's task is to provide information on the aim, objectives, thematic plan, assessment criteria and recommendations for the learning of the course. This information should be included in the distance learning learning environment (moodle) in written and video format. In order to create the effect of the lecturer's presence and interaction between the lecturer and the student, a video introduction of the lecturer was prepared, lasting up to five minutes, in which the lecturer introduces himself/herself and verbally presents all the information related to the study course. The introductory part of the course also includes a glossary of commonly used terms and concepts, which allows the student to clarify or recall the meaning of a particular term at any point during the course. The content of the course was structured in thematic blocks, while the presentation of each topic was organised according to a common structure. At the beginning of the topic, the student is presented with the competences to be acquired according to the cognitive skills assessment categories of Bloom's taxonomy [11] and the digital competences according to levels 5-6 of the DigComp 2.1 framework [12].

Each topic is first presented by the lecturer in a video lecture, which integrates interactive tools and a lecture presentation based on a common, pre-defined design. The total duration of the video lectures per course was initially set at six academic hours or 270 minutes. Following the development of the courses, this criterion was modified to

define the total duration of the video material to include both the delivery of the lecture and other video material that complements the learning of the course content.

The purpose of using H5P tools in the presentation of course content is to ensure interactivity between the lecturer and students, as well as to create dynamic and varied learning of course content. All lecture presentations in the moodle environment were included in the H5P format. In each video lecture the lecturers included a number of interactive questions that the learner has to answer before continuing to listen to the video lecture. After each such question, the lecturer also included feedback on the answers to the questions in the video lecture, allowing the learner to self-assess his/her performance and to re-listen to the previously presented material as needed. In each course, the lecturer was required to include at least one branching scenario as one of the practical activities. The branching scenarios are learning opportunities that depend on the choices made by the students. They require the user to make decisions and then reflect the consequences of the action taken. For example, in the course Research “Methods and Presentation Skills”, a branching scenario task was to identify the steps to be taken in a study to find out students' satisfaction with a university parking service. In the course “Record-keeping”, the objective of the branching scenario was to follow the correct sequence of steps for filing an electronically signed appeal with the court.

Each video lecture is accompanied by reading material in text form with visualisations (images, diagrams, etc.) prepared by the lecturer. In addition to this compulsory material, the lecturer also provides guidance on additional resources for learning the topic, e.g. literature, websites, broadcasts, videos, etc. In several courses, lecturers supplemented the content with interviews with industry experts, managers of real companies, thus creating synergies between theory and practice. In face-to-face studies, this function is performed by the lecturer or guest lecturers, so video interviews with invited experts are seen by lecturers as a way to ensure this in an asynchronous study process.

At the end of the topic, the student is given the opportunity to complete self-assessment exercises, which are not graded, but which allow students to monitor their own progress in the topic and to be aware of the need to revise the topic or any issues related to it. In designing the self-assessment tasks, the lecturers' responsibility was to design them in such a way that they required the student to apply digital competences in order to develop or acquire new ones. For example, in the course “Project Management”, the assignment was to review the Project Management Institute website, select from the “Case Studies” section an article of interest to the student on the application of project management methodology to a real business problem and prepare a short presentation with video commentary on the main information and the student's opinion on the article.

According to the lecturers' interview results, within the study course digitisation process they had improved their digital skills in asynchronous communication, learned new technology-based teaching methods, and overcome psychological barriers when delivering video lectures.

Those lecturers who had already added digital content to the face-to-face learning process during the intervention emphasised in interviews that this approach allows them to focus on practical tasks in the classroom, observe students in action and develop such students' skills as debating, collaboration, argumentation, problem-solving and conflict resolution, critical and creative thinking and others.

In order to obtain students' evaluation of the developed distance learning courses, an evaluation questionnaire was included at the end of each course with four closed-ended questions and answer options according to a five-point Likert scale and one open-ended question. The questionnaire included the following indicators: the comprehensibility of the course presentation, the format of the course presentation, the usefulness of the supplementary materials offered (podcasts, interviews, additional reading, etc.), the overall quality of the course and recommendations for further development of the course. The overall results of the survey in absolute figures are summarised in Table 1. The course evaluations provided so far (n=46) show that the majority of students' evaluations fall into the positive categories, i.e. 42 students rated the readability of the course presentation as rather or very good, 42 students indicated that the format of the course presentation was rather or very interesting, 41 informant indicated that the supplementary material was rather or very useful for learning the course content and 44 students rated the overall course quality as excellent or outstanding.

TABLE 1. STUDENTS' EVALUATION OF DISTANCE LEARNING COURSES (N=46, COUNT)

Indicator/ Survey question	1	2	3	4	5
How do you rate the comprehensibility of the course outline on a scale from 1 to 5, where 1 means the course outline is very difficult to comprehend, 5 – the course outline is very well comprehensible?	2	0	2	19	23
How do you evaluate the format of the course outline on a scale from 1 to 5, where 1 means the course outline is very monotonous, 5 means the course outline is very interesting?	2	0	2	21	21
To what extent did you find the additional materials offered, such as podcasts, interviews, additional literature, etc., useful for the study of the course?	2	2	1	17	24
Please evaluate the overall quality of this distance learning course on a scale of 1 to 5, where 1 is poor and 5 is excellent.	1	0	1	18	26

Analysing the students' recommendations, three thematic groups of suggestions can be identified: firstly, to improve the other distance learning courses on the model of the improved and newly developed courses, and to supplement the face-to-face courses with moodle-based content; secondly, to add subtitles to the video lectures; and thirdly, to provide more practical examples on the topic.

In order to assess the changes in the level of digital competences of the students after the completion of the improved and newly developed courses, a reassessment of the students' digital competences was carried out (re-survey

in December 2023). According to the results, 22% of students increased their information and data literacy competence by at least one level (e.g. from low to basic or from basic to intermediate), 17% – their communication and collaboration competence, 39% – their digital content creation competence, 26% – their digital security competence and the same proportion increased their competence in using digital technologies to solve problems.

Through an integrated analysis of the results of the student evaluations and the qualitative interviews with lecturers, a number of insights can be put forward for discussion. The role of the lecturer in the learning process is changing with the digitalisation of higher education and the increasing shift towards self-regulated learning. The lecturer is no longer just a knowledge transmission agent, but also a visionary, coach, mentor and cognitive guide. It is no longer enough to know a specific area of knowledge, a course of study. The lecturer must have the competences to transfer and create new knowledge in a way that is engaging for the student of the digital age. The learning process must be dynamic, practical, technological, open and collaborative in order to mitigate the risk of social skills weaknesses, social communication competences. The model courses developed serve as a basis for integrating digital learning materials and activities into face-to-face studies.

Teaching and learning have changed significantly in the last five years as a result of various external environmental factors and the entry of new generations into the education space. The university is no longer just a geographically defined place; its physical boundaries are no longer strictly defined. The diversity of digital and technical infrastructures increases the accessibility of higher education and creates new forms of learning. However, as the lecturers interviewed in the study acknowledged, the digital transformation of education, along with the development of generative artificial intelligence, also poses risks and challenges. The main risks are seen as the weakness of qualitative thinking (which includes analytical, critical and creative thinking) and social skills.

In order to use the full potential of the diversity of environments, contents and forms of modern higher education, the intervention analysed in this study has led to a decision to increasingly combine face-to-face learning with digital tools for self-directed learning environments, providing access to distance learning course materials to students studying on the programme in a face-to-face mode. In turn, face-to-face workshops should be organised for distance learning students.

IV. CONCLUSIONS

The digital transformation of higher education is a process that involves the adaptation of educational institutions to the digital environment using information and communication technologies. This process includes both technological infrastructure development as well as pedagogical and administrative practices to improve the effectiveness and efficiency of educational processes. The digital transformation of higher education is essential to shape the education system according to today's requirements and opportunities, as well as to ensure better learning experiences and results for students.

Multimedia in higher education refers to the integration of various forms of media such as text, images, audio, video, animations, and interactive elements into the teaching and learning process. This approach aims to enhance the educational experience by catering to diverse learning styles, promoting engagement, and facilitating deeper understanding of complex concepts. Multimedia enriches the teaching and learning experience in higher education by providing diverse and interactive ways to engage with course materials, fostering deeper understanding, and catering to the needs of a diverse student population.

The intervention has strengthened digital capacity in existing and new study courses and ensured piloting of the integration of the new digital solutions in distance and face-to-face studies. The developed study courses serve not only as a prototype for the development of distance learning study courses, but also for the integration of digital learning materials and activities in face-to-face studies.

The digitalisation of the study process and the inclusion of multimedia systems in the study courses expand the space for asynchronous and direct communication between lecturers and students, the development of students' social and general competences, as well as the development of practical knowledge and skills, increasing the efficiency of the study process and the quality of higher education.

In the digital transformation of higher education, the role of the lecturer is also changing with the diversification of the content and form of studies. The lecturer becomes a support for self-directed learning and builds horizontal partnership relations with students in the study process. The study supports the assumption that the integration of multimedia systems in the learning process provides additional support for students in strengthening their self-directed learning skills and digital competences. This assumption needs to be further examined in future research on the impact of digitisation of the study process on students' academic, social and digital performance.

REFERENCES

- [1] E. Lamarre, K. Smaje and R. Zimmel, *Rewired: McKinsey Guide to Outcompeting in the Age of Digital and AI*, Wiley, 2023.
- [2] G. Vial, *Understanding Digital Transformation: A Review and a Research Agenda*, *The Journal of Strategic Information Systems*, Vol. 28, Issue 2, June 2019, pp. 118-144. <https://doi.org/10.1016/j.jsis.2019.01.003>
- [3] R. A. Ellis and P. Goodyear, *Models of learning space: integrating research on space, place and learning in higher education*, *British Educational Research: Review of Education*, 2016. <https://doi.org/10.1002/rev3.3056>
- [4] S. Grajek and B. Reinitz, *Getting Ready for Digital Transformation: Change Your Culture, Workforce, and Technology*, *EDUCAUSE Review*, 2019. Available: <https://er.educause.edu/articles/2019/7/getting-ready-for-digital-transformation-change-your-culture-workforce-and-technology> [Accessed February 18, 2024].
- [5] *Global Higher Education Market Size By Student Demographic, By Educational Services, By Institution Type, By Geographic Scope And Forecast*, 2024. Available: <https://www.verifiedmarketresearch.com/product/global-higher-education-market-size-and-forecast/> [Accessed February 20, 2024].
- [6] J. Schneider, *The Transformative Power of Multimedia in Higher Education Online Course Design*, 2024. Available: <https://blogs.luc.edu/techtips/2024/02/07/the-transformative-power-of-multimedia-in-higher-education-online-course-design/> [Accessed February 20, 2024].
- [7] K. Martinosane and A. Pipere (zin.red.), *Zinātniskās darbības metodoloģija: starpdisciplināra perspektīva*, Rīga: RSU, 2021.

- [8] S. Kushner, Evaluative Research Methods: Managing the Complexities of Judgment in the Field, Information Age Publishing Inc., 2017. [35910513/](https://doi.org/10.30476/JAMP.2022.94833.1609) [Accessed February 12, 2024]. DOI: 10.30476/JAMP.2022.94833.1609
- [9] M. Saunders, C. Sin and S. Dempster, Evaluative Research in Higher Education Policy Analysis, in book: Theory and Method in Higher Education Research, Vol. 1, Chapter 3, Emerald Group Publishing Limited, 2015, pp. 49-69, <https://doi.org/10.1108/S2056-375220150000001003>
- [10] K. Charokar and P. Dulloo, Self-directed Learning Theory to Practice: A Footstep towards the Path of being a Life-long Learner, Journal of Advances in Medical Education & Professionalism, 2022, pp. 135-144. Available: <https://pubmed.ncbi.nlm.nih.gov/>
- [11] B. S. Bloom, Reflections on the development and use of the taxonomy. In Rehage, J. Kenneth, L. W. Anderson, L. A. Sosniak (eds.). Bloom's taxonomy: A forty-year retrospective. Yearbook of the National Society for the Study of Education, Vol. 93, Chicago: National Society for the Study of Education, 1994.
- [12] G. S. Carretero, R. Vuorikari and Y. Punie, DigComp 2.1: The Digital Competence Framework for Citizens with eight proficiency levels and examples of use, Publications Office of the European Union, Luxembourg, 2017, DOI:10.2760/38842

A Generalized Net Model for Accessing Information Resources in a Secure Environment

Miroslav Kochankov
Bulgarian Defense Institute
„Professor Tsvetan Lazarov“
Sofia, Bulgaria
m.kochankov@armf.bg

Rosen Iliev
Bulgarian Defense Institute
„Professor Tsvetan Lazarov“
Sofia, Bulgaria
r.iliev@di.mod.bg

Abstract. The purpose of the study is to describe and present the process of accessing information resources in a secure military computer network as generalized net model. A simulation of the model was carried out using specialized software for working with generalized nets - GN IDE, and the most important results are visualized in the report.

Keywords: Generalized net, modeling, military network, access control.

I. INTRODUCTION

Any secured military computer network that store and process secured information or provide access to secured services requires incensement of security measures. [5], [8], [14].

The access control to the network and provided resources is carried out in accordance with the regulatory documents and modern technologies. [9], [10], [11], [13].

II. MATERIALS AND METHODS

One approach to provide secured and reliable access to a secured military computer network is the mechanism of personal smart card and personal access code [15]. The smart card has an integrated programmable verification chip that contains the necessary information about the card holder to guarantee access to the system's resources. The personal access code confirms the authenticity of the cardholder and validates access to the system [15]. Access to the system is granted after reading the information from the smart card and entering a valid pin code, otherwise access is denied and the system generates an error message.

When the user gets access to the system and make a request to the certain service provided by the system, it checks the user clearance, if the check is successful the system makes a check for access to the service performed on a need-to-know basis. In accordance to this principle,

the user's access is limited only to that information that is necessary for the performance of official duties or for the performance of a specific task [6]. If the specified checks are passed, the user has access to the service if it is available, otherwise access is denied and the system generates an error message.

The generated errors are fed into the network analysis and monitoring module, where an analysis of the errors and possible security issues in the system is performed.

One of the possible approaches for describing the process is the generalized netus created by K. Atanasov [1], [2], [3], they allow a detailed description of the individual steps and creation of an interaction model.

The usage of intuitionistic fuzzy sets in the process description allows a detailed evaluation of possible failures of the system access control.

Five transitions are used in the present work to represent the process of accessing services in a secure military computer network.

The scheme of the process represented by a generalized net is shown in Fig1.

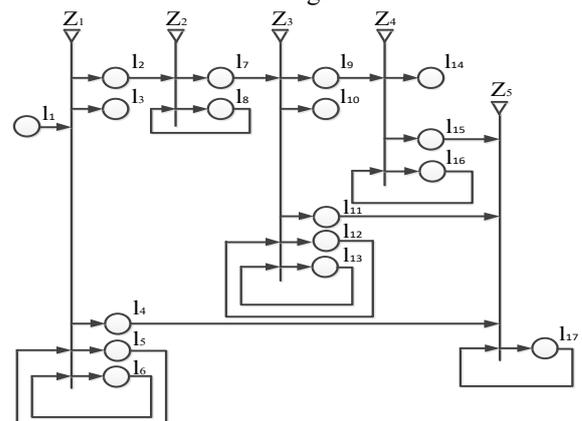


Fig.1 Generalized net model

Print ISSN 1691-5402
Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8034>

© 2024 Miroslav Kochankov, Rosen Iliev. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

Tokens into the net:

- α - users;
- β – smart cards data base;
- γ – PIN codes data base;
- δ – list of services;
- ε – clearances data base;
- ϵ – need to know data base.

Generalized net is presented by a set of transitions E = {Z₁, Z₂, Z₃, Z₄, Z₅}, where transitions describe the following processes:

- Z₁ – User authorization
- Z₂ – Service request / network resource/
- Z₃ – Services access level
- Z₄ – Services access confirmation
- Z₅ – Errors evaluation and analysis

Transition Z₁ - User authorization

Z₁ = {l₁, l₅, l₆}, {l₂, l₃, l₄, l₅, l₆}, r₁, V(l₁, l₅, l₆), where:

- l₁ – user
- l₂ – authorized user
- l₃ – exit
- l₄ – authorization failed
- l₅ – pin codes data base
- l₆ – smart cards data base

$$r_1 = \begin{array}{c|ccccc} & l_2 & l_3 & l_4 & l_5 & l_6 \\ \hline l_1 & F & F & F & F & T \\ l_5 & W_{5,2} & W_{5,3} & W_{5,4} & T & F \\ l_6 & F & W_{6,3} & W_{6,4} & W_{6,5} & T \end{array}$$

T (true) – possible transition, F (false) – no possible transition

- W_{5,2} – authorized user
- W_{5,3} – the pin code is not valid
- W_{5,4} – pin code validation failed
- W_{6,3} – the smart card is not valid
- W_{6,4} – smart card validation failed
- W_{6,5} – the smart card is valid

All user credential checks are performed in this transition - Z₁. At position l₆ the system checks smart card validity, if it is valid, the system checks pin code at l₅. If the smart card or pin code are not valid the tokens go to exit, position l₃. If both checks are valid tokens go to position l₂.

Transition Z₂ – Service request

Z₂ = {l₂, l₈}, {l₇, l₈}, r₂, V(l₂, l₈)

- l₇ – authorized user
- l₈ – services provided by the system

$$r_2 = \begin{array}{c|cc} & l_7 & l_8 \\ \hline l_2 & F & T \\ l_8 & T & F \end{array}$$

Transition Z₃ - Services access level

Z₃ = {l₇, l₁₂, l₁₃}, {l₉, l₁₀, l₁₁, l₁₂, l₁₃}, r₃, V(l₇, l₁₂, l₁₃)

- l₉ – authorized user
- l₁₀ – exit

- l₁₁ – validation failed
- l₁₂ – „need to know” data base
- l₁₃ – clearances data base

$$r_3 = \begin{array}{c|ccccc} & l_9 & l_{10} & l_{11} & l_{12} & l_{13} \\ \hline l_7 & F & F & F & F & T \\ l_{12} & W_{12,9} & W_{12,10} & W_{12,11} & T & F \\ l_{13} & F & W_{13,10} & W_{13,11} & W_{13,12} & T \end{array}$$

W_{12,9} – authorized user with services access

W_{12,10} – the user has no access to the requested service

W_{13,10} – the user has no valid clearance

W_{13,11} – error occurred

W_{13,12} – valid clearance

At this transition (Z₃) are performed users service access level checks. At position l₁₃ the system checks user clearance, if it is valid and at the same level as required service, the system checks users request according „need to know” principle at l₁₂. If the clearance or „need to know” parameters are not the same tokens go to exit, position l₁₀. If both checks are valid tokens go to position l₉.

Transition Z₄ - Services access confirmation

Z₄ = {l₉, l₁₆}, {l₁₄, l₁₅, l₁₆}, r₄, V(l₉, l₁₆)

- l₁₄ – exit/service provided
- l₁₅ – requested service is not available
- l₁₆ – available services

$$r_4 = \begin{array}{c|ccc} & l_{14} & l_{15} & l_{16} \\ \hline l_9 & F & F & T \\ l_{16} & W_{16,14} & W_{16,15} & F \end{array}$$

Transition Z₅ - Errors evaluation and analysis

Z₅ = {l₄, l₁₁, l₁₅, l₁₇}, {l₁₇}, r₅, V(l₄, l₁₁, l₁₅, l₁₇)

l₁₇ – errors evaluation and analysis

$$r_5 = \begin{array}{c|c} & l_{17} \\ \hline l_4 & T \\ l_{11} & T \\ l_{15} & T \\ l_{17} & T \end{array}$$

In transition Z₅ – Evaluation and analysis of errors, an evaluation of possible errors during system operation is carried out. Initially, in the absence of information coming from any of the transition input positions l₄, l₁₁, l₁₅, l₁₇, the values are <0,0>>

When k ≥ 0 then (k+1) grade is based on previous grades according to:

$$\langle \mu_{k+1}, \nu_{k+1} \rangle = \frac{\mu_k + \mu}{k + 1}, \frac{\nu_k + \nu}{k + 1}$$

When k ≥ 0, grade is calculated based on the previous grades, where <μ_k, ν_k> is the previous grade and <μ, ν> is the latest grade.

III.RESULTS AND DISCUSSION

Model simulation and results

The simulation of the proposed model was performed with the GN IDE (Generalized Nets Development

Environment) [4],[7],[12]. The software allows graphical representation of the model and track the model operation, as well as possible errors that occur. In the presented model, it is assumed that on every tenth step starts a new simulation cycle.

The rules for performing the simulation are set in the program code, with a 90% probability of passing the set checks, 7% of failed attempts and a 3% probability of errors.

Fig.2 represents the initial state of the simulation, I_1 is in the initial position before entering and activating transition Z_1 .

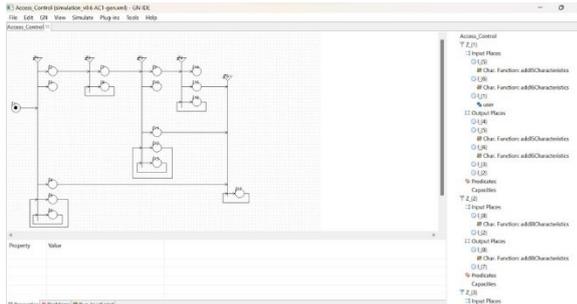


Fig.2. Initial state

Fig. 3 shows the final state of the simulation, where the characteristics of tokens that has successfully passed all set checks.

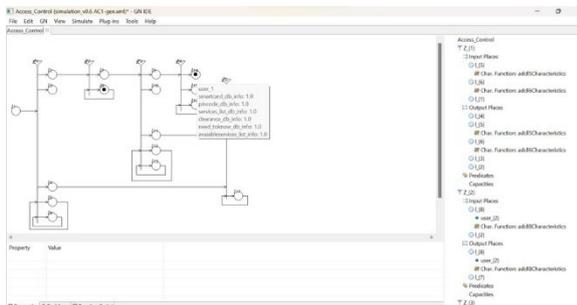


Fig.3. Final state

Possible errors that occur during the simulation.

Performing a simulation of the proposed generalized net model with the GN IDE software requires N number of runs and passes through the model to generate different results. Two types of errors are possible in presented model, known type and unknown type. Known type errors for example are invalid smart card, wrong pin code, unavailable service user does not have valid clearance. Errors of a known type generate an error message and go to exit place. For errors of unknown type, tokens go to the error analysis block.

Fig. 4 shows an error where the user does not have access to the requested service according to the "need to know" principle.

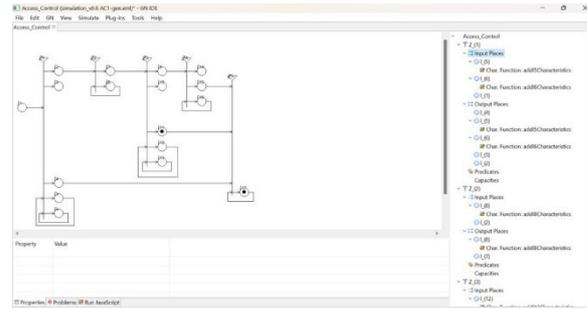


Fig.4. The user does not have access according to the "need to know" principle.

Fig. 5 shows an error where there is a pin code problem.

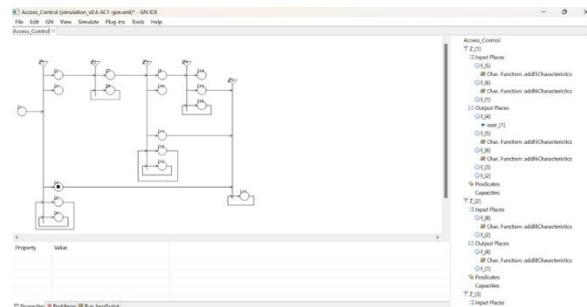


Fig.5. Pin code error

V.CONCLUSION:

At this article is presented generalized net model describing the access control military computer network. Ensuring secure and reliable access control is a priority task to prevent unregulated access to information and services provided by the network.

The model can be used independently or like a component of other generalized model with additional security parameters. This model can help examination, analyze and optimization of access control to secured military network.

ACKNOWLEDGEMENTS:

This publication was financed by the Ministry of Education and Science in implementation of the National Science Program "Security and Defence", adopted with PMC № 731 of 21.10.2021 and according to Agreement № Д01-74/19.05.2022.

REFERENCES

- [1]. Atanassov K. Theory of Generalized nets (an algebraic aspect). AMSE Review, 1, №2, 27-33, 1984.
- [2]. Atanassov, K.(ed.). Applications of Generalized nets. World Scientific, Singapore, New Jersey, London 1993.
- [3]. Atanassov K, Generalized Nets, World Scientific, Singapore, New Jersey, London 1991
- [4]. Angelova, N, Todorova, M., Atanasov, K. GN IDE Implementation, improvements and algorithms. pp 69.411-420, 2016
- [5]. Boyanov, P., Using a specialized software for comprehensive monitoring the suspicious states in computer networks, a refereed Journal Scientific and Applied Research (Licensed in EBSCO, USA), Konstantin Preslavsky University Press, ISSN 1314-6289, vol. 6, 2014, pp. 148-154
- [6]. Classified Information Protection Act, Ch1, Art3, (2), 2023

- [7]. Dimitrov, D.G. GN IDE – A software tool for Simulation with generalized nets. Proceedings of Tenth International Workshop on Generalized nets, Sofia, 2009, pp 70-75.
- [8]. Hristov, Hr., Boyanov, P., Trifonov, T., Approaches to identify vulnerabilities in the security system of the social organization and computer resources, a refereed Journal Scientific and Applied Research (Licensed in EBSCO, USA), Konstantin Preslavsky University Press, ISSN 1314-6289, vol. 5, 2014, pp. 101-107.
- [9]. Kolev, A., P. Nikolova, Instrumental Equipment for Cybe-rattack Prevention, Information & Security: An International Journal 47, no. 3 (2020): 285-299. <https://doi.org/10.11610/isij.4720>
- [10]. Александрова, К., Ив. П. Иванов, Архитектура на пасивна бистатична радарна система базирана на DVB-T сигнали и софтуерно-дефинирана платформа, "Сборник доклади от международна научна конференция "Хемус 2016", стр. III-193 – III-201, ISSN 1312-2916, 2016 г.
- [11]. Александрова, К., Ив. П. Иванов, Перспективни радари срещу електронните заплахи на съвременното бойно поле. "Сборник доклади от международна научна конференция "Хемус 2016", стр. III-202 – III-210, ISSN 1312-2916, 2016 г.
- [12]. Димитров, Д. Графична среда за моделиране и симулация с обобщени мрежи. 2021 г.
- [13]. Спасов, Св. Международни академични програми и модели за обучение по противодействие на корупцията и приложението им в УНСС. Научни трудове на УНСС, 69-95 стр., 2022 г.
- [14]. Спасов, Св. Европейска архитектура за сигурност. Книга, Издателство на УНСС, ISBN: 978-954-644-340-3, 2012 г. <https://www.iogear.com/product/GSR205/> – last seen 06.02.2024.

Rapid Development of Chatbot for Tourism Promotion in Latgale

Sergejs Kodors
Institute of Engineering
Rezekne Academy of Technologies
Rezekne, Latvia
sergejs.kodors@rta.lv

Imants Zarembo
Institute of Engineering
Rezekne Academy of Technologies
Rezekne, Latvia
imants.zarembo@rta.lv

Guna Kanepe
Rezekne Academy of Technologies
Rezekne, Latvia
gk11056@edu.rta.lv

Lienīte Litavniece
Research Institute for Business and
Social Processes
Rezekne Academy of Technologies
Rezekne, Latvia
lienite.litavniece@rta.lv

Daniēls Zeps
Rezekne Academy of Technologies
Rezekne, Latvia
dz22036@edu.rta.lv

Abstract. The release of ChatGPT technology identified the large language models as a new disruptive technology, which changes the behaviours of society and its attitude towards the presence of artificial intelligence in everyday life. The tourism industry is one of the economic sectors, which will be impacted by the large language models through personalized marketing and advertisements. A common approach to capture the attention of AI-centric tourists, who want to get answers to their questions without manually researching the topic or using services of the travel advisors, is to integrate a chatbot or virtual assistant in the tourism information system. We applied this approach to the promotion of tourism in East Latvia (Latgale) by rapidly developing a chatbot by using a prompt method with context-oriented material. Two models were prepared for tourism promotion in Latgale. The models were evaluated through a pilot survey to understand the satisfaction of target users. The data analysis was applied. The study identified the importance of trustworthy information and answer saturation. The trade-off between dialog freedom and trustworthiness of answers can be achieved through the development of microservices, which are grouped as one system to direct conversation with chatbot. The appropriate conceptual models are presented in the article.

Keywords: chatbot, large language models, system modelling, tourism.

I. INTRODUCTION

Tourism is an important sector of the national economy, as it constitutes a significant part of the GDP of many countries and employs many people. This encourages fierce competition between different tourism destinations to motivate and interest potential tourists. As a result,

significant importance is attached not only to the customer service process when the tourist has already arrived at the final destination but also to interest the tourist in choosing this final destination.

To attract tourists, different tools and ways of presenting information are used to create interest, taking into account also the behaviour patterns and trends of consumers, when it is necessary to be able to find information quickly, investing as little time as possible.

One of the latest technologies that is used in various fields is artificial intelligence (AI). Speaking about tourism, AI is enabling technology, which can underpin current service innovations that impact firm-customer interactions with implications for service management and marketing. Large language model (LLM) is a type of AI, which can process and generate text. For example, automated teller machines (ATMs) have been in use since the 1960s, whilst chatbots, such as Siri and Alexa are now widely adopted as customer-facing service robots [1].

The aim of study is to evaluate the user-satisfaction with a chatbot rapidly developed by using LLM and prompt method.

Our experiment showed that users are mainly satisfied with the developed chatbots for tourism promotion in Latgale. However, the chatbots sometimes generate false or too abstract information about the region, which strongly decreases the user satisfaction with the chatbots. In result we propose to apply LLMs as microservices to transform tourist personal preferences into data search parameters for

Print ISSN 1691-5402
Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8060>

© 2024 Sergejs Kodors, Guna Kanepe, Daniēls Zeps, Imants Zarembo, Lienīte Litavniece.
Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

standard algorithms, which can satisfy the truthfulness of data.

II. MATERIALS AND METHODS

The experiment design is based on a similar study, which was conducted to evaluate question and answer (Q&A) LLM trained on medical data [2].

The experiment is organized in two stages:

1) prepare a chatbot; 2) conduct a pilot survey to understand user satisfaction through the questionnaire.

The chatbot was developed using the ChatPDF tool, which takes contextual prompts as a PDF document. As result, this tool provides a rapid development of a chatbot simply collecting tourism material about the target region.

To get more objective results, we have asked two experts to prepare promotional material about the Latgale region. We asked experts to include the material of 8 themes: Latvia, Latgale, Daugavpils (the city in Latgale), restaurants, recreational activities, local producers, cycling routes, and observation towers. The experts collected promotion materials independently one from another. As a result, we developed two chatbots, which can be integrated into the tourism platform through ChatPDF API.

The questionnaire was taken from the study of Singhal et al. (2023) [2]. The following six questions were included in the questionnaire:

- Q1: Alignment with question consensus;
- Q2: Reading comprehension;
- Q3: Knowledge recall;
- Q4: Reasoning;
- Q5: Inclusion of irrelevant content;
- Q6: Omission of important information;

Additionally, we included questions about “Incorrect data” (Q7) and “Satisfaction with chatbot” (Q8).

The pilot group included 12 students (volunteers) and 3 tourism industry experts. Each respondent needed to ask questions to the chatbot about tourism possibilities considering the mandatory themes and evaluate the chatbot using Likert scale 5, where 1 – very weak, 5 – very strong. Each theme was evaluated by the respondent independently to get the mean values after conversation. Meanwhile, the respondents must ask similar questions to both chatbots and fill answers in the comparative style.

III. RESULTS

Overall, both chatbots obtained sufficiently high scores. The mean satisfaction of Chatbot A is 4.29 and Chatbot B

– 4.18 (good). However, the most of the respondents preferred Chatbot B (see Fig. 1). The respondents adduced in the open conclusions that they were more satisfied with Chatbot B. However, we can see the smaller mean value, which can be explained by the high deviation of the satisfaction with Chatbot B (see Fig. 1). Let’s investigate the impact factors on the user decisions.

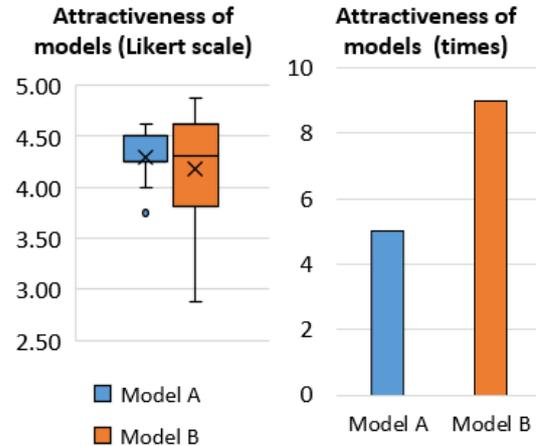


Fig. 1. Satisfaction with chatbots (Q8): left – Likert 5, right – how many times one model was better than the other.

The data analysis showed that this deviation is called by incorrect and abstract answers provided by Chatbot B (see Fig. 2). Fig. 2 is organized in the comparative style: the answers on similar questions are placed near for both chatbots.

The data analysis was completed through anomaly investigation. We can see that the standard deviation of all questions can be separated into three groups: near 1.0, near 0.5, and near 0.3 (see Fig. 2); where the highest group “near 1.0” belongs to Q5, Q6, and Q7. These questions are related to the precision of information provided by the chatbots.

These three questions (Q5-7) show anomalies. The review of the anomaly in questionnaire showed comments about incorrect locations of tourism products, which compromises the user's trust in the chatbot and satisfaction with it. The mean value of Q5-7 was compared with Q8 using Spearman correlation, which showed a strong negative impact of -0.75 and -0.80 for Chatbot A and Chatbot B respectively.

The group “near 0.5” belongs to Q3 (knowledge recall), which describes the abstraction level of answers. In this case, Spearman correlation was very strong -0.92 for Chatbot B and very weak for Chatbot A (-0.07). The review of the comments supports the importance of respondent satisfaction with conciseness and accuracy of answers. However, the abstraction impact is mentioned more rarely than precision.

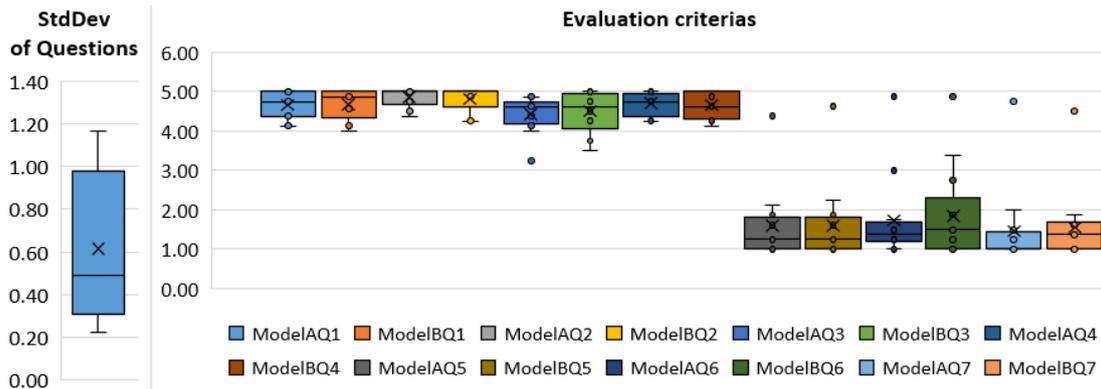


Fig. 2. Answers of respondents: Model A belongs to Chatbot A, Model B – to Chatbot B, Q1-7 identify questions respectively.

It must be noted that we completed data cleaning through the investigation of anomalies and reviewing the standard deviation of questions to scope the summary opinions. We excluded one questionnaire, which contained very good results without comments. The other two were partially cleaned based on the comments, which identified that the respondents wanted to get specific answers from chatbot related to their subjective preferences.

Analysing the comments, the reason why respondents prefer Chatbot B, they mention the more structured answers of the chatbot. Reviewing the PDF document of Chatbot B, the second expert used material with a similar structure: lists of tourism products instead of descriptive text. Document A contained 477 pages, but Document B – 712 pages. It is possible that too long prompts can call for unstable answers of Chatbot B. Therefore, it is recommended to make compact and structured documents (catalogues) for chatbot prompts.

IV. DISCUSSION

So, the prompt-based chatbot is sufficiently usable for the conversation with clients. It can be applied to attract attention and interest to tourists. However, it is not a sufficiently stable and trustworthy solution to generate personalized travel plans for tourists, additionally, it can lead to the opposite effect creating a negative experience to its users. In result it is required to discuss enhancement solutions to overcome this problem.

The success of LLMs lies in their ability to capture the statistical patterns and linguistic nuances present in the training data [3]. By processing and analysing vast amounts of text, LLMs gain a comprehensive understanding of language to be able to generate coherent and contextually relevant responses [4]. Considering to Chinchilla scaling law for LLM, which was developed by Hoffman et al. (2022) [5], the LLM size and the amount of training data should be increased in approximately equal proportions. It means that the training from scratch of LLM is a costly process, especially for multi-language tasks, that includes the cost of computing and data collection.

Another approach is fine-tuning of LLM and retraining it on the target domain data. E.g. G. Trichopoulos et al. (2023) fine-tuned GPT-4 to assist museum visitors in providing textual data about locations and exhibition narratives [6]. However, it is hard to guarantee the precision of location due to the black-box principle of neural networks as well as the textual description of

orientations of the whole geographical region will be too challenging.

The non-real-time information, incomplete knowledge, and insufficient spatial awareness are mentioned by other researchers too [7]. As a solution, LLM is presented as a microservice, which transforms the tourist request into JSON parameters applied by the itinerary planning system to provide the personalized content (see Fig. 3).

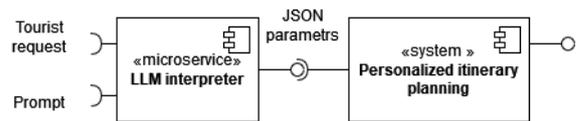


Fig. 3. LLM as microservice for tourist request interpretation with chatbots.

The systems with user profile data can apply LLMs in opposite directions. E.g. LLM can add emotions to the personalized messages generated by the recommendation system based on the tourist profile data (see Fig. 4) [8].

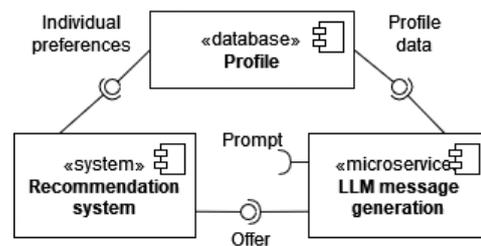


Fig. 4. LLM generates personalized message.

Speaking about microservice architecture, it is typical and preferable for the tourism domain due to the possibility to extend recommendation systems with different data sources and services (see Fig. 5) [9].

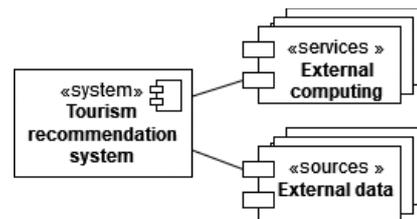


Fig. 5. Microservice architecture of tourism recommendation systems.

Additional factor is real-time data processing by LLMs. LLM simply can not be retrained to use these data due to the short time of their actuality, e.g., weather data, tickets,

events, etc. Another example is speech generation using LLM output text. E.g. Yoshimaru et al. (2023) applied one LLM to get search parameters for sightseeing DB, meanwhile, the second LLM for speech generation to sound out recommendations [10].

The limits of a single LLM are mentioned by different authors. Meanwhile, Wu et al. (2023) presented a multi-agent framework, which connects together multiple LLMs where each is prepared for specific tasks. Additionally, LLMs can communicate with one other to complete complex tasks [11].

Considering the rapid development, the optimal solution is expressed by the possibility to combine multiple LLMs into one system completing the minimal LLM training and combining them with data sources and secure algorithms. The sketch of a tourism chatbot, which can solve the problems with spatial awareness, abstraction, and multiple language support for East Latvia's promotion to tourists, is depicted in Fig. 6. That is our next frontier for research and development.

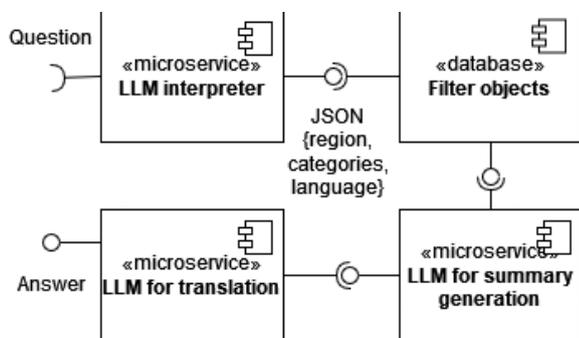


Fig. 6. Promotion chatbot based on microservice architecture with LLMs.

CONCLUSIONS

The experiment has shown that while LLM based chatbots are a very interesting and prospective direction for future technological advancements in the tourism industry, there are a number of challenges yet to overcome before confidently integrating virtual assistants into publicly available tourism information systems. Lack of factual correctness when it comes to tourism object details and locations requires the addition of more mature technologies to support LLMs to be able to come close to generating travel plans or itineraries. Microservice approach proposed in this paper is designed to take the planning load off of the LLM and leave only the input interpretation, textual content translation, and output decoration functions. The microservice approach can be extended by additional service providers to enable additional features, like booking, weather forecasting, and external image scraping.

ACKNOWLEDGEMENT

This research is funded by the Latvian Council of Science project “Digital twin to promote tourism

competitiveness and complementarity development: a Latgale region use case”, project No. lzp-2022/1-0350.

REFERENCES

- [1] D. Buhalis, T. Harwood, V. Bogicevic, G. Viglia, S. Beldona, C. Hofacker, “Technological disruptions in services: lessons from tourism and hospitality,” *Journal of Service Management*, vol. 30, no. 4, pp. 484-506, May 2019. <https://doi.org/10.1108/JOSM-12-2018-0398>
- [2] K. Singha, T. Tu, J. Gottweis, R. Sayres, E. Wulczyn, L. Hou, K. Clark, S. Pfohl, H. Cole-Lewis, D. Neal, M. Schaekermann, A. Wang, M. Amin, S. Lachgar, P. Mansfield, S. Prakash, B. Green, E. Dominowska, B. Arcas, N. Tomasev, Y. Liu, R. Wong, C. Semturs, S. Mahdavi, J. Barral, D. Webster, G. Corrado, Y. Matias, S. Azizi, A. Karthikesalingam and V. Natarajan, “Towards Expert-Level Medical Question Answering with Large Language Models,” *May 16, 2023*. [Online]. Available <https://doi.org/10.48550/arXiv.2305.09617> [Accessed Feb. 27, 2024]
- [3] P. Li, M. Zhang, P. Lin, J. Wan, and M. Jiang, “Conditional embedding pre-training language model for image captioning,” *Neural Processing Letters*, vol. 54, no. 6, pp. 4987–5003, 2022. <https://doi.org/10.1007/s11063-022-10844-3>
- [4] M. Hadi, Q. Al-Tashi, R. Qureshi, A. Shah, A. Muneer, M. Irfan, A. Zafar, M. Shaikh, N. Akhtar, J. Wu, and S. Mirjalili, “A Survey on Large Language Models: Applications, Challenges, Limitations, and Practical Usage,” July 2023. [Online] Available https://www.researchgate.net/publication/372258530_Large_Language_Models_A_Comprehensive_Survey_of_its_Applications_Challenges_Limitations_and_Future_Prospects [Accessed Feb. 27, 2024]
- [5] J. Hoffmann, S. Borgeaud, A. Mensch, E. Buchatskaya, T. Cai, E. Rutherford, D. Casas, L. Hendricks, J. Welbl, A. Clark, T. Hennigan, E. Noland, K. Millican, G. Driessche, B. Damoc, A. Guy, S. Osindero, K. Simonyan, E. Elsen, J. Rae, O. Vinyals and L. Sifre, “Training Compute-Optimal Large Language Models,” Mar 29, 2022. [Online] Available <https://doi.org/10.48550/arXiv.2203.15556> [Accessed Feb. 27, 2024]
- [6] G. Trichopoulos, M. Konstantakis, G. Alexandridis, G. Caridakis, “Large Language Models as Recommendation Systems in Museums,” *Electronics*, vol. 12, no. 18, p. 3829, 2023. <https://doi.org/10.3390/electronics12183829>
- [7] Y. Tang, Z. Wang, A. Qu, Y. Yan, K. Hou, D. Zhuang, X. Guo, J. Zhao, Z. Zhao, W. Ma, “Synergizing Spatial Optimization with Large Language Models for Open-Domain Urban Itinerary Planning,” Feb. 11, 2024. [Online] <https://doi.org/10.48550/arXiv.2402.07204> [Accessed Feb. 27, 2024]
- [8] M. Remountakis, K. Kotis, B. Kourtzis, G. Tsekouras, “Using ChatGPT and Persuasive Technology for Personalized Recommendation Messages in Hotel Upselling,” *Information*, vol. 14, p. 504, 2023. <https://doi.org/10.3390/info14090504>
- [9] L. Garcia, S. Aciar, R. Mendoza and J. Puello, “Smart Tourism Platform Based on Microservice Architecture and Recommender Services,” In: *International Conference on Mobile Web and Intelligent Information Systems*, Jul. 14, 2018, pp 167–180 [Online]. <https://doi.org/10.1007/978-3-319-97163-6>
- [10] N. Yoshimaru, M. Okuma, T. Iio and K. Hatano, “AsyncMLD: Asynchronous Multi-LLM Framework for Dialogue Recommendation System,” Dec 21, 2023. [Online] Available <https://doi.org/10.48550/arXiv.2312.13925> [Accessed Feb 27, 2024]
- [11] N. Yoshimaru, M. Okuma, T. Iio and K. Hatano, “AsyncMLD: Asynchronous Multi-LLM Framework for Dialogue Recommendation System”, Dec 21, 2023. [Online] Available <https://doi.org/10.48550/arXiv.2308.08155> [Accessed Feb 27, 2024]

Application of Gamification in Higher Education: Training of Early Childhood and Primary Education Teachers in Ukraine

Tetiana Koval

*Faculty of Preschool and Elementary
Education named after Valentina
Voloshina
Vinnytsia Mykhailo Kotsiubynskyy
State Pedagogical University
Vinnytsia, Ukraine*

Nataliia Oliinyk

*Department of Primary Education
Vinnytsia Mykhailo Kotsiubynskyy
State Pedagogical University
Vinnytsia, Ukraine*

Tetiana Kryvosheya

*Department of Preschool Education
Vinnytsia Mykhailo Kotsiubynskyy
State Pedagogical University
Vinnytsia, Ukraine*

Anna Khilya

*Department of Primary Education
Vinnytsia Mykhailo Kotsiubynskyy
State Pedagogical University
Vinnytsia, Ukraine
anika.line@gmail.com*

Abstract. Over the past five years, the issue of gamification of education in Ukraine has been actively discussed in academic community, expanding through the practice of innovative teachers, and the availability of online courses using various platforms and applications. But still, in some cases, the issue of gamification is reduced to the question of preparation for interaction during a traditional game. That is why we have addressed several issues in this scientific review.

First, what is the difference between gamification of education and the use of games in the educational process. Secondly, we decided to analyse the gaming interests and preferences of young people who plan to work in educational institutions. This allowed us to outline not only the range of interests, but also to highlight the levels of student readiness to use gamification through the existing offer and develop their own game complexes for work in preschool or elementary schools. Thirdly, we analysed the market offer for primary and preschool education in terms of online exercises and applications that are comprehensive. This helped us to identify (from our point of view) a list of quality platforms and applications that are effective for development. They can be used in training as training examples for future teachers when studying teaching methods of various subjects, or used for school preparation, etc. In addition, we have partially repeated the reasons for confusion in terms and risks associated with the

implementation of international experience in the practice of Ukrainian education due to the economic, social and military-political situation. We believe that such a comprehensive view of gamification in higher education in Ukraine will allow us to expand the scope of understanding and implementation of appropriate training for use by teachers and comprehensive multi-component social development of educational game content for preschool and primary education.

Keywords: *gamification, higher education, preschool education, primary education, teacher training.*

I. INTRODUCTION

The fourth scientific and technological revolution, the "Industry 4.0", has already changed the existing spheres of human activity and formed new forms of interaction in society. In the case of changes in the educational process, we need to keep in mind the digital attributes that, with economic growth and accessibility, become part of the educational process or influence it. Particular attention should also be paid to ensuring the continuity of teaching and learning processes that began in the 2019-2020 academic year, which encouraged the use of technological resources that allowed communication and transfer of information and knowledge through instant messaging, with the most common means of communication being

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8051>

© 2024 Tetiana Koval, Nataliia Oliinyk, Tetiana Kryvosheya, Anna Khilya.

Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

information and game videos, video conferencing, blogs, and learning platforms [1].

We can also note that among the most significant attributes of the digital world for learning are video and audio materials, video hosting, information pages, websites, blogs; gaming and development platforms; computer and mobile gaming applications and gadgets that make the information world accessible as an integral part of education and personal development.

All of these materials and forms of interaction are used by teachers to varying degrees, but the spontaneous use of digital world content outside of school and work exceeds the time spent and affects the audience that comes to the office or classroom. Therefore, paying attention to the education sector, we observe that:

- teachers who do not keep up with the progress, or have little interest in updates and information that is the primary source for their students;
- from which students read and imitate emotional reactions and behavioural patterns,
- It is becoming increasingly difficult to keep the attention of children and adolescents and to promote their harmonious development.

That is why, in this aspect of our research, the purpose was to analyse the issue of training specialists in preschool and primary education through the introduction of gamification in the educational process of higher education in Ukraine.

This goal setting allowed us to pay attention to the following components of the process of introducing gamification in teacher training and to define the objectives of the scientific review based on them:

- to explore the terminological difference between gamification of education and the use of games in the educational process;
- to analyse the gaming interests and preferences of young people who plan to work in educational institutions;
- to analyse the market offer for primary and preschool education in terms of online exercises, applications that are comprehensive and acceptable for implementation in the educational process.

II. MATERIALS AND METHODS

Based on the purpose and objectives defined for this scientific review, we have taken the following steps in the study of gamification.

Firstly, to define the terminology and differences in the perception and practical implementation of gamification of education, we analysed foreign and domestic theoretical and practical works.

The next step was to conduct a survey on the gaming interests of students. The survey was conducted in 2020-2024 as part of the Viral Questionnaire. The results presented in this scientific review relate to the second section, which dealt specifically with the gaming interests of students and their immediate environment, in which 158 people took part.

And the last step of our research concerned the issue of market supply, which we studied with the help of Ukrainian-language content offered in the public domain for use in primary education or for preschool children.

This approach allowed us to comprehensively draw conclusions on the issue of gamification in higher education in Ukraine in practice and identify areas where it is necessary to expand the work of both teachers and students to fully utilise the potential of open access technologies.

III. RESULTS AND DISCUSSION

Therefore, if we move on to terminology, the term gamification is quite common today. It is used both in the entertainment industry and in education. But for education, this term has ambiguous implications. After all, gamification involves the use of game approaches that intersect with game-based learning methods.

Thus, according to the theory, the issue of game methods in education is closely related to the game, and has the following connections with teaching methods. In particular, game teaching method can be called a specific game action that forms a way to achieve a specific learning goal, which is part of a system of activities aimed at achieving a common goal, that is, a teaching method, and game techniques can be part of both game and non-game teaching methods [2].

In addition, the game is designed to strengthen social relations between different members of society through the transmission of social values, to promote the preservation of knowledge and practices [3]. This type of activity focuses on conditions and situations aimed at reproducing and appropriating social experience, in which self-management of behaviour is developed and improved [4]. Also, the game is still considered today as an innovative educational proposal, which is a very versatile didactic resource that has great potential for the development of any topic related to the content of the curriculum, allowing to analyse the choices and decisions that children made during the game, to know and understand the socio-educational and cognitive evolution of each of them, as well as to develop their emotional intelligence and build a close relationship between teacher and student [5].

If we turn to the issue of computer games, we have a different range of terminology, such as:

- 2D-game - a two-dimensional game - a game in which two-dimensional images are used [6].
- 3D-game - a three-dimensional game - uses three-dimensional models and a three-dimensional game world [6].

In our opinion, this partially overlaps with the issues of game-based learning methods. That is why we have focused on the terminology that accompanies the process of gamification of education and presents this definition as follows:

- gamification is the use of game mechanics, aesthetics and game thinking to engage people, motivate action, promote learning and problem solving [7];

- gamification is a process related to stimulating the thinking of players using game techniques to engage users and solve problems [8];
- gamification is the use of elements of computer games outside the game activity [7];
- gamification is the transformation of the entire learning process into a game, and game-based learning is the use of a game as part of the learning process [7].

But at the same time, it is worth noting that, according to scientists, gamification is not identical to game-based learning and the concept of game should not be used as a synonym for gamification, and according to research, it is not just a game in the classroom [7], [8]. Indeed, the main purpose of gamification will never be a game, but rather the elements of a game for learning in a classroom environment will focus on developing academic aspects and a number of competences (social, civic, digital, etc.) [8].

In addition, in terms of practical application, current gamification trends cover three key areas that aim to promote

- socialisation and collaboration
- transformation of systems, services and activities;
- promotion of beneficial behaviours at the individual and societal levels [9].

Thus, we must understand that the search for simple solutions is at the heart of mixing concepts and replacing gamification processes. And, as our fellow scientists point out, back in 2014, gamification in the Ukrainian educational space was at the stage of "loss of illusions", as most of the existing solutions did not fulfil their goals. The analysis of the situation allowed us to explain this situation through excessive attention to external details (points, awards, progress bars, levels, leaderboards) of the developed courses [10], which often distracted attention from the goal and reduced motivation to learn due to the complexity of the processes of interaction with the course materials.

The described difficulties of implementation and the very concept of gamification led us to believe that this situation depends on the basic gaming level of the developers. That is, the design and accessibility of a game or course for students will depend on how often and how well teachers themselves interact with game content, and what content they choose.

That is why, in the second stage of our study, we analysed the gaming interests of 2nd year bachelor students who studied in 2020-2024. This gave us information about the involvement of future innovators and methodologists in the educational process, their awareness and understanding of modern game design and priorities in choosing an interaction system for a quality game.

A total of 158 people completed the survey. The main questions worth mentioning in the context of gamification are "Do you play games?" (the results of the distribution by age and number of participants are presented in Figure

1), "What games do you like to play?", "What is your favourite game?", "Write any one game that you would suggest to others". These questions gave us the opportunity to learn about the gaming interests of future primary school teachers. And it is these interests that encourage us to further reflect on the introduction of innovations in the educational process, the durability and prospects that await projects that are already being implemented or are just being developed for the digitalisation of education and research on gamification. In addition, the issue of students' readiness for such innovative activities has a direct impact on the next few years, in our opinion, about 10 years, of the functioning of the educational system.

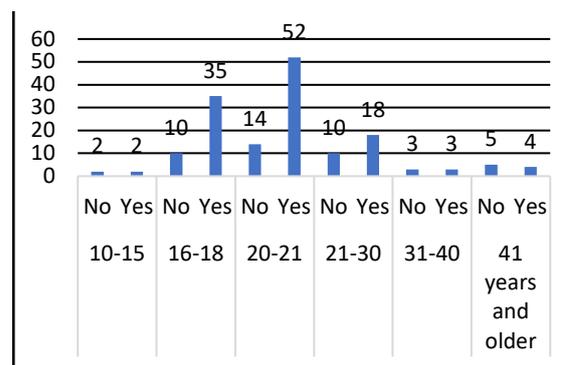


Fig. 1. Quantitative indicators of age distribution.

Therefore, the first question of this section gave us information about the number of people who perceive the gaming space and those who exclude gaming moments from their field of vision. As we can see from Table 1, the majority of students aged 16 to 21 play games, while in younger and older groups this figure is at a minimum level or tends to decrease the gap between those who play and those who do not play games.

That is why we proposed the following question: "What games do you like to play?". We added a list of answers where you could choose one or all options. Among them were the following: Outdoor games; Lying on the couch, crosswords, etc.; On the phone; On the computer; Hide and seek with the fridge; Board games; Educational/learning games. These questions were partly humorous and were intended to analyse the pattern of respondents' thinking. For the custom option, we also included a line where respondents could indicate their own option that would allow them to go beyond the templates.

For example, 7 respondents repeated the answer "I don't play games" in the other option box, one respondent added the answer "puzzles" (although this is a variant of a board game) and another option "I play with my niece". Others chose from the options that were offered. It is worth noting that 76 respondents out of 158 play games on their phones and 35 play games on their personal computers (we did not distinguish between laptops and PCs). This allowed us to say that 48% and 22% respectively have information (at least at the intuitive user level) about the issues of accessible design in the development of online courses and applications for

education. But, in our personal opinion, this figure is too low to create a critical mass in the process of innovation, including the gamification of education.

The next two questions gave us the opportunity to monitor the honesty of the respondents' answers and confirm or deny the lack of acceptance and involvement in the processes of technical and information change that will further influence the choice of methods and forms of interaction between future specialists in the classroom and their students. For example, "What is your favourite game?", "Write any one game that you would suggest to others", we analysed the elections and re-elections, and compared the game content (summarised data are presented in Table 1).

Based on the analysis, it was found that the difference between those who had no suggestions (i.e. did not choose game content) and the answers to the last two questions was 6%. This allows us to conclude that the majority of those who reported no gaming habits have not changed, and the remaining 6% are not a critical mass for changes in gamification processes.

But in any case, the data on the use of computer and mobile games suggests that the audience that has the greatest influence on gamification in education has little information about game design and its combination with educational purposes. It is also worth noting that among mobile game applications, respondents suggested such applications as Homescapes, PUGB Mobile, Club Romance, Clash royale, Talking Tom, fishdom, Garden Affairs, mobie legends, Among us, and Fortress Defence, which cannot be classified as a game-based learning environment, as this content lacks learning objectives and goals. In addition, to be used in any of the educational projects, their value for mastering certain competencies must be tested and described qualitatively. However, it is the design and accessibility issues used in the proposed games that can help teachers design and develop individual elements for the educational process. It is worth mentioning the applications proposed by respondents such as Minecraft, Block Puzzle, mahjong, puzzles (Spichki), which can be used for educational purposes and are already used in STEM education and in mathematics lessons. If we take puzzles, this element is used even in work with preschoolers.

TABLE 1. RESPONDENTS' CHOICE OF GAMING MATERIALS

Respondents' choice	Questions	
	<i>What is your favourite game?</i>	<i>Write any one game that you would suggest to others</i>
	<i>Total choices summarised</i>	
Moving games	24	13
Board games	78	82
Mobile games	13	13
Computer games	18	13
None	34	39
Total choices	167	168

The next set of suggestions is computer games. Among them, respondents suggested shooters (Dota 2, Counter-Strike, GTA, Witcher 3, The Matrix, PUGB, WOT Tanks, Mafia 2, League of Legends, Total War, Stalker, Lineage 2, Far Cry 3), racing, strategies (Farm, The Sims, and adventure Subnautica, Fire and Water. But

this content is also largely unusable in the educational process, as it does not contribute to socialisation or the promotion of useful behaviours at the individual and societal levels.

This is what brought us back to the problems in interpreting gamification, i.e. to the first question. Although educational games are favoured in the game content of board or mobile games, the potential of video games, apps or gaming applications is not much considered in terms of socialisation, behaviour, emotional responses, etc. However, as video games begin to gain more and more recognition, going beyond the entertainment function, gaining importance as an art form and as a means of learning, influencing or informing and contributing to the emergence of "Serious Games" [11] According to researchers and scientists, such a game is a computer program that consistently combines both serious aspects, such as learning or communicative intentions, and game elements of video games, such as cooperation, competition and strategy, aimed at improving users' skills, activity and productivity [12]. For example, when creating the concept of serious games, developers rely on the capabilities of traditional games (card and board games) in optimising learning in educational institutions in complex societies to combat school failure, as they improved motivation and connected educational content with the real world through game modelling, which facilitated the transition from theoretical to practical implementation of scenarios with analogue, digital games or mixed proposals and allowed us to observe positive changes in the development of the value-motivational, cognitive and activity-reflective components of students' learning activities [13].

It is also worth mentioning that simulation with elements of gamification is competence-based and aimed at engaging students in various activities to create learning intrigue and maintain student concentration, interest and motivation to learn [14]. The markers that should be used when selecting game applications for gamification of the educational process can be taken as those identified by the team of scientists as those that may limit the use of simulation games:

- inconsistency with reality;
- the players' decisions lack responsibility;
- impossible without spatial and hardware resources;
- learning takes place in a limited game environment;
- participants often treat games as entertainment, but not as learning;
- there is a significant difference in the behavioural patterns of participants when they are in a game and in real life [14].

These are exactly the aspects that we partially mentioned when describing the proposed gaming applications and computer games by our respondents. In addition, in this part, in our opinion, it is necessary to keep in mind the growing role of the teacher, who, in addition to teaching new material, takes on additional functions of a consultant, coordinating the educational and cognitive process and constantly improving their own courses and

systematically improving their own qualifications in accordance with innovations [15].

Based on the selected tips for selecting content for gamification of the educational process, we considered the availability of comprehensive Ukrainian-language offers of educational content for children. As a result of communication with students, we found out that there is no comprehensive approach to using apps. Most young teachers use exercises developed for a specific subject by innovative teachers or their colleagues, which are posted on the Lerningapp and word wall gaming platforms. Or analogues of game content posted on the portals Vseosvita, OsvitaUA, Na urok, etc. that can be printed and used in the classroom without the use of technology.

While searching for options on the Internet, we came across the LogicLike website, which offers a range of developments from multi-level games to specific tasks for developing thinking or related to specific subjects. The products can be used for both preschoolers and primary school students. Vivid images and accessibility are certainly not the only example of complexity in the context of education and gamification today, but this example can help teachers develop games in accordance with the goals and objectives of learning, in accordance with the competencies that students should acquire and without crossing the fine line between education and entertainment.

Another thing we noticed while searching for content was the lack of Ukrainian platforms for developing such a set of materials. Whereas in the English-speaking world, teachers and others are offered information and sources for developing their own resources, such as on the websites of eLearning Industry, GoodWorkLabs, Yellow, etc.

IV. CONCLUSIONS

The analysis of information on the gamification of education cannot, of course, answer all the questions related to changes and innovations in education, but we have revealed the question of why the content is being replaced and the concepts of gamification of the educational process and game-based learning methods are being substituted.

In our opinion, the market offer for primary and pre-school education in terms of online exercises and applications that are comprehensive and acceptable for implementation in the educational process is not complete and requires a deeper analysis and a separate presentation. But at the same time, this did not prevent us from making a better presentation of the gaming interests and preferences of bachelor's students in 2020-2024 who plan to work in educational institutions. This allowed us to identify the limitations to the use of game content, including its relevance to real-life situations, its impact on socialisation, behaviour and emotions of the student, the lack of a boundary between the entertainment context of the game and its educational purpose, the reduction of educational value in the game, etc. that may affect the quality of the educational process.

Thus, we analysed the issues that were the focus of this study. We have presented positive and negative trends that have a direct impact on the educational process in the training of future primary school teachers and preschool teachers. And which, in turn, affect the implementation of gamification directly in first-level educational institutions. This allowed us to outline the main possibilities of adapting gamification in higher education for the training of preschool and primary education teachers in Ukraine.

REFERENCES

- [1] J. F. Alvarez-Herrero, R. Martinez-Roig, & M. Urrea-Solano. Use of digital technologies in early childhood education in times of pandemic. *Campus Virtuales*, 2021. 165-174.
- [2] P. Kuposov. Kharakterystyka ihrovykh metodiv navchannia. Rozdil III. Sutnist navchalno-ihrovoi diialnosti u metodychnii systemi suchasnoi dydaktyky. Nova ukrainska shkola: dydaktychni osoblyvosti orhanizatsii navchalno-ihrovoi diialnosti uchniv 1-2 klasiv. 2021. <https://nuschool.eu/teaching/elementary/game/9.html>.
- [3] A. R. D. Daza, M. B. I. Fonseca, & A. C. Angola. La importancia de los juegos ancestrales como mecanismo de valoración cultural y fortalecimiento de las relaciones sociales. *Prisma Social: revista de investigación social*, 2020. (30), 207-228.
- [4] N. M. Kravets, O. V. Hrechanovska. Ihrovi tekhnologii navchannia yak odna z innovatsiinykh form navchalno-vykhovnoho protsesu VNZ. *Vinnytsia*. 2017. URL: <http://ir.lib.vntu.edu.ua/handle/123456789/17640?show=full>
- [5] L. M. Hierro, & E. P. Seller. El aprendizaje basado en el juego como herramienta socioeducativa en contextos comunitarios vulnerables. *Revista prisma social*, 2020. (30), 88-114.
- [6] V.S. Breslavets. Tekhnologii rozrobky kompiuternykh ihor: dovidnyk modulua. X.: «Drukarnia Madryd». 2018. 162.
- [7] E. T. Opiř, É. Bálint-Svella, & I. Zsoldos-Marchiř. Prospective Preschool and Primary School Teachers' Knowledge and Opinion about Gamification. *Acta Didactica Napocensia*, 2021. 14(1), 104-114.
- [8] A. Lorenzo-Lledó, E. Pérez-Vázquez, E. Andreu, & G. Lorenzo. Application of gamification in Early Childhood Education and Primary Education: thematic analysis. 2023.
- [9] P. F. Arias, E. O. Olmedo, D. V. Rodríguez, & A. I. G. Vallecillo. La gamificación como técnica de adquisición de competencias sociales. *Prisma Social: revista de investigación social*, 2020. (31), 388-409.
- [10] O. O. Makarevych. Heimifikatsiia yak nevidiemnyi chynnyk pidvyschennia efektyvnosti elementiv dystantsiinoho navchannia. *Molodyi vchenyi*. 2015.
- [11] P. Felicia. Using educational games in the classroom: guidelines for successful learning outcomes. A handbook for teachers. Hertz, B., Pinzi, V., Sefen, M., Eds. 2020.
- [12] R. Lamrani, & E. H. Abdelwahed. Game-based learning and gamification to improve skills in early years education. *Computer Science and Information Systems*, 2020. 17(1), 339-356.
- [13] S. Gómez-García, & J. A. Carrillo-Vera. El discurso de los newsgames frente a las noticias falsas y la desinformación: cultura mediática y alfabetización digital. *Revista prisma social*, 2020. (30), 22-46.
- [14] I. Zvorych, S. M. Kalaur, N. M. Prymachenko, I. V. Romashchenko, & O. I. Romanyshyna. Gamification as a tool for stimulating the educational activity of students of higher educational institutions of Ukraine and the United States. *European Journal of Educational Research*, 2019. 8(3), 875-891.
- [15] A. Lytvynov, Y. Topolnyk, L. Chumak, N. Prykhodkina, L. Antoniuk, & S. Kramka. E-Learning Technologies for Future Teachers: Introduction of Educational Innovations in Higher School Practice. *BRAIN. Broad Research in Artificial Intelligence and Neuroscience*, 2022. 13, 403-421.

Limits of the use of artificial intelligence in law – ethical and legal aspects

Inga Kudeikina
Riga Stradiņš University
Riga, Latvia
inga.kudeikina@rsu.lv

Sandra Kaija
Riga Stradiņš University
Riga, Latvia
sandra.kaija@rsu.lv

Abstract. The article is devoted to legal and ethical problems pertaining to the use of artificial intelligence (hereinafter – AI) in law. AI solutions are already being applied in some areas of law, and the use of AI will undoubtedly be expanding. There are problems relating to the regulatory framework because AI has no expressly defined legal status and the scope of AI is not clear either. AI could successfully be employed for data processing in certain areas, such as forensic science and criminology, as well as legal proceedings, where AI could assess procedural documents for their conformity with formal requirements, namely as a means of assisting a human, who is a decision maker. Recognising AI's decision-making ability is extremely challenging. Thus, AI would transform from a means into a subject of law empowered to make decisions about other subjects of law. The existing legislation is not ready to embrace it, and AI's decision-making ability is related to issues of an ethical nature, considering that decisions about people would be made by a non-human subject.

Keywords: artificial intelligence, justice, law

I. INTRODUCTION

The fair resolution of controversial legal relationships is one of the objectives of law. Society rightly expects justice to be ensured by law enforcement authorities, whose job is to secure that justice is done. It is common knowledge that justice contributes to social peace, thereby ensuring a country's sustainable growth. In today's world, with evolving technologies, it is being increasingly discussed how to use artificial intelligence for ensuring and also administering justice. Technological capabilities provided by artificial intelligence are broad enough, but it still remains unclear how artificial intelligence fits into the legal system and whether it can be recognised as a legal subject at all.

The research deals with problems relating to limits of the use of artificial intelligence in law, especially with regard to ensuring justice in dispute resolution.

II. MATERIALS AND METHODS

The objective of the research is to explore the use of artificial intelligence in law within the scope of the existing legal framework in order to assess ethical and legal aspects and formulate suggestions for improving legislation.

The research has employed descriptive, analytical, deductive and inductive methods. The descriptive method will be used to introduce the essence of artificial intelligence, ethical and legal problems of its use and their solution. Deductive and inductive methods will be used to express conclusions and suggestions. These methods have been used to analyse laws and the opinions of legal scholars and formulate conclusions and suggestions.

III. RESULTS AND DISCUSSION

A. Possibilities of using artificial intelligence in legal proceedings

Nowadays the term 'artificial intelligence' (AI) denotes technologies based on computerised and autonomous algorithms. AI is being used in health care, transport and a number of other industries. Challenges are related to the use of AI technologies in law. There is a public debate ongoing about whether AI will replace judges, but it should be stressed that adjudication is just an area of law. Using AI in law can be viewed in several dimensions: adjudication; support of the adjudication process (for example, drawing-up minutes of court hearings, assessing whether documents submitted to court conform to formal requirements); other areas of law. In the legal industry, AI can arguably be used in forensic science (acquiring and examining evidence, preparing expert reports), criminology (analysing elements of crime), civil transactions (drafting various contracts) and, certainly, administering justice. Law as a system can be viewed from two aspects. First, these are technological solutions that have a support function, such as databases, registers, data storage and processing systems, etc., which neither resolve

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8016>

© 2024 Inga Kudeikina, Sandra Kaija. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

disputes nor make decisions. There are no physical and legal obstacles to using AI technologies for these support mechanisms. Legislation of the Republic of Latvia is based on the Law on State Information Systems [1], whose purpose is to ensure the accessibility and quality of the information to be provided by authorities in the state information systems. Also, every system is governed by a special regulation, so making data processing safe and effective. It should be stressed that automated data processing systems facilitate the effective performance of duties by institutions or officials. For example, for the purposes of a notarial certification, a sworn notary can verify the data of a participant of a deed or certification in the Biometric Data Processing System by comparing the person's finger prints with the data available on this system. [2] One criticism is that there is no regulation in place for attesting reliability of data derived from automated systems. Data so derived are often accepted as reliable by default. Thus, a major challenge in the use of AI is to secure that inputs remain unchanged. This could be achieved, for example, by means of electronic signature.

Second, law can be viewed as a set of actions aimed at settling legal relationships by resolving a dispute, prosecuting offences according to law, enforcing decisions made by courts or other competent authorities, and carrying out other mandatory actions causing a direct impact on a right-holder's rights and duties. In this context, it can be concluded that the supreme goal of law is to ensure justice. This follows from the provisions of the Convention for the Protection of Human Rights and Fundamental Freedoms. [3] There is no doubt that justice ensures social peace and should therefore be recognised as a basis for sustainability of both society and the state. Adjudication as the supreme guarantee of justice, which involves assessing the relevance, reliability, admissibility and sufficiency of evidence obtained during preceding stages and drawing logical conclusions based on evidence and also personal experience for settling disputes in civil proceedings (for example, recovery of damages, reinstatement, termination of a transaction) or for convicting and imposing a penalty in criminal proceedings, is carried out by a human, namely an official appointed in accordance with the statutory procedure. Can justice be administered by AI, an algorithm that will make a dispassionate assessment by relying only on the legal circumstances of a case? The existing legislation sets forth special requirements for judges, namely: apart from professional qualifications and other formal requirements, where in theory there should be no doubt as to AI's ability to provide professional competence, a judge is required to have impeccable reputation. [4] The Law on the Judiciary does not contain any specific features or objective criteria by which reputation could be measured or determined. [5] However, it is impeccable reputation that, first, characterises a person and cannot be attributed to AI; second, the reputation requirement obliges a judge to apply the highest moral and ethical standards in the administration of justice. Relationships between right-holders are of a social nature, so they should be solved by assessing not only legislation, but also moral and ethical standards prevailing in society at a given point in time. It

is expressly laid down in Article 97(1) of the Civil Procedure Law that a court assesses evidence according to their own convictions which are based on evidence that has been examined thoroughly, completely, and objectively at the hearing and according to legal consciousness based on the principles of logic, scientific findings, and observations drawn from every-day experience. [6] As a result, legal consciousness has an essential role in the administration of justice. AI is not and cannot be endowed with legal consciousness. According to scientific literature, "Legal culture is unthinkable without a person and his actions, which are determined worldview, without the progressive orientation of this action and this thinking. It acts as a social phenomenon with a clearly defined goal orientation." [7] Legal consciousness is inherent only in individuals, live beings, it is formed over the entire life of a person as individual social experience. Legal consciousness cannot fully be objectivised by means of an algorithm, and it will always be subject to a certain bias. But it is legal consciousness that makes legal relationships so individualised and unique. Even if AI had legal consciousness, there would arise other legal and ethical issues. Considering that AI technologies are designed by a human, how can a relevant person's legal consciousness be distinguished from that of AI? Second, presuming that AI would be able to acquire legal consciousness, how can conformity with ethical and moral principles be achieved?

B. Artificial intelligence and legal awareness

Researcher T.J.M. Bench-Capon rightly points out that it is important that AI tools behave in an ethical manner and their decisions are not harmful. [8] Scientific literature specifically deals with ethical aspects, in the context of both technological solutions and ethics. Based on the analysis of literature, technology is ready to offer solutions that would ensure ethical behaviour of AI. Researchers D. Vanderelst and A. Winfield offer a method for implementing ethical behaviour in robots inspired by cognitive simulation theory. [9] Despite technological possibilities, using AI in the adjudication process should be analysed very carefully, considering a significant impact produced by court rulings on an individual's fundamental rights. Modern society has accepted the natural rights doctrine, according to which an individual has natural and inalienable rights prevailing over positive rights. [10] It can be concluded that the scope of rights and duties granted to an individual may be different in certain situations according to specific laws, but – as human beings, as live beings – all people are equal. These principles are reflected in the United States Declaration of Independence of 4 July 1776, which holds as self-evident that all men are created equal, that they are endowed with certain unalienable rights, and that among these are life, liberty and the pursuit of happiness. To secure these rights, governments are instituted among men, deriving their just powers from the consent of the governed. [11] All proceedings are subject to rights. Proceedings represent merely a set of conditions for exercising objective rights, whose goal is to ensure the equality of all people. The fact that a person is given more rights in particular proceedings does not mean that the person has superiority over other people.

At present, every court ruling is produced by human consciousness, namely: a ruling is delivered by a person who is granted relevant competence by law. A judge and a party to a case have different social roles, while they are equal in horizontal terms, meaning that they both are human. Therefore, a judge and a party to a case differ only in the context of proceedings. The situation would change if the adjudication function had been assigned to AI. In this case, legal differences that are inherent only in proceedings would disappear and the equality criterion would change radically, namely: AI is not a human, which means that a non-human subject would decide on rights that are essential for people. This situation is unacceptable from the ethical standpoint because, in administering justice, judges rely not only on legislation and logic, but also on their life experience. Both facts and personal experience used to interpret them are important for ensuring justice. Justice is not only about the legally correct interpretation of facts and the application of relevant laws. This view would be too narrow in the context of social relationships. Mg. iur. Mārtiņš Birģelis refers to elements of justice in his essay, where he rightly points out that the interaction between happiness and justice has preoccupied several legal scholars. [12] It is doubtful that AI could be endowed with a sense of happiness that is unique to humans. However, several researchers are optimistic about using AI in the adjudication process, specifically underscoring its role in the acceleration of proceedings by using AI technologies for online judicial solutions. For example, Richard Suskind predicts that AI, machine learning and virtual reality are likely to dominate the judicial service. [13] This prediction concerning the role of AI in the administration of justice could be accepted, but only in respect of the effective and much broader use of AI technology for performing support functions, meaning proceedings-related actions other than adjudication, such as assessing the conformity of documents with formal requirements. [14] Society is being increasingly interested in court rulings, thus calling for better privacy protection, and, as regards possibilities provided by AI for raising public awareness, it should be noted that AI would be a great tool for assessing information to be made public, and for selecting the most significant rulings, conducting an analysis and making reports on them. This function is explained in observations by researcher Ahmed Sabreen: "However, the modern avenues also pose major challenges to the Right to Privacy which is often overlooked by the advocates of the open justice principle." [15] It is stressed in scientific literature that "Artificial intelligence related technologies are currently employed in a variety of human endeavours in an effective manner, such as from facial recognition on a smartphone screen to composing music and art from scratch. Considering these facts, legal science can make more decisions with the use of high-tech tools in criminal trials to determine criminal penalties and several ways of criminal law which influences those who have engaged in socially harmful behaviour." [16] Using AI would add value to a relatively under-researched but important aspect, which is the translation of court rulings into a "plain" legal language, i. e. using terminology that

can be understood by the general public. Scientific literature describes important results of a study, namely: "We propose that artificial intelligence (AI) could help in this task by automatically analysing the court rulings and extracting information from their text about the circumstances of each case, the requests of the parents, the decisions of the judge, and the facts that were taken into account. Law is language and, therefore, natural language processing occupies a prominent place among the applications of AI to the legal field." [17]

We should not neglect uses of AI in other fields of law, one of them being forensic examination. In forensic examination, unlike in the administration of justice, it is essential to ensure the independence of experts from external factors. Pursuant to Article 2 of the Law on Forensic Experts, an expert examination has to be unbiased, judicial and scientifically justified [18]. It is also noted in scientific literature that AI technologies can be used to achieve a standardised and anonymised assessment of a person being examined, making it independent of subjective perception of a forensic expert [19].

For the most part, using AI for the detection of criminal offences or the investigation of crime will not lead to ethical dilemmas. These fields of law will use technological possibilities provided by AI, and results will be interpreted by a human, who will make legally binding decisions, so AI will only be a tool in the hands of a human. Using AI is and will remain a subject of much debate. AI is also one of priorities at European Union level, aimed at the design, development and implementation of reliable AI systems, without undermining fundamental rights of the European Union. On 7 December 2018, the European Commission adopted the Coordinated Plan on Artificial Intelligence [20], which encouraged Member States to develop their own national strategies on artificial intelligence. Latvia has articulated such a strategy, and, on 4 December 2020, the Cabinet approved an information report on developing artificial intelligence solutions drawn up by the Ministry of Environmental Protection and Regional Development. [21] Meanwhile, the European Parliament adopted amendments to the Artificial Intelligence Act on 14 June 2023. [22]

As a result of the research, the authors have arrived at the following:

- 1) at present, using artificial intelligence in law is hindered by the lack of legislation that would deal with artificial intelligence as a legal subject;
- 2) artificial intelligence can still be used as a set of technological tools for ensuring certain functions of law enforcement authorities, while there are no grounds for asserting that artificial intelligence is able to replace humans in administering justice.

In the legal sector, AI technologies are emerging as a tool to help people in various fields of law. Ethical issues will indeed be faced by society if it is attempted to give AI discretionary decision-making powers. The existing regulatory framework does not provide a comprehensive definition of AI, neither does it define the scope of using technologies and their place in the legal system.

IV. CONCLUSIONS

There are no reasons to believe that technologies will stop advancing, and the increased use of artificial intelligence should undeniably be expected, also in legal practice. It is concluded that anticipated challenges are associated with determining areas/procedural steps where artificial intelligence can be used, and positioning factual information derived by artificial intelligence in the evidencing system.

The nearest future will call for radical decisions to be made concerning AI. This matter is of both legal and ethical nature.

If we are increasingly going to use the assistance of or delegate decisions to AI systems, we need to make sure these systems are fair in their impact on people's lives, that they are in line with values that should not be compromised and able to act accordingly, and that suitable accountability processes can ensure this. [23]

AI technology makes both everyday life and the fight against crime easier by completing tasks faster and more accurately, being able to process much more information than a human can in less time. This is the technological aspect, or possibilities, of AI. While AI is used as a tool in the hands of a human, ethical issues can be solved within the existing system. It is clear how decisions are made and can be appealed against, the decision-making power is granted to a human, who is also responsible for their decisions. It is a traditional and established procedure, in which society has confidence. In fact, granting the decision-making power to AI would mean recognising AI as a subject of law, which would lead to both legal and ethical issues, whose solution would require establishing public opinion and significant legislative amendments.

REFERENCES

- [1] Law on State Information Systems. 22 May 2002. [Online]. Available: <https://likumi.lv/ta/en/en/id/62324-law-on-state-information-systems> [Accessed: January. 21, 2024]
- [2] Notariate Law. 09 July 1993. [Online]. Available: <https://likumi.lv/ta/en/en/id/59982-notariate-law> [Accessed: Jan. 21, 2024]
- [3] Convention for The Protection of Human Rights and Fundamental Freedoms. 04 November 1950. [Online]. Available: <https://likumi.lv/ta/en/starptautiskie-ligumi/id/649-convention-for-the-protection-of-human-rights-and-fundamental-freedoms> [Accessed: Jan. 21, 2024]
- [4] On Judicial Power. 01 January 1993. [Online]. Available: <https://likumi.lv/ta/en/en/id/62847-on-judicial-power> [Accessed: Jan. 21, 2024]
- [5] I. Kudeikina and S. Kaija “Problems Relating to Judicial Selection in the Context of Sustainable Development of Society”, *European Journal of Sustainable Development* (2022), 11, 4, 115-125 ISSN: 2239-5938, pp.120. Doi: 10.14207/ejsd.2022.v11n4p115.
- [6] Civil Procedure Law. 01 March 1993. [Online]. Available: <https://likumi.lv/ta/en/en/id/50500-civil-procedure-law> [Accessed: Jan. 21, 2024]
- [7] M. Kozhukhova and M. Zhiyenbayev “Conceptualizing legal culture and legal awareness: meaning and structural components”. *SHS Web of Conferences*, vol. 55, 02009 (2018) [Online] Available: https://www.shs-conferences.org/articles/shsconf/pdf/2018/16/shsconf_icpse2018_02009.pdf [Accessed: Jan. 21, 2024]
- [8] T.J.M. Bench-Capon “Ethical approaches and autonomous systems” *Artificial Intelligence*, vol.281, April 2020, 103239. [Online]. Available: <https://www.sciencedirect.com/science/article/abs/pii/S0004370219300621> [Accessed: Jan. 21, 2024]
- [9] D. Vanderelst and A. Winfield “An architecture for ethical robots inspired by the simulation theory of cognition”, *Cognitive Systems Research*, vol.48, May 2018. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S1389041716302005> [Accessed: Jan. 22, 2024]
- [10] Dabiskās tiesības. [Online]. Available: <https://enciklopedija.lv/skirklis/26219> [Accessed: Jan. 23, 2024]
- [11] ASV 1776. gada 4. jūlija Neatkarības deklarācija. [Online]. Available: <https://www.archives.gov/founding-docs/declaration-transcript> [Accessed: 23.01.2024.]
- [12] M. Birģelis “Laires un taisnīguma kolīzija tiesību zinātnē”. *Jurista Vārds*, 15 February 2021. Available: <https://m.juristavards.lv/eseja/278294-laires-un-taisniguma-kolizija-tiesibu-zinatne/> [Accessed: 23.01.2024.]
- [13] R. Suskind “Online Courts and the Future of Justice”. 14 November 2019. Available: <https://academic.oup.com/book/41081> [Accessed: 23.01.2024.]
- [14] I. Kudeikina and S. Kaija “Legal aspects of using artificial intelligence in cassation proceedings in a criminal and civil process”, *PRÁVO – OBCHOD – EKONOMIKA : ZBORNÍK VEDECKÝCH PRÁC*, 2021, pp.114-122.
- [15] A. Sabreen “Online Courts and Private and Public Aspects of Open Justice: Enhancing Access to Court or Violating the Right to Privacy?” *The Age of Human Rights Journal*, (20), e7516. Available: <https://revistaselectronicas.ujaen.es/index.php/TAHRJ/article/view/7516> [Accessed: 23.01.2024.]
- [16] P.Gund, S. Patil, and V. Phalke “INVESTIGATING CRIME: A ROLE OF ARTIFICIAL INTELLIGENCE IN CRIMINAL JUSTICE” *The Online Journal of Distance Education and e-Learning*, April 2023 Volume 11, Issue 2 [Online] Available: <https://www.tojdel.net/?pid=showissue&issueid=278> [Accessed: 23.01.2024.]
- [17] José Félix Muñoz-Soro, Rafael del Hoyo Alonso, Rosa Montañes, Francisco Lacueva “A neural network to identify requests, decisions, and arguments in court rulings on custody” *Artificial Intelligence and Law*. 9 January 2024. Available: <https://link.springer.com/journal/10506> [Accessed: 23.01.2024.]
- [18] Law On Forensic Experts. 15 March 2016. [Online] Available: <https://likumi.lv/ta/en/en/id/280576-law-on-forensic-experts> [Accessed: 23.01.2024.]
- [19] I. Kudeikina, M. Loseviča and N. O. Gutorova “Legal and practical problems of use of artificial intelligence-based robots in forensic psychiatry” *Wiadomości Lekarskie, VOLUME LXXIV, ISSUE 11 PART 2, NOVEMBER 2021*. [Online] Available: <https://wiadlek.pl/wp-content/uploads/archive/2021/WLek2021112.pdf> [Accessed: 23.01.2024.]
- [20] Eiropas Komisija. Komisijas paziņojums Eiropas Parlamentam, Eiropadomei, Padomei, Eiropas Ekonomikas un Sociālajai komitejai un Reģionu komitejai. Koordinētais mākslīgā intelekta plāns. 2018 [Online] Available: <https://eur-lex.europa.eu/legal-content/LV/TXT/HTML/?uri=CELEX:52018DC0795&from=EN> [Accessed: 23.01.2024.]
- [21] Latvia AI Strategy Report. 2020. [Online] Available: https://ai-watch.ec.europa.eu/countries/latvia-0/latvia-ai-strategy-report_en [Accessed: 23.01.2024.]
- [22] EIROPAS PARLAMENTA PIENĒMTIE GROZĪJUMI COM(2021) 0206 – C9-0146/2021 – 2021/0106 (COD) PRIEKŠLIKUMĀ EIROPAS PARLAMENTA UN PADOMES REGULAI, KAS NOSAKA SASKAŅOTAS NORMAS MĀKSLĪGĀ INTELEKTA JOMĀ (MĀKSLĪGĀ INTELEKTA AKTS) UN GROZA DAŽUS SAVIENĪBAS LEGISLATĪVOS AKTUS, PIENĒMTI: 14.06.2023. [ONLINE] AVAILABLE: [HTTPS://EUR-LEX.EUROPA.EU/LEGAL-CONTENT/LV/TXT/?URI=CELEX%3A52021PC0206](https://eur-lex.europa.eu/legal-content/LV/TXT/?uri=CELEX%3A52021PC0206) [ACCESSSED: 22.01.2024.]
- [23] ETHICS GUIDELINES FOR TRUSTWORTHY AI. 2019. [ONLINE] AVAILABLE: [HTTPS://DIGITAL-STRATEGY.EC.EUROPA.EU/EN/LIBRARY/ETHICS-GUIDELINES-TRUSTWORTHY-AI](https://digital-strategy.ec.europa.eu/en/library/ethics-guidelines-trustworthy-ai) [ACCESSSED: 22.01.2024.]

Exploring the Efficacy of Online Proctoring in Online Examinations: A Comprehensive Review

Milena Kuleva

Dept. Language Learning and Internet Technologies
National Sports Academy "Vassil Levski"
Sofia, Bulgaria
milena.kuleva@nsa.bg

Ognyan Miladinov

Athletics department
National Sports Academy "Vassil Levski"
Sofia, Bulgaria
ogimil@nsa.bg

Abstract. *With the rapid growth of online education, ensuring academic integrity in online examinations has become a significant concern. Online proctoring has emerged as a solution to monitor students remotely during exams, aiming to deter cheating and maintain assessment credibility. This scientific article thoroughly reviews the literature to investigate the effectiveness, challenges, and implications of using online proctoring in online examination settings.*

A systematic review was conducted by searching electronic databases, including popular scientific databases such as Web of Science, Ebsco, Scopus, and Google Scholar, for relevant articles published between 2018 and 2023. Keywords such as "online proctoring", "remote invigilation", "academic integrity" and "online examination" were used to identify pertinent studies. Various research designs, including experimental studies, case analyses, and qualitative assessments, were considered to capture diverse perspectives.

The review synthesized findings from existing literature to elucidate the multifaceted aspects of online proctoring in online examinations. Studies highlighted the potential of online proctoring to mitigate cheating behaviors through real-time monitoring, identity verification, and surveillance mechanisms. Proponents of online proctoring argue that it offers a scalable solution to uphold academic standards in online learning environments. Furthermore, some research indicated that students perceive online proctoring as a fair method to ensure equal treatment and transparency during assessments.

However, challenges such as privacy concerns, technological issues, and the potential for bias in proctoring algorithms were identified as significant drawbacks. Additionally, the implementation of online proctoring may exacerbate disparities in access to resources and exacerbate test anxiety among students.

In conclusion, integrating online proctoring in online examinations presents opportunities and challenges for academic institutions. While online proctoring offers a means to enhance exam security and maintain academic integrity in remote learning environments, its implementation requires careful consideration of ethical, technical, and pedagogical implications. Adopting online proctoring should be balanced with the need to uphold academic standards while ensuring

equitable access and promoting student well-being in online education.

Keywords: *dishonesty, effectiveness, online proctoring, online exams.*

I. INTRODUCTION

The rapid evolution of technology and the unforeseen circumstances brought about by the COVID-19 pandemic have significantly accelerated the transition to online education and assessment methods. This shift has necessitated the adoption of online proctoring systems to maintain academic integrity and fairness in examinations conducted remotely. Online proctoring, which employs various technologies to monitor examinees during tests to prevent academic dishonesty, has become a crucial component of online education. This comprehensive review explores the efficacy of online proctoring in online examinations, examining its impact on academic integrity, student experience, and challenges.

There are several basic types of proctoring - Live, recorded, and automated proctoring. [1].

The transition to online education has posed significant challenges and opportunities in maintaining the integrity of examinations. Traditional in-person proctoring methods, which play a critical role in deterring academic dishonesty, are not feasible in remote settings, leading to the adoption of online proctoring solutions. These solutions range from automated systems using artificial intelligence (AI) for suspicious activity detection [2] to live proctoring by individuals through videoconferencing platforms [3]. The effectiveness of these systems in detecting and deterring academic dishonesty has been a topic of extensive research, with studies showing varying levels of success [4], [5].

Moreover, the impact of online proctoring on the educational experience cannot be overlooked. While some studies suggest that online proctoring can enhance the credibility and reliability of online assessments [6], others

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8058>

© 2024 Milena Kuleva, Ognyan Miladinov. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

raise concerns about the potential for increased anxiety among students and the feeling of being surveilled, which could negatively affect their performance [7]. The ethical considerations surrounding privacy and the psychological impact of surveillance are critical issues that need to be addressed [8].

The adoption of online proctoring technologies has also been influenced by the need for scalable and efficient methods to conduct examinations remotely. Innovations in AI and machine learning have led to the development of sophisticated proctoring solutions capable of identifying suspicious behaviors with high accuracy [9 – 10]. However, the effectiveness of these systems in different contexts and their acceptance among academic communities remain areas of ongoing research.

The literature on online proctoring needs to be critically evaluated, with attention to its effectiveness in preventing cheating, its impact on the student experience, and its ethical and legal challenges. By examining a wide range of research and perspectives, this review aims to provide a comprehensive understanding of the current state of online proctoring and offer insights into future directions for research and practice in this area.

II. METHODOLOGY

This review synthesizes data from various scientific articles focusing on online proctoring systems. The methodology involved a systematic review of literature published between 2018 and 2023, identifying studies that assess the effectiveness, challenges, and perceptions of online proctoring in higher education. Keyword searches included terms such as "Online proctoring", "Online exam", "remote examination," "academic integrity", and "e-assessment". 445 results were found, from which we selected 27 scientific articles after a thorough review based on the inclusion criteria. Both qualitative and quantitative studies provided a comprehensive understanding of the subject. Additionally, this review examined technological advancements in proctoring software, including AI-driven monitoring, biometric identification, and behavioral analysis, to evaluate their contributions to academic integrity.

Following the study's main objective, i.e., to investigate the efficacy of online proctoring systems, we provided inclusion and exclusion criteria for the articles in this study.

A. Inclusion criteria

1. An online exam proctoring environment was examined, and the tests included researched participants.
2. Explored the opinion of surveyed participants about their experience during online testing.
3. An overview study on online exam proctoring has been done.
4. Analysis (including comparative analysis) of different online proctoring systems.

B. Exclusion criteria

1. An article that presents only the technical description and parameters of an online proctoring system.

After thoroughly applying the criteria, 22 articles were selected as eligible to be included in the review article. Some of them research the opinions and results of

participants in an online exam with a different proctoring product, and a few prepare essay articles on the topic. Five articles address the exclusion criterion.

Although the research team is part of a university institution with a sports focus, we chose not to limit the study to this topic because, despite their focus, the exams are mainly theoretical and do not differ radically in approach from those in, for example, geography, mathematics or agricultural sciences. Students at the National Sports Academy " Vassil Levski" are not tested entirely in physical achievements as athletes but in theoretical ones - as future coaches, teachers of physical education and sport, and also physiotherapists.

III. RESULTS AND DISCUSSION

Several issues were identified from the detailed analysis of the articles that are of utmost importance concerning "Online Proctoring" and conducting examinations in an electronic environment.

In general, the articles report a relatively positive effect in their study of the application of the online proctoring method.

M. Bernardo and E. Bontà [11] found that it turns out that using an e-proctoring tool alone is not entirely satisfactory from a timing viewpoint while resorting to video surveillance alone is even risky as it provides no systematic feedback about what is happening on students' computers. They strongly believe that using an online proctoring system is essential, but on the other hand, they find that teachers are not fully prepared for this type of testing. On the other hand, Chan and Ahn [12] conclude that online exams, even when unproctored, are a viable assessment tool.

An interesting study is presented by Nurpeisova et al. [13], who consider not only the technical characteristics and features of different systems but also the actual applied experience of the learners. They find that a considerable percentage of students (85%) manage to take the tests in an online environment using an exam proctoring system. For this reason and overall, a positive effect is reported. However, this effect would not have been reported as such if it were not for the relatively good internet speed provided for the exams. In conducting the study on the system, it was found that the lighting of the exam location is of great importance as it can give wrong information on the eye position, and the system can report it as an error.

An interesting result was shared by the authors Hussein et al. [14] in their paper, such as the fact that learners were satisfied not only with the use of the mock-proctored test system but also since they could take the exam in a wider time-frame window. Another positive element is that such a system reduces travel and accommodation costs, which in turn justifies the cost of paying for the system. The only negative aspect that emerges in the study is the discomfort of some students being recorded all the time. This, in turn, is a solvable problem, as an automated system is used, and there is no human behind it to supervise, and the recordings are only available for review when necessary.

In the study by Cramp et al. [15], the importance of communication with students and preparation in advance of exams to reduce cognitive load is acknowledged.

Students' own prepractice for the exam and familiarising faculty with the details and instructions to clarify specific information for students is a mandatory element.

Similar to the experience described above, Griffiths [16] also concludes that it is crucial for students to read the instructions before taking the exam. Another interesting approach is to reconfirm the knowledge of some of the students scoring very high on their test two days after the exam by answering two additional questions. As the author mentions, although the students' opinions were not specifically sought, the challenge was to set up the webcam in a way that matched the instructions sent to the students.

In the study by Purpura et al. [17], no serious problems were reported with the use of a proctoring system, but it was reported as a problem that not all learners were proficient enough in English, and when technical assistance was needed from the system's help desk, a communication problem was reported. In this case, the problem was solved with assistance from the training institution, who were available when a problem arose. Despite the difficulties in adapting and switching to online testing, the authors of the study report an overall positive effect and that the implementation of such a system is for the better.

Oeding [18] describes in detail the possible case studies that can most often be described as rule violations in online testing when using a proctoring system. The author suggests paying utmost attention to examining the video recordings of those with the highest rank for suspicious behavior, especially in reporting the examinee's eye movements on the screen.

As shortcomings in proctoring systems are reported in the study of Arno et al. [19], a more specific problem appears to be the system's lack of precision in detecting irregularities. In conclusion, they outline the need to limit the number of learners who appear for an exam, as this increases the complexity of monitoring and the fact that pre-preparation of an exam conducted in an electronic environment supported by a proctoring system is mandatory.

The so-called "hidden labor" of maintaining an "automated" system is one of the critical remarks in the Selwyn et al. study [20]. Also, the article examines the adoption of online proctoring in universities as a short-term solution during a crisis, suggesting it might become a long-term fixture. It highlights the benefits from an institutional perspective, such as catering to remote learners through data-driven examination methods. However, it also raises significant concerns about privacy, ethics, and the commercialization of education by normalizing automated monitoring and outsourcing educational functions. The piece suggests that these practices may fundamentally alter the nature of university education and emphasizes the need to rethink online proctoring in alignment with educational values that respect users and promote quality education.

The ethicality of the process is also addressed in the article by Coghlan et al. [21], as they consider the use of online proctoring software to be rather unethical in terms of using facial recognition and data without the fully informed consent of examinees. We believe that this is rather a manageable problem, but the need for clarification and the provision of additional information is mandatory.

In their article, Kharbat and Abu Daabes [22] raise essential questions about online proctoring technologies. Interesting feedback was received from research subjects who reported anxiety during exams about not being able to control sounds coming from family members or other external objects or from the fact that due to certain cultural or other beliefs, the family disagreed with the use of such technology to conduct exams. The study has shown that students' overall satisfaction with e-proctoring was below their expectations.

From the analysis conducted in the study by Chen et al. [23], they believe that "*if students are willing to cheat in an academic context, it seems probable that they would also cheat as an employee if given sufficient opportunity*". They conclude that "*proctoring online exams is important in maintaining exam integrity and for the reputation of an academic program or university*".

The study by Lee and Fanguy [24] addresses the view that it is necessary to foster a more positive and democratic future in online higher education post-pandemic. There is a need to support innovative assessment practices that emphasize trust and formative assessment over surveillance. Similar to the practice of using books during examination or project-based assessments, the article suggests that educational technology and higher education institutions should support and collaborate with teachers who engage in innovative assessment practices.

The system considered in the article by Guney et al. [10] has been reported to be capable of producing false positive or false negative test results. In conclusion, they theorize that in the near future, it is expected that exam-based proctoring environments of this kind will be used outside of educational environments, namely for hiring employees for various companies and fields.

Evidence of exam anxiety is also discussed in the article by Conijn et al. [7]. In this study, it was found that factors such as lack of study space, lack of reliable technology, or financial issues were found to increase test anxiety.

Barrio [25] makes a general discussion on online proctoring technologies and identifies significant concerns regarding privacy, equity, and pedagogical integrity. The legal aspects of the problem and the specificity of GDPR legislation are discussed. He considers that the "lawfulness of the processing is highly disputable, taking into account the existence of assessment methods that, in addition to having a better education value, do not infringe students' rights."

An interesting study on the value of a proctored versus non-proctored testing environment for online class exams was prepared by Reisenwitz [26]. He considers that there may be fewer or no opportunities for academic dishonesty due to the implementation of proctored online exams, but also that the students may be attracted to online classes because of the increased opportunity for academic dishonesty in the case of instructors who do not proctor their exams. And the results of his research lead directly to the conclusion that exams need to be proctored.

In their study, Tweissi et al. [5] compare exam results conducted through an online proctoring system with embedded artificial intelligence, and the same is analyzed

through human decisions about misconduct during the exam. After testing and analysis, the conclusion drawn was that online proctoring becomes more accurate when the system is automated with less human intervention. It is also found that there are misconduct cases that human proctors cannot easily identify during the examination, especially in the case of large numbers of students.

Having conducted their research, Dendir and Stockton Maxwell [4] conclude that the use of online proctoring technology is effective, and although it is not a perfect tool, its use is important to be encouraged.

In the exams compared and experiments done, Vazquez et al. [27] found that students who were not subject to proctoring scored, on average, 11% higher compared to those who were required to use a proctor. Although their research is more about the unfair methods used in testing (in-person and online), it can be said that collaboration as an approach is the most prevalent method in online testing, using their notes, books, or the internet.

IV. CONCLUSIONS

We found that some of the articles did not have as positive a view towards proctoring solutions for exam integrity, but at the same time, could not be sorted into those with an entirely positive effect, a mixed effect, or an entirely negative effect of using these forms of exam proctoring in an online environment.

We could formulate some conclusions and lines for future research from the analysis of the presented articles.

Challenges emerge in the use of proctoring systems for online examinations in distance form by students with different types of disabilities, but on the other hand, facilitation for students with physical disabilities or (temporary) injuries. Also, students with insufficient computer experience and who type more slowly or look at the keyboard when typing would find it a real challenge to use this kind of system.

The lack of a stable internet could also be identified as a significant challenge in conducting online examinations through a proctoring system.

The development of an automated AI-based proctoring system demonstrated high accuracy in detecting suspicious activities, thus enhancing the integrity of online exams. As artificial intelligence evolves, it will be interesting to track from a scientific perspective whether systems for detecting unfair practices in online environments will become more sophisticated or more challenging in terms of AI's popularity among learners.

According to student satisfaction, studies revealed mixed effects on student satisfaction and performance, with some students reporting satisfaction with online proctoring services while others faced performance issues. Conversely, some research indicates that the stress associated with being monitored can negatively impact performance, particularly for test-takers with anxiety disorders. Perceptions of online proctoring among students and faculty are varied. Many students appreciate the flexibility and convenience of online examinations but express concerns about privacy and the invasiveness of proctoring software. Faculty members recognize the necessity of online proctoring for maintaining academic

standards but highlight challenges in implementing these systems, including technical issues and the need for extensive training.

As a general conclusion, it could be said that online systems can be used as a supplementary, short-term option for schools or universities during sudden, critical situations. They are an effective and practical solution, although not ideal in terms of accuracy, but could detect suspicious behavior during an exam to a very high level. However, the effectiveness varies depending on the proctoring method (live, recorded, or automated) and the robustness of the technology used. Flexibility in the decisions of educational institutions would be rather positive for them, as it would not restrict their learners and, at the same time, ensure the fairest possible approach to taking an exam in an electronic environment.

REFERENCES

- [1] M. J. Hussein, J. Yusuf, A. S. Deb, L. Fong, and S. Naidu, "An evaluation of online proctoring tools," *Open Praxis*, vol. 12, no. 4, p. 509, Dec. 2020. <https://doi.org/10.5944/openpraxis.12.4.1113>
- [2] P. Tejaswi, S. Venkatramaphanikumar, and K. Venkata Krishna Kishore, "Proctor Net: An AI framework for Suspicious Activity Detection in online proctored examinations," *Measurement*, vol. 206, p. 112266, Jan. 2023. <https://doi.org/10.1016/j.measurement.2022.112266>
- [3] A. Okada, P. Scott, and M. Mendonça, "Effective web videoconferencing for proctoring online oral exams: A case study at scale in Brazil," *Open Praxis*, vol. 7, no. 3, p. 227, Jul. 2015. <https://doi.org/10.5944/openpraxis.7.3.215>
- [4] S. Dendir and R. S. Maxwell, "Cheating in online courses: Evidence from online proctoring," *Computers in Human Behavior Reports*, vol. 2, p. 100033, Aug. 2020. <https://doi.org/10.1016/j.chbr.2020.100033>
- [5] A. Tweiswi, W. Al Etaiwi, and D. Al Eisawi, "The accuracy of AI-based automatic proctoring in online exams," *Electronic Journal of e-Learning*, vol. 20, no. 4, pp. 419–435, Oct. 2022. <https://doi.org/10.34190/ejel.20.4.2600>
- [6] A. S. Milone, A. M. Cortese, R. L. Balestrieri, and A. L. Pittenger, "The impact of proctored online exams on the educational experience," *Currents in Pharmacy Teaching and Learning*, vol. 9, no. 1, pp. 108–114, Jan. 2017. <https://doi.org/10.1016/j.cptl.2016.08.037>
- [7] R. Conijn, A. Kleingeld, U. Matzat, and C. Snijders, "The fear of big brother: The potential negative side-effects of proctored exams," *Journal of Computer Assisted Learning*, vol. 38, no. 6, pp. 1521–1534, Feb. 2022. <https://doi.org/10.1111/jcal.12651>
- [8] S. Coghlan, T. Miller, and J. Paterson, "Good proctor or 'big brother'? Ethics of Online Exam Supervision Technologies," *Philosophy & Technology*, vol. 34, no. 4, pp. 1581–1606, Aug. 2021. <https://doi.org/10.1007/s13347-021-00476-1>
- [9] Y. Atoum, L. Chen, A. X. Liu, S. D. Hsu, and X. Liu, "Automated online exam proctoring," *IEEE Transactions on Multimedia*, vol. 19, no. 7, pp. 1609–1624, Jul. 2017. <https://doi.org/10.1109/tmm.2017.2656064>
- [10] C. Guney, O. Akinci, and K. Çamoğlu, "Artificial Learning-based proctoring solution for remote online assessments: VPROCTOR," *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, vol. XLVI-4/W5-2021, pp. 235–238, Dec. 2021. <https://doi.org/10.5194/isprs-archives-xxvi-4-w5-2021-235-2021>
- [11] M. Bernardo and E. Bontà, "Teaching and Learning Centers and coordinated technologies for an effective transition at COVID-19 pandemic time to massive distance learning and online exams," *Journal of e-Learning and Knowledge Society*, 19(2), 22-29. 2023 <https://doi.org/10.20368/1971-8829/1135492>
- [12] J. C. Chan and D. Ahn, "UNPROCTORED online exams provide meaningful assessment of student learning," *Proceedings of the National Academy of Sciences*, vol. 120, no. 31, Jul. 2023. <https://doi.org/10.1073/pnas.2302020120>

- [13] A. Nurpeisova et al., "Research on the development of a proctoring system for conducting online exams in Kazakhstan," *Computation*, vol. 11, no. 6, p. 120, Jun. 2023. <https://doi.org/10.3390/computation11060120>
- [14] M. J. Hussein, J. Yusuf, A. S. Deb, L. Fong, and S. Naidu, "An evaluation of online proctoring tools," *Open Praxis*, vol. 12, no. 4, p. 509, Dec. 2020. <https://doi.org/10.5944/openpraxis.12.4.1113>
- [15] J. Cramp, J. F. Medlin, P. Lake, and C. Sharp, "Lessons learned from implementing remotely invigilated online exams," *Journal of University Teaching and Learning Practice*, vol. 16, no. 1, pp. 137–155, Jan. 2019. <https://doi.org/10.53761/1.16.1.10>
- [16] B. J. Griffiths, "Mitigating cheating during online proctored exams," *Research on Education and Media*, vol. 14, no. 2, pp. 9–14, Dec. 2022. <https://doi.org/10.2478/rem-2022-0016>
- [17] J. E. Purpura, M. Davoodifard, and E. Voss, "Conversion to remote proctoring of the Community English Language Program Online Placement exam at Teachers College, Columbia University," *Language Assessment Quarterly*, vol. 18, no. 1, pp. 42–50, Jan. 2021. <https://doi.org/10.1080/15434303.2020.1867145>
- [18] J. M. Oeding, "The prevention and detection of academic dishonesty: Watch the online exam proctoring videos.," *Quarterly Review of Distance Education*, <https://eric.ed.gov/?id=EJ1363637> (accessed Feb. 23, 2024).
- [19] S. Arnò, A. Galassi, M. Tommasi, A. Saggino, and P. Vittorini, "State-of-the-art of commercial proctoring systems and their use in academic online exams," *International Journal of Distance Education Technologies*, vol. 19, no. 2, pp. 55–76, Apr. 2021. <https://doi.org/10.4018/ijdet.20210401.0a3>
- [20] N. Selwyn, C. O'Neill, G. Smith, M. Andrejevic, and X. Gu, "A necessary evil? the rise of online exam proctoring in Australian universities," *Media International Australia*, vol. 186, no. 1, pp. 149–164, Apr. 2021. <https://doi.org/10.1177/1329878x211005862>
- [21] S. Coghlan, T. Miller, and J. Paterson, "Good proctor or 'big brother'? Ethics of Online Exam Supervision Technologies," *Philosophy & Technology*, vol. 34, no. 4, pp. 1581–1606, Aug. 2021. <https://doi.org/10.1007/s13347-021-00476-1>
- [22] F. F. Kharbat and A. S. Abu Daabes, "E-proctored exams during the COVID-19 pandemic: A close understanding," *Education and Information Technologies*, vol. 26, no. 6, pp. 6589–6605, Feb. 2021. <https://doi.org/10.1007/s10639-021-10458-7>
- [23] C. Chen, K. T. Jones, M. Lawrence, and J. M. Simpson, "Can educators prevent a 'wild west' scenario in giving online exams?," *Quarterly Review of Distance Education*, <https://eric.ed.gov/?id=EJ1363616> (accessed Feb. 23, 2024).
- [24] K. Lee and M. Fanguy, "Online exam proctoring technologies: Educational innovation or deterioration?," *British Journal of Educational Technology*, vol. 53, no. 3, pp. 475–490, Jan. 2022. <https://doi.org/10.1111/bjet.13182>
- [25] F. Barrio, "Legal and pedagogical issues with online exam proctoring," *European Journal of Law and Technology*, 2022 <https://ejlt.org/index.php/ejlt/article/view/886> (accessed Feb. 23, 2024).
- [26] T. H. Reisenwitz, "Examining the necessity of proctoring online exams," *Journal of Higher Education Theory and Practice*, vol. 20, no. 1, Apr. 2020. <https://doi.org/10.33423/jhetp.v20i1.2782>
- [27] J. J. Vazquez, E. P. Chiang, and I. Sarmiento-Barbieri, "Can we stay one step ahead of cheaters? A field experiment in Proctoring Online Open Book Exams," *Journal of Behavioral and Experimental Economics*, vol. 90, p. 101653, Feb. 2021. doi:10.1016/j.socec.2020.101653

Exploring the Integration of Virtual Reality in Physical Education: A Comprehensive Review

Milena Kuleva

*Department of Language Learning and Information Technologies
National Sports Academy "Vassil Levski"*

Sofia, Bulgaria
milena.kuleva@nsa.bg

Abstract. Virtual Reality (VR) has emerged as a promising technology with diverse applications across various domains, including education. In the realm of physical education (PE), VR presents an innovative approach to enhance learning experiences, offering immersive environments and interactive simulations. This study provides a comprehensive review of existing literature to explore the integration of VR in PE, focusing on its efficacy, challenges, and potential outcomes.

A systematic search of academic databases, including ProQuest/Web of Science, EBSCO, DOAJ, and Gale databases, was conducted to identify relevant studies published between Jan. 2016 and Feb. 2024. Keywords such as "virtual reality" and "physical education" were used to filter the literature. Studies involving diverse research designs, including experimental trials, case studies, and qualitative analyses, were included in the review.

The review revealed a growing amount of literature exploring the integration of VR in PE, highlighting its potential to enhance engagement, motivation, and skill acquisition among students. Studies reported positive outcomes in various systems around the world. VR-based interventions demonstrated effectiveness in improving performance, knowledge retention, and adherence to exercise regimens. Moreover, immersive simulations enabled experiential learning, providing students with realistic scenarios. However, challenges such as equipment cost, technical limitations, and user discomfort were noted as barriers to widespread adoption. Additionally, concerns were raised regarding the potential isolation of students and the need for adequate supervision in VR environments.

In conclusion, the integration of VR technology in PE shows promise as a valuable tool to enrich teaching and learning experiences. With continued advancements in technology and pedagogy, VR has the potential to revolutionize PE education, providing students with immersive and interactive learning environments conducive to holistic development.

Keywords: *VR, Physical Education, Gamification, Immersion, Personalized Learning, Accessibility.*

INTRODUCTION

The integration of technology into Physical Education (PE) has gained significant momentum, driven by its potential to enrich the teaching-learning process and enhance student engagement and learning outcomes. Adopting Virtual Reality (VR) and Augmented Reality (AR) in PE is particularly noteworthy, representing a frontier in educational technology that combines digital and physical environments to offer innovative learning experiences. AR can magnify the user's visual field with data and information under an instant real-world environment [1]. These technologies enable the simulation of diverse physical activities and environments, providing students with interactive and immersive learning opportunities. The use of VR and AR in PE has shown positive impacts on students' understanding, cognitive motivation, motor skills performance, and physical activity levels. Such a positive impact could also be found for people with different disabilities. [2-6]. However, despite the growing interest and evident benefits, research in this area is still in its early stages, indicating a need for further exploration and evidence-based integration into PE curricula.

As Chen et al. [7] also confirmed in 2019, a significant amount of research exists on motion training systems and methodologies utilizing virtual reality. However, these studies have not provided detailed evaluations of user motion learning outcomes across different immersive environments nor offered thorough insights into the connection between users' learning achievements and their VR experiences. Such evaluations and analyses are crucial for developing upcoming immersive motion learning systems.

VR technology enhances sports science by boosting physical activity via exergames, advancing performance through training programs, and aiding injury recovery [8].

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8057>

© 2024 Milena Kuleva. Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

The integration of VR and AR in educational environments is a new era, especially within the field of physical education. This new technological frontier offers unparalleled opportunities to improve teaching methods, engage students in immersive learning experiences, and address long-standing teaching challenges.

A. The Rise of VR/AR in Education

The adoption of VR and AR technologies in education has been progressively increasing, motivated by their potential to provide immersive, interactive learning environments that engage students in a manner traditional methods cannot. In the context of PE, these technologies promise to revolutionize how physical skills and health concepts are taught, learned, and assessed. Unlike conventional PE approaches that are limited by physical space, equipment availability, and safety concerns, VR/AR can simulate a wide array of physical activities and sports in a controlled, safe environment. This allows students to practice skills, understand complex concepts, and receive immediate feedback in an engaging and effective way.

It could be said that in the school programs of different countries, different sports are offered to students depending on the region. For example, countries around the Mediterranean do not practice the same sports as more northern countries, and vice versa. The implementation of VR technology effectively bridges this gap, allowing for a more inclusive and diverse range of sports from both regions to be integrated into the teaching content. [9].

B. Engagement and Motivation

One of the most significant advantages of integrating VR/AR into PE is the potential to increase student engagement and motivation significantly. By immersing students in virtual environments that simulate real-world sports scenarios or physical activities, VR/AR makes learning more compelling and enjoyable. This heightened engagement can improve attendance and participation rates, especially among students who may not be traditionally interested in physical activities or feel self-insecure in physical settings. [10-11]

Skill Acquisition and Performance

VR/AR technologies have shown promise in enhancing skill acquisition and performance in PE. Through the use of virtual simulations, students can practice specific skills repeatedly, with the technology providing instant feedback on their performance. This immediate feedback loop allows for rapid adjustments and improvements, potentially accelerating the learning process. Moreover, VR/AR can offer personalized learning experiences, adapting to each student's skill level and learning pace, thus optimizing skill development across diverse student populations. [12-13]

C. Possibilities for Introduction in PE Classes

Introducing VR systems in PE classes opens up many possibilities for educators and students. For instance, VR can simulate challenging environments or scenarios that are impossible or impractical to experience in a school setting, such as mountain climbing, kayaking, or even spacewalking. This not only enriches the curriculum but also ensures that students have access to a broader range

of physical activities, fostering a more inclusive and comprehensive approach to physical education.

Furthermore, AR applications can overlay digital information onto the physical world, offering a unique way to learn about anatomy, physiology, and the science of exercise through interactive experiences. For example, AR can project the muscular system on a student's body as they perform an exercise, providing a deep understanding of the mechanics involved.

D. Challenges and Considerations

Despite the promising potential, the integration of VR/AR into PE faces several challenges, including high costs of equipment, the need for technical support and training for educators, and concerns about equitable access for all students. Addressing these challenges requires strategic planning, investment in infrastructure, and ongoing professional development for educators. The value of creating VR environments is based on many hours of work by professionals - both technical and psychological-pedagogical.

II. MATERIALS AND METHODS

This study conducts a comprehensive literature review focusing on the integration of virtual reality in physical education and sports classes in schools and universities around the world. The articles part of this research are from January 2016 to February 2024, with a total of 3065 sources. By using digital library access to numerous scientific databases such as ProQuest/Web of Science, EBSCO, DOAJ, Gale databases, and others, the search was defined to include as many articles as possible for exact coverage. The keyword strategy encompassed combinations like "Virtual reality AND PE classes", "VR AND Sports education" and "VR AND Physical Education", among others. Due to the sheer volume of articles, the study was limited to making sure that both applied terms necessarily appeared either in the title of the publications or in the subject line. On this basis, the number of articles that were reviewed was 78. To be able to identify articles that would fall as close as possible to our study, the following criteria were set:

Inclusion Criteria:

- Explicit use of a virtual environment.
- Involvement of physical activity or sports with reported outcomes for a Physical education class.
- Publication in English.
- Minimum of 5 participants.
- Detailed results, preferably with tables and graphical representations.

Exclusion Criteria:

- Case studies.
- Absence of informed consent.
- Non-English publications.
- Studies without physical activity or sports participation or not in the educational process.
- Theoretical research only.
- Participants with diagnosed diseases or in hospital settings.

III. RESULTS AND DISCUSSION

After applying the inclusion and exclusion criteria, only seven publications were included in the analyzed articles. Of the total number of articles examined, 71 were dropped for the following reasons:

- The publication was not on the subject of physical education and sport - 25 pcs.
- There was no examination of research subjects in the publication - 16 pcs.
- The publication included researched persons with various diseases - 1 pc.
- The publication was a review - 11 pcs.
- The publication was theoretical - 18 pcs.

The review of the seven articles, as a whole, highlighted mainly the positive aspects of VR and its application.

The study by Chang et al. [14] that we will review found that AR-assisted learning with 3D models can improve performance in motor skills learning compared to video learning. However, there were challenges with the AR mobile carrier that needed to be addressed, and the satisfaction of students using AR-assisted instruction was generally higher than that of traditional methods.

The AR-PE class can be adapted to provide learning opportunities in athletic competitions and training experiences beyond individual motor skills training by incorporating virtual reality (VR) into the assistive system. This would enable situational learning, allowing learners to experience realistic athletic scenarios and training environments. Additionally, the integration of mixed reality, which combines augmented and virtual reality, can be explored as a research direction for athletic training aids. This approach would offer a more comprehensive and immersive learning experience for athletic competitions and training beyond individual motor skills training.

Building on the initial findings, further analysis through literature research, expert interviews, and questionnaire surveys explored the impact of VR technology on physical training teaching in college classrooms in the study of Wang et al. [15]. Their experimental results affirmed the validity of all research hypotheses, indicating a positive impact of VR technology on physical education. They reported that a significant portion of participants reported improvements in various aspects of learning due to VR technology. Specifically, 80% found that VR stimulated interest in learning, 75% observed that it attracted more attention, and 63% believed it improved learning efficiency. Such findings highlight VR's capability to make education more engaging and effective. They also conclude that VR technology has shown its potential to significantly enhance educational outcomes by a deeper understanding of physical training, increasing learning efficiency, and accelerating learning progress.

Chen's paper [16], which was published in 2022, on the use of Cross-Country Skiing Teaching, is interesting. Research has been done, but unfortunately, no particular conclusions stand out, and this probably means that research needs to be furthered in this direction. It is a sport that is not commonly practiced in physical education

classes but could be included, to some extent, to introduce it and spark learners' interest in doing it. Probably, a vast majority of the learners would not have come into contact with this sport had it not been for the opportunity created through VR.

Dong's [17] research, published in 2020, highlights the significant role that advancements in technology, specifically mobile communication and virtual reality, play in enhancing physical education and exercise. As living standards improve and the importance of fitness gains momentum, incorporating high-tech means such as 5G and VR into physical training has made sports more engaging, entertaining, and effective in improving physical quality. Their approach is mainly aimed at the younger generation, emphasizing the necessity of integrating their physical health into educational reforms. Smart physical education, facilitated by using 5G and VR for anytime, anywhere fitness exercises, not only raises exercise awareness among students but also fosters a healthy lifestyle by blending interest with physical activity. However, the study indicates a positive impact of intelligent physical education on students' physical performance. The future of physical education looks promising, with the potential for an integrated sports and entertainment project, underscoring the need for ongoing development in this field to organize the most effective teaching schemes for contemporary students.

An important study was conducted by the team of Geisen et al. [18] from Germany in 2023. The authors of the study implemented VR in dance-related sports activity classes. According to their research, the analysis of the VR rotation task reveals its potential to evoke unique perceptual experiences and unexpected behavioral responses among students, highlighting the complex interplay between physical and mental processes and modern technology. The integration of VR with an electric turntable introduced novel physical and mental rotational perceptions, though it also presented challenges that required effort and adaptation. Despite these challenges, the VR rotation task shows promise for diagnostic and training purposes in perceptual and attentional aspects, particularly in extracurricular dance classes. The task's difficulty suggests the need for extended training and adaptation across various learning environments and age groups, positioning it as a valuable tool for cognitively demanding tasks in various educational fields. Feedback from the study indicates that the VR rotation task can enhance motivation and promote independent, self-organized learning among students, fostering behaviors crucial to dance education, such as observation, communication, interaction, and synchronization. They conclude that the VR rotation task significantly contributes to dance practice's didactic and collaborative aspects, supporting the holistic development of young learners. The findings suggest a promising path for future research into VR-enhanced training tools in sports education and beyond, emphasizing the importance of further exploration and integration of technology in pedagogical strategies to enhance learning experiences and outcomes in sports education fields.

In the research of Chen et al. [7], presented in 2019, they make interesting findings. They developed research with Taichi, which is a special type of Chinese martial art

with particular motion features. They indicate that measuring or predicting learning quality proves more challenging than determining learning time. It was noted that an overly immersive VR environment, such as one provided by head-mounted displays (HMDs), while facilitating rapid learning, may negatively impact learning quality due to excessive immersion, such as the inability for students to see their bodies, potentially misrepresenting motion learning. Quite the opposite, environments that offer good sensory engagement and immersion without overdoing it, like the CAVE system, showed higher motion quality scores and quality of student performance ratings than both overly immersive HMDs and non-immersive PC setups. High presentation quality also plays a vital role in enhancing learning quality. They generally conclude that designing future immersive motion learning systems should balance several key factors: providing an engaging VR experience, ensuring visibility of the learner's body, avoiding motion impediments, delivering high-quality multimedia content, and maintaining a comfortable learning environment. These elements attract learners and significantly improve both the efficiency and quality of the learning experience, highlighting the nuanced relationship between immersion and educational outcomes in VR-based learning environments.

The environment showcased exhibits characteristics of effective immersion, high-quality presentation, ease of use, and separation from distractions, thereby establishing itself as the optimal learning setting despite its cost.

Lee and Oh [2] present a study in 2022 that contributes significantly in three key areas. Firstly, it expands the traditional Technology Acceptance Model (TAM) to include presence and flow, attributes specific to VR/AR media, enhancing understanding of user acceptance and participation intentions in VR/AR sports experiences. Secondly, by identifying experience economy factors as precursors to increasing user presence in VR/AR sports, the study empirically explores the causal link between these factors, providing a nuanced understanding of user engagement. Finally, it offers strategic insights for strengthening the VR/AR sports experience sector.

However, the study faces limitations, notably in its demographic scope, focusing primarily on university students with a sports major, which may not fully represent the broader population engaging with VR/AR sports experiences. Future research is encouraged to explore these findings across different age groups and incorporate qualitative analyses to deepen the understanding of VR/AR sports experiences among different user profiles.

Xiong [19] also concluded that a positive experience with the use of VR technologies was derived from their study in 2021. They focused on martial arts as the subject matter. The research utilized questionnaire surveys to identify the learning needs of martial arts students and the functional requirements of a martial arts teaching system. The system demonstrated a significant improvement in both the learning experience and efficiency for learners, showcasing the potential of integrating advanced technologies in PE teaching methodologies.

An interesting study with adding artificial intelligence to VR is presented by Yuehong Shi [20]. The study was published in 2024 and is one of the most recent studies in this paper, making both an interesting study and essential conclusions. The study investigates the impact of integrating big data technology and genetic algorithms within a VR-based intelligent teaching system for physical education. Through comprehensive research and system development, followed by data analysis on VR technology's application in physical education, they present several key findings:

Applying an AI-driven VR teaching system to aspects such as physical form, quality, and learning attitude does not show statistically significant effects, with p-values exceeding 0.05 in their study. This indicates that both traditional and VR-assisted teaching methods contribute to enhancing students' physical quality, albeit without significant differences between the two approaches.

A focused analysis of tennis technical skills assessment employing VR technology, which Shi [20] presents in their research, reveals a notable improvement in the experimental group's performance. The experimental group scored significantly higher in technical assessments than the control group, demonstrating that VR-assisted tennis teaching can effectively elevate students' tennis skills.

Their study also highlights a 19% to 20% increase in physical education efficiency attributable to VR technology, a significant enhancement in educational efficiency that underscores the effectiveness of VR-assisted teaching methods in physical education settings.

CONCLUSIONS

Based on the above analysis, several conclusions could be drawn.

With the development of VR technologies, more and more researchers are doing their research on the topic. According to the present study, the researches are mainly done by Asian researchers, with the most significant percentage of them being from China.

Instead, there is currently a lack of research investigating the effect of virtual reality in physical education and additional sports in extracurricular activities. The study lacks more in-depth, detailed, and sufficient examination and research on physical education that requires the application of virtual reality technology. However, an opinion may rather be formed that VR and AR in physical education present an exciting opportunity to redefine the learning experience, making it more engaging, inclusive, and effective. As these technologies continue to evolve and become more accessible, their potential to enhance physical education and promote a lifelong love of physical activity among students is boundless. The journey of integrating VR/AR into PE is just beginning, and it promises to pave the way for a future where education is not just about absorbing information but experiencing and interacting with knowledge in profound and meaningful ways.

It could be pointed out that the theory and technical mastery of virtual reality technology are not thorough enough, and there is a lack of comprehensive understanding of its application. This applies more to the

development of appropriate virtual reality environments as well as to specific pedagogical scenarios providing subject-specific knowledge and competencies.

Although not a part of the studied articles that met the inclusion criteria, research on the application of virtual reality in different, not-so-accessible sports that could not be applied in a regular physical education class is found. In this respect, using technology provides an opportunity to enrich the learners' knowledge in the sports that are "not applicable" in the class.

Regarding the financial aspect of virtual reality, it is noteworthy that many of the studies conducted with virtual reality have received funding from research projects or have received funding from an educational institution or a government. This is probably also due to the fact that the cost of developing and testing a virtual reality environment is time-consuming, which automatically makes it an expensive endeavor. It is not just the purchase of the technology - the various helmets - but the constant input of human labor and ideas that makes the product expensive.

The application of VR technology in physical training teaching shows promising results in enhancing learning outcomes, student engagement, and teaching methodologies, and there are opportunities for further research and development to overcome current challenges and fully realize VR's potential in education.

Understanding the current progress in this research area is crucial for its development, given that integrating technology into physical education classes can significantly enhance their quality. This enhancement could be achieved by creating enjoyable student experiences, ultimately aiming to instill lifelong physical sports habits. Therefore, this research holds huge promise for sports practice, offering educators innovative methods to elevate PE class quality through practical experiences and novel technological applications. Furthermore, it emphasizes the advantages these technologies offer students while providing guidelines for their effective implementation in educational settings. Doing so aims to motivate more PE teachers to incorporate technology into their teaching and ensure its proper application, thereby realizing the anticipated benefits highlighted throughout this study.

REFERENCES

- [1] A. Raouf Khan and K. Cheng, "Augmented reality for manufacturing," Springer Series in Advanced Manufacturing, pp. 1–56, 2011. https://doi.org/10.1007/978-0-85729-186-8_1
- [2] K. Lee and S. Oh, "The Users' Intention to Participate in a VR/AR Sports Experience by Applying the Extended Technology Acceptance Model (ETAM)," *Healthcare*, vol. 10, no. 1117, 2022, <https://doi.org/10.3390/healthcare10061117>
- [3] F. Ji, X. Zhang, Zhao, S., and Fang, Q. (2023). Virtual reality: a promising instrument to promote sail education. *Frontiers in Psychology*, 14:1185415. <https://doi.org/10.3389/fpsyg.2023.1185415>
- [4] M. Peng, "Evaluation and analysis of the implementation effects in practical-course blended learning based on virtual reality technology," *International Journal of Emerging Technologies in Learning (IJET)*, vol. 18, no. 15, pp. 94–108, Aug. 2023. <https://doi.org/10.3991/ijet.v18i15.42379>
- [5] N. A. Mokmin and N. N. Ridzuan, "Immersive Technologies in physical education in Malaysia for students with learning disabilities," *IAFOR Journal of Education*, vol. 10, no. 2, pp. 91–110, Aug. 2022. <https://doi.org/10.22492/ije.10.2.05>
- [6] K. Zhao and X. Guo, "Analysis of the application of virtual reality technology in football training," *Journal of Sensors*, vol. 2022, pp. 1–8, Mar. 2022. <https://doi.org/10.1155/2022/1339434>
- [7] X. Chen, Z. Chen, Y. Li, T. He, J. Hou, S. Liu, Y. He, "ImmerTai: Immersive Motion Learning in VR Environments," in *Journal of Visual Communication and Image Representation*, vol. 58, pp. 416-427, 2019. <https://doi.org/10.1016/j.jvcir.2018.11.039>
- [8] A. Denche-Zamorano et al., "Rehabilitation is the main topic in virtual and Augmented Reality and Physical Activity Research: A Bibliometric analysis," *Sensors*, vol. 23, no. 6, p. 2987, Mar. 2023. <https://doi.org/10.3390/s23062987>
- [9] F. Wang and Z. Wei, "Research on the Application of VR Technology in Physical Education," *Frontiers in Sport Research*, vol. 2, no. 6, pp. 116-123, 2020, <https://doi.org/10.25236/FSR.2020.020615>.
- [10] N. A. Mokmin and N. N. Ridzuan, "Immersive Technologies in physical education in Malaysia for students with learning disabilities," *IAFOR Journal of Education*, vol. 10, no. 2, pp. 91–110, Aug. 2022. <https://doi.org/10.22492/ije.10.2.05>
- [11] L. Whalen, J. Barcelona, E. Centeio, and N. McCaughtry, "#healthykidsquarantined: Supporting schools and families with virtual physical activity, physical education, and nutrition education during the Coronavirus Pandemic," *Journal of Teaching in Physical Education*, vol. 40, no. 3, pp. 503–507, Jul. 2021. <https://doi.org/10.1123/jtpe.2020-0299>
- [12] Jiongjiong Fan, "Practical Paths and Countermeasures to Improve the Quality of Physical Education for Future Metaverse Education: Evidence from A Study in China," *International Journal of Education (IJE)*, vol. 4, no. 01, pp. 60-86, 2023, <https://doi.org/10.17605/OSF.IO/47KPZ>
- [13] X. HE, "A conceptual exploration: Incorporating physical education with metaverse," *International Journal of Education and Literacy Studies*, vol. 11, no. 4, pp. 325–331, Oct. 2023. <https://doi.org/10.7575/aiac.ijels.v.11n.4p.325>
- [14] K.-E. Chang, J. Zhang, Y.-S. Huang, T.-C. Liu, and Y.-T. Sung, "Applying augmented reality in physical education on Motor Skills Learning," *Interactive Learning Environments*, vol. 28, no. 6, pp. 685–697, Jun. 2019. <https://doi.org/10.1080/10494820.2019.1636073>
- [15] N. Wang, M. N. Abdul Rahman, and B.-H. Lim, "Teaching and curriculum of the preschool physical education major direction in colleges and universities under Virtual Reality Technology," *Computational Intelligence and Neuroscience*, vol. 2022, pp. 1–10, Mar. 2022. <https://doi.org/10.1155/2022/3250986>
- [16] W. Chen, "College cross-country skiing teaching and sports training based on VR," *Mathematical Problems in Engineering*, vol. 2022, pp. 1–9, Mar. 2022. <https://doi.org/10.1155/2022/8301746>
- [17] Y. Dong, "Analysis of intelligent physical education teaching scheme based on 5G communication + VR technology," *Mobile Information Systems*, vol. 2022, pp. 1–8, Apr. 2022. <https://doi.org/10.1155/2022/8598077>
- [18] M. Geisen, A. Fox, and S. Klatt, "VR as an innovative learning tool in sports education," *Applied Sciences*, vol. 13, no. 4, p. 2239, Feb. 2023. <https://doi.org/10.3390/app13042239>
- [19] Xiuzu Xiong, "A New Physical Education Teaching System and Training Framework Based on Human-Computer Interaction and Auxiliary Interaction," *IJET*, Vol. 16, No. 14, 2021, <https://doi.org/10.3991/ijet.v16i14.24045>.
- [20] Yuehong Shi, "The Application of Computer VR Technology in Physical Education," *Applied Mathematics and Nonlinear Sciences*, vol. 9, no. 1, 2024, <https://doi.org/10.2478/amns.2023.2.00252>

An Implementation of Brain-Computer Interface in Research Activities

Dmytro Mamchur

¹Department of Information Technology,
²Computer Engineering and Electronics Department,
¹Turiba University,
²Kremenchuk Mykhailo Ostrohradskyi National University,
¹Riga, Latvia
²Kremenchuk, Ukraine
dgmamchur@gmail.com

Janis Peksa

¹Department of Information Technology,
²Institute of Information Technology,
Faculty of Computer Science and Information Technology,
¹Turiba University
²Riga Technical University
^{1,2}Riga, Latvia
janis.peksa@turiba.lv

Abstract. The paper provides brief overview of Brain-Computer Interface (BCI), highlighting BCI-based assisting technologies for disabled persons in healthcare applications as one of the key priorities. A proposed solution for implementation OpenBCI-based hardware and software in research on computer typing assistance system described, including general view of experimental test bench and software approach description. An experimental verification of a possible computer typing assistance system is presented, as well as basic test results obtained along with their interpretation and discussion.

Keywords: BCI, ANN, EEG, signal analysis.

I. INTRODUCTION

Brain-Computer Interface (BCI) technology is a cutting-edge field at the intersection of neuroscience, engineering, and computer science. It aims to establish direct communication pathways between the brain and external devices, bypassing traditional peripheral nerves and muscles. The fundamental principle behind BCI is to interpret neural signals, typically extracted non-invasively using electroencephalography (EEG), magnetoencephalography (MEG), functional magnetic resonance imaging (fMRI), or invasive methods like electrocorticography (ECoG) and intracortical electrodes [1].

The concept of BCI dates back to the late 1960s when researchers first demonstrated the feasibility of translating brain signals into control commands for external devices. Since then, significant advancements in signal processing algorithms, machine learning techniques, and hardware technology have propelled the development of more sophisticated and reliable BCI systems.

BCI technology holds immense promise for various applications, ranging from medical rehabilitation to

assistive technologies, neuroprosthetics, gaming, and beyond. In the medical domain, BCI offers new possibilities for individuals with severe motor disabilities, such as spinal cord injuries or amyotrophic lateral sclerosis (ALS), enabling them to control assistive devices, communicate, and even regain some degree of autonomy.

Moreover, BCI research has expanded beyond clinical applications to explore cognitive neuroscience, human-computer interaction, and neuroergonomics. By studying brain activity patterns during different tasks or cognitive states, researchers gain insights into neural mechanisms underlying human behavior, perception, and cognition.

Despite remarkable progress, several challenges remain in the field of BCI technology. These include signal processing artifacts, low signal-to-noise ratios, limited spatial resolution, user training requirements, and ethical considerations surrounding invasive BCI approaches. Addressing these challenges requires interdisciplinary collaboration, innovative research approaches, and continuous improvement in hardware and software technologies.

In general, BCI technology represents a transformative approach to interfacing with the human brain, with the potential to revolutionize healthcare, communication, and human-computer interaction. Continued research and development efforts are essential to unlock the full capabilities of BCI and translate them into practical applications that benefit individuals and society as a whole.

II. MATERIALS AND METHODS

A. Overview of existing BCI applications in research

A literature overview of existing BCI applications in research reveals a wide range of domains where BCI technology has been employed to address various scientific

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8055>

© 2024 Dmytro Mamchur, Janis Peksa. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

questions and practical challenges. Here's a glimpse into some key areas of BCI research applications [1–5].

Neuroscience and Cognitive Psychology. BCI technology allows researchers to study brain activity associated with cognitive processes such as attention, memory, decision-making, and language comprehension. For instance, studies have used BCI to investigate neural correlates of attentional control by decoding attentional states from EEG signals. Similarly, BCI paradigms have been employed to explore neural mechanisms underlying motor imagery, mental rotation, and spatial navigation tasks, providing insights into brain-behavior relationships.

Motor Rehabilitation and Neurorehabilitation. BCI-based rehabilitation approaches offer promising strategies for restoring motor function and facilitating neuroplasticity in individuals with motor disabilities. Research in this area focuses on using BCI systems to provide real-time feedback for motor imagery-based training, functional electrical stimulation, or robotic-assisted therapy. These studies demonstrate the potential of BCI technology to enhance motor learning, promote neural recovery, and improve functional outcomes in patients with stroke, spinal cord injury, or motor impairments.

Assistive Technology and Augmented Communication. BCI systems have been developed as assistive devices to facilitate communication and control for individuals with severe motor disabilities. These applications range from spelling and typing interfaces based on EEG signals to more sophisticated control systems for robotic prosthetics or smart home devices. BCI research in assistive technology aims to improve the accuracy, speed, and reliability of communication channels, enabling individuals to express their intentions, navigate their environment, and interact with external devices using brain signals alone.

Human-Computer Interaction and Gaming. BCI technology is increasingly integrated into interactive systems and gaming platforms to create immersive

experiences and adaptive interfaces. Studies explore the use of BCI for controlling virtual avatars, playing neurofeedback-based games, or enhancing user engagement in virtual reality environments. BCI research in human-computer interaction seeks to optimize user interfaces, design intuitive interaction paradigms, and personalize user experiences based on real-time brain activity patterns.

Clinical Diagnosis and Monitoring. BCI methods hold potential for diagnosing and monitoring neurological disorders, such as epilepsy, attention-deficit/hyperactivity disorder (ADHD), or Alzheimer's disease. Researchers investigate the utility of BCI-based biomarkers for early detection, differential diagnosis, and disease progression tracking. BCI research in clinical applications aims to develop reliable diagnostic tools, identify neurophysiological signatures of pathology, and facilitate personalized interventions for patients with neurological and psychiatric conditions.

Brain-Computer Interface Technology Development. Beyond specific applications, BCI research contributes to advancing the fundamental principles and technological capabilities of BCI systems. Studies focus on developing novel signal processing algorithms, improving feature extraction methods, enhancing machine learning techniques for brain signal decoding, and exploring innovative neuroimaging modalities or electrode technologies. These advancements drive the evolution of BCI technology, making it more robust, versatile, and accessible for research and practical applications.

Overall, the literature on BCI applications in research highlights the multifaceted nature of BCI technology, its potential to address diverse scientific questions and societal needs, and the ongoing efforts to harness its capabilities for improving human health, cognition, and interaction with technology.

Basing on provided overview, main benefits and challenges of BCI methods were summarized in table 1.

TABLE 1 PROS AND CONS FOR GREEN STRATEGIES IMPLEMENTATION

<i>Pros</i>	<i>Challenges</i>
Insights into Brain Function: BCI offers a unique window into the workings of the human brain, allowing researchers to directly observe and manipulate neural activity. By decoding brain signals associated with specific tasks or cognitive processes, BCI facilitates a deeper understanding of brain function, organization, and plasticity.	Signal Quality and Variability: BCI performance is influenced by the quality and variability of brain signals, which can be affected by factors such as electrode placement, participant movement, environmental noise, and individual differences in brain anatomy or physiology. Ensuring robust signal acquisition and processing remains a significant challenge in BCI research, requiring advanced signal processing techniques and artifact removal methods.
Precise Control and Measurement: BCI provides precise control over experimental variables and enables real-time measurement of neural activity with high temporal resolution. This level of control allows researchers to design experiments with fine-grained manipulation of stimuli, tasks, or feedback modalities, enhancing the reliability and reproducibility of research findings.	User Training and Adaptation: Effective BCI operation often requires user training and adaptation to learn new control strategies or mental tasks. This training process can be time-consuming, challenging, and subject to individual variability in cognitive abilities, attentional control, or motor imagery proficiency. Developing user-friendly training protocols and enhancing user engagement are essential for improving BCI usability and user experience.
Non-invasive Exploration: Non-invasive BCI modalities, such as EEG or fMRI, enable researchers to investigate brain function in human participants without the need for invasive procedures. This approach enhances the ethical	Limited Spatial and Temporal Resolution: Non-invasive BCI modalities, such as EEG or fMRI, have inherent limitations in spatial and temporal resolution compared to invasive techniques like ECoG or intracortical recording.

<i>Pros</i>	<i>Challenges</i>
acceptability and accessibility of neuroscientific research, allowing for the study of diverse populations and longitudinal assessments.	These limitations constrain the spatial specificity and temporal precision of neural measurements, posing challenges for deciphering fine-grained neural dynamics and distinguishing between closely related brain processes.
Interdisciplinary Collaboration: BCI research fosters interdisciplinary collaboration among neuroscientists, psychologists, engineers, clinicians, and computer scientists. This collaborative approach leverages diverse expertise to tackle complex research questions, develop innovative methodologies, and translate scientific discoveries into practical applications for healthcare, rehabilitation, and human-computer interaction.	Ethical and Privacy Considerations: BCI research raises ethical and privacy concerns related to the collection, storage, and use of sensitive neural data. Ensuring participant confidentiality, informed consent, and data security is crucial for protecting individual privacy and maintaining trust in BCI research. Ethical guidelines and regulatory frameworks are needed to address these concerns and uphold ethical standards in BCI research.
Clinical Translation and Therapeutic Potential: BCI research holds promise for translating scientific discoveries into clinical applications and therapeutic interventions. BCI-based rehabilitation protocols, assistive devices, and diagnostic tools offer new avenues for improving patient outcomes, enhancing quality of life, and promoting neurorecovery in individuals with neurological disorders or disabilities.	Generalization and Transferability: BCI-trained skills and neural patterns may not always generalize or transfer effectively to real-world contexts or novel tasks. Achieving robust generalization requires understanding the underlying neural mechanisms, identifying task-relevant features, and optimizing training protocols to promote adaptive learning and transfer of BCI skills across domains.

In general, while BCI offers numerous benefits for advancing neuroscience research and technological innovation, it also presents challenges related to signal quality, user training, ethical considerations, and generalization of findings. Addressing these challenges requires interdisciplinary collaboration, methodological innovation, and ethical stewardship to harness the full potential of BCI in research activities.

B. Review of relevant studies on BCI implementation

The seminal review [6] provides an overview of the principles, techniques, and applications of BCI technology, focusing on its potential for communication and control in individuals with severe motor disabilities. The authors discuss various BCI paradigms, signal acquisition methods, and decoding algorithms, highlighting key challenges and future directions for BCI research and clinical translation.

Another review article [7] examines the historical development, current state, and future prospects of brain-machine interfaces (BMIs), including BCI systems. The authors discuss the evolution of BMI technology, from early experimental demonstrations to contemporary applications in neuroscience, prosthetics, and neurorehabilitation. They also explore emerging trends in BMI research, such as closed-loop systems, neuroprosthetic devices, and neuroethics considerations.

In [8] authors explore the expanding scope of BCI technology beyond medical applications, highlighting its potential in non-medical domains such as gaming, neurofeedback, and human augmentation. The authors discuss recent advancements in BCI hardware, software, and signal processing techniques that have enabled new applications and enhanced user experience. They also address challenges and opportunities for future BCI development, including ethical considerations and interdisciplinary collaboration.

Study [9] investigates the feasibility of using a P300-based BCI for communication and control in patients with amyotrophic lateral sclerosis (ALS). The authors

demonstrate that individuals with severe motor disabilities can learn to use the BCI system to spell words and phrases using only their brain signals. The study highlights the potential of BCI technology to improve communication and quality of life for individuals with neurodegenerative diseases.

Review article [10] discusses future directions and challenges in brain-machine interface (BMI) research, with a focus on BCI applications. The authors explore emerging technologies, such as optogenetics, nanotechnology, and neural prosthetics, that hold promise for advancing BMI capabilities and addressing current limitations. They also emphasize the importance of interdisciplinary collaboration, ethical considerations, and translational efforts to realize the full potential of BMI technology for research and clinical applications.

These studies provide valuable insights into the principles, applications, and challenges of BCI implementation, contributing to the advancement of neuroscience research, clinical practice, and technological innovation in the field of brain-computer interfaces.

C. Methodology

Current study deals with development of experimental setup, both hardware and software, capable to be employed for research activities with the use of BCI technology. As a target area of implementation, it was chosen computer typing assistant for patients with motion disabilities. As a hardware component it was chosen OpenBCI solutions, which is an easy-to-use system and good choice for initial experiments with BCI technology.

Designing an experimental setup for research on computer typing assistance using an OpenBCI set involves several components and considerations to ensure reliable data acquisition, user comfort, and experimental control.

OpenBCI hardware used for acquiring EEG signals from the user's scalp. These devices offer flexibility,

highlighted character demonstrated thru LCD monitor for each tested person.

During training stage, a supervised Artificial Neural Network was trained for character recognition based on previously detected features for each signal for each tested person separately. System should recognize each imagined character during 10 attempts per each character demonstrated in random sequence (in total – 40 attempts).

Finally, during verification stage, system should use trained ANN for character recognition [11]. This stage also employed 10 attempts per each character demonstrated in random sequence.

Averaged results for each tested character detection are presented in fig. 2.

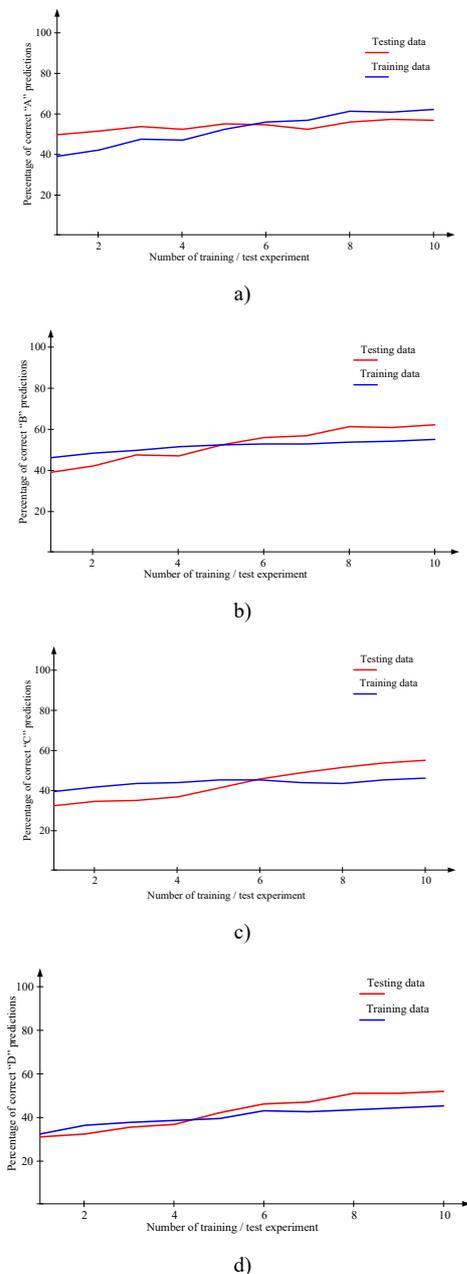


Fig. 2 Test and experiment results on imagined character recognition: a) for letter “A”, b) for letter “B”, c) for letter “C” and d) for letter “D”

Experimental results demonstrated average character recognition accuracy at 57.8% with slight decrease in testing experiments accuracy over training.

In general, signal processing and feature classification algorithms implemented in this research should be improved and extended for all character set. However, main result of current study is implementation of experimental test bench along with developed software solutions which could be further used in research activities on BCI investigations on university premises.

IV. CONCLUSION

The paper presents results on possible solution for BCI implementation in research activities. Analysis of existing trends in the area confirms importance of BCI research on possibilities of its implementation in real-life solutions, especially in healthcare, particularly, in development assistant systems for motion disabled patients.

A possible solution for computer typing assistance, based on OpenBCI hardware and software, was proposed and described in the paper. Main features and attributes of proposed system are highlighted.

A research experiment plan with the use of proposed system, was designed, and implemented within current research. Experiment results revealed lower character recognition accuracy than expected, but important outcome of this research is the developed experimental test bench for BCI research.

Future work will be related to improvement signal processing and feature classification algorithms, extending experimental character set for all alphabet, numbers and special characters used in computer typing.

REFERENCES

- [1] Peksa, J. and Mamchur, D., 2023. State-of-the-Art on Brain-Computer Interface Technology. *Sensors*, 23(13), p.6001
- [2] Mridha, M.F.; Das, S.C.; Kabir, M.M.; Lima, A.A.; Islam, M.R.; Watanobe, Y. Brain-Computer Interface: Advancement and Challenges. *Sensors* 2021, 21, 5746. <https://doi.org/10.3390/s21175746>
- [3] Belwafi, K.; Gannouni, S.; Aboalsamh, H. Embedded Brain Computer Interface: State-of-the-Art in Research. *Sensors* 2021, 21, 4293. <https://doi.org/10.3390/s21134293>
- [4] Siribunyaphat, N.; Punsawad, Y. Brain-Computer Interface Based on Steady-State Visual Evoked Potential Using Quick-Response Code Pattern for Wheelchair Control. *Sensors* 2023, 23, 2069. <https://doi.org/10.3390/s23042069>
- [5] Amprimo, G.; Rechichi, I.; Ferraris, C.; Olmo, G. Measuring Brain Activation Patterns from Raw Single-Channel EEG during Exergaming: A Pilot Study. *Electronics* 2023, 12, 623. <https://doi.org/10.3390/electronics12030623>
- [6] Wolpaw, J.R., Birbaumer, N., McFarland, D.J., Pfurtscheller, G. and Vaughan, T.M., 2002. Brain-computer interfaces for communication and control. *Clinical neurophysiology*, 113(6), pp.767-791.
- [7] Lebedev, M.A. and Nicolelis, M.A., 2006. Brain-machine interfaces: past, present and future. *TRENDS in Neurosciences*, 29(9), pp.536-546
- [8] Van Erp, J., Lotte, F. and Tangermann, M., 2012. Brain-computer interfaces: beyond medical applications. *Computer*, 45(4), pp.26-34.
- [9] Sellers, E.W. and Donchin, E., 2006. A P300-based brain-computer interface: initial tests by ALS patients. *Clinical neurophysiology*, 117(3), pp.538-548.

- [10] Lebedev, M.A., Tate, A.J., Hanson, T.L., Li, Z., O'Doherty, J.E., Winans, J.A., Ifft, P.J., Zhuang, K.Z., Fitzsimmons, N.A., Schwarz, D.A. and Fuller, A.M., 2011. Future developments in brain-machine interface research. *Clinics*, 66, pp.25-32.
- [11] Baradaran, F.; Farzan, A.; Danishvar, S.; Sheykhivand, S. Customized 2D CNN Model for the Automatic Emotion Recognition Based on EEG Signals. *Electronics* 2023, 12, 2232. <https://doi.org/10.3390/electronics12102232>

Application of Artificial Intelligence in E-Learning

Daniela Mirtcheva-Ivanova

Bulgarian Defense Institute

"Professor Tsvetan Lazarov"

Sofia, Bulgaria

mirchevadany@gmail.com

Abstract: The article examines the control and evaluation of students' knowledge, with the aim of determining and analyzing the mistakes made and their prevention in order to achieve a better education. The role of electronic tests as a preferred and applied means of knowledge assessment is shown. Emphasis is placed on the application of artificial intelligence as an assistant to the learner for the rapid elimination of gaps and assimilation of knowledge, when weaker results are reported on electronic tests in a given academic discipline.

Keywords: *elctronic learning, electronic test, artificial intelligence, learner.*

I. INTRODUCTION

In modern society, an important part and main task is the education of the younger generation. The education of young people plays a key role, since the good future of a country depends on their fruitful and comprehensive development and realization.

Education remains a fundamental activity in society, but with the rapid development of information technology and models, it is also changing and developing [18, 19, 20, 22, 23]. Traditional synchronous school teaching is increasingly using asynchronous and e-learning not only as a support activity for learning the material, but also becoming the main way of learning.

In the learning process, an important factor is the assessment and control of knowledge. They assist in determining the level of knowledge of the students and determining the nature of the mistakes they made with the aim of better education and achieving maximum results [1], [2].

II. MATERIALS AND METHODS

The report describes the digital technologies used and their application methods to achieve better results in

education. Information from the global information environment was used, analyzing and predicting the role of digital tests for assessing students' knowledge and the capabilities of artificial intelligence as an assistant to learners. Various AI chat platforms are explored and presented. An approach to working with the ChatGPT platform was used, which included the preparation of specific questions, analysis of the received information and assessment of its reliability, credibility and relevance. Examples generated by the chat platform ChatGPT are presented.

One of the preferred and applied means of knowledge assessment are electronic tests. They ensure objectivity, reliability and validity of the assessment. Tests serve as a guide and determine the speed of learning and the level of complexity of the material in the further teaching of knowledge [3].

When considering the results of the conducted electronic tests, some of the obtained grades are weaker. Based on the assessment and the errors received, guidelines are outlined for improving the knowledge of the studied subject. In case of lower test results, the student must read and learn a large volume of studied material from a taught discipline in a relatively short time. For the quick removal of gaps and assimilation of knowledge, students can use the possibilities and applications of artificial intelligence.

Artificial intelligence is the intelligence of computers used to solve complex tasks over large volumes of data. The concept of technology and its beginning was put forward in the 50s of the last century by Alan Turing. The operation and functions of artificial intelligence have developed very rapidly in recent years, due to the increase in processor power, the use of new algorithms and the creation of large data sets [21].

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8053>

© 2024 Daniela Mirtcheva-Ivanova. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

In the modern world, AI is much more than computers, it is present to an ever greater extent and in more areas of our lives. Its applications are in the field of medicine - diagnosis and prediction, transportation - self-driving cars, advertising - personalized advertising campaigns, language assistants, voice translations and others [4], [5]. Undoubtedly, one of the commonly used functions of AI is in the field of learning. Teachers use it to draw up topic plans, create electronic materials, brief summaries of books, while learners use its capabilities to search for information on topics, self-study in various disciplines, help in creating content on a given topic [6], [7].

In case of lower test scores, learners can use some of the AI platforms to improve their knowledge. AI chat platforms with the largest number of users are ChatGPT - a large language model trained for dialogue [8], Bard - a chatbot created by Google, which was renamed Gemini in early 2024. Gemini fixes Bard's shortcomings and is upgraded with additional possibilities [9]. Other widely used chat platforms are Bing Chat - integrates ChatGPT into Bing [10] and Claude - a generative Chatbot at the level of ChatGPT, available for US and UK and via VPN from other countries [11], [12], [13].

The principle of operation and the role of created AI platforms are to work in dialogue. ChatGPT can help student learning in many ways by turning it into a personal assistant.

Identifying knowledge gaps. The AI can analyze the data from the assessments, solved tasks and exercises of the learner and generate a diagnostic assessments of the level of knowledge acquired in a certain subject.

Personalized virtual training. Learners understand and learn material differently, using different working and learning styles and absorbing material at a slower or faster pace. Artificial intelligence has the ability to analyze large amounts of data and build a model for personalized learning of each learner [8], [14], [15], [16], [17].

Help with self-preparation. Learning by asking questions about a specific topic Fig. 1. Questions should be clear and precise.

A sample discussion for C#: <https://chat.openai.com/c/1226b333-1e32-4f74-93ea-ae7a7ad41daa>.

Many additional questions can be asked on the same topic for more details Fig. 2.

Generate practice exercises and assignments on a selected topic. It is best to study material on a given topic by solving practical exercises. ChatGPT can create assignments and exercises by topic. AI can generate task conditions, instructions for solving them and the solution of the set tasks itself [8], [14], [15], [16] Fig. 3.

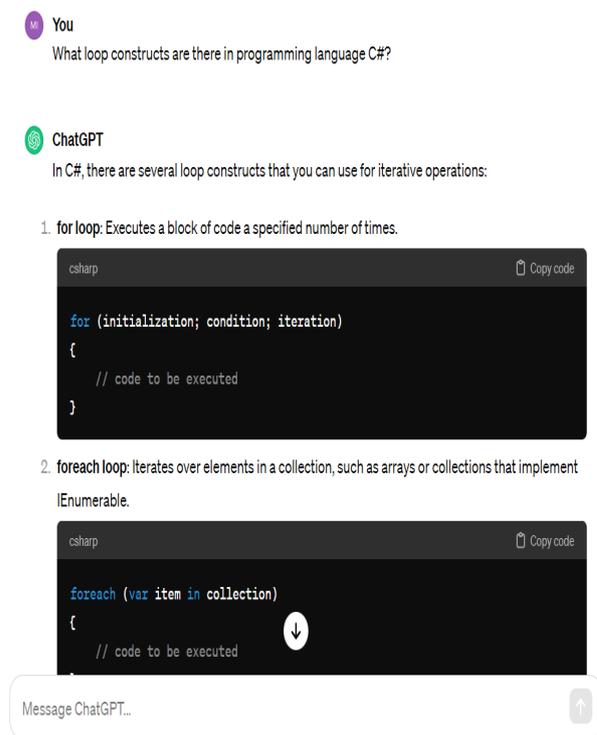


Fig. 1. Questions about a specific topic.

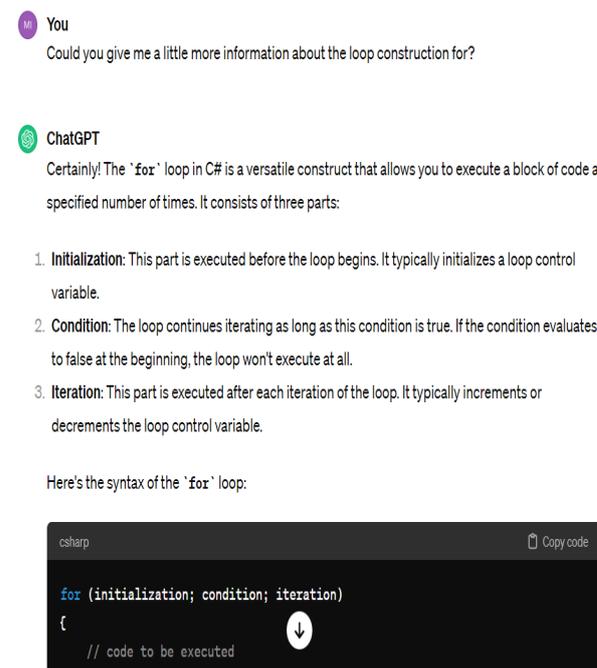


Fig. 2. Additional questions.

ChatGPT

Sure! Here's an example of using a 'for' loop in C# to create a task condition:

```

csharp
using System;

class Program
{
    static void Main(string[] args)
    {
        // Task: Print numbers from 1 to 10
        for (int i = 1; i <= 10; i++)
        {
            Console.WriteLine(i);
        }
    }
}
    
```

Fig. 3. Generated task by GhatGPT.

Test preparation. Self-study assistance by generating a quiz on a given topic or typed content Fig 4.

You

Can you create a sample test for me that includes C# for statement questions?

ChatGPT

Certainly! Here's a sample test that includes questions related to the 'for' statement in C#:

C# 'for' Statement Test

Question 1:

What does the following 'for' loop print?

```

csharp
for (int i = 0; i < 5; i++)
{
    Console.Write(i + " ");
}
    
```

a) 01234

Fig. 4. Quiz on a given topic or typed content.

AI can give directions to solve the test and post the correct answers [8], [16], [17] Fig. 5.

You

Can you give me the answers to the test?

ChatGPT

Sure! Here are the answers to the sample test:

1. Question 1:
Correct answer: a) 0 1 2 3 4
2. Question 2:
Correct answer: c) 55
3. Question 3:
Correct answer: a) 6
4. Question 4:
Correct answer: d) 15
5. Question 5:
Correct answer: a)

```

csharp
for (int i = 0; i < 5; i++)
{
    // code block
}
    
```

Fig. 5. AI to solve the test.

Generating feedback to learners. AI analyzes the learner's work through his achievements and with the help and means of applied machine learning algorithms returns the analyzed result [8], [15], [16], [17].

III. RESULTS AND DISCUSSION

The online test to assess the level of knowledge and the application of ChatGPT AI chat platforms was carried out in 44 Secondary School - Sofia in the 2023/2024 academic year in the 12th grade. Specific questions were prepared, the information received was analyzed and evaluated, and an assessment was made of the relevance and credibility of the material received from ChatGPT.

From the work of the students in AI chat platforms ChatGPT and the observations made, it is concluded that the students learn to ask questions correctly, evaluate the received information accurately and correctly, and have an interest in using the digital environment. Students report that they manage to find accurate and correct information without wasting much time.

IV. CONCLUSIONS

The possibilities for providing help and support to learners through AI are numerous. They can use them purposefully in their learning by asking the right questions and critically and intelligently evaluating the information received.

The ChatGPT platform demonstrates to us the effectiveness of technological innovation in the educational process. AI chat platforms have a clear strategy and potential to be upgraded and offer more opportunities, providing an innovative solution to enhance the learning material in education and maintain its role as a student's assistant.

ACKNOWLEDGEMENTS

This work was supported by the National Science Program "Security and Defence" program, which has received funding from the Ministry of Education and Science of the Republic of Bulgaria under the grant agreement no. Д01-74/19.05.2022.

REFERENCES

- [1] S. Bacheva, Verification and feedback in training. National Education, Sofia, 1981 (in Bulgarian) (С. Бъчева, Проверката и обратната информация в обучението. Народна просвета, София, 1981)
- [2] P. Rangelova, Plovdiv University "Paisii Hilendarski"[Online]. Available: https://www.researchgate.net/publication/293482891_FORMIRANE_NA_MOTIVI_ZA_UCENE_CREZ_PROVERKA_I_OCENKA_NA_ZNANIATA_I_UMENIATA_NA_UCENICITE [Accessed: Jan. 12, 2024].
- [3] Plovdiv University "Paisii Hilendarski", Internal university standards for testing, control and assessment of knowledge, "Kavangard" EOOD. (in Bulgarian) [Online]. Available: https://uft-plovdiv.bg/site_files/file/Eeducations/Standarti%20new.pdf [Accessed: Jan. 12, 2024].
- [4] 5 applications of artificial intelligence that will amaze you. (in Bulgarian) [Online]. Available: <https://dcfusion.org/5-uses-of-artificial-intelligence-that-will-blow-your-mind> [Accessed: Jan. 17, 2024].
- [5] 10 examples of how artificial intelligence improves education. [Online]. Available: <https://www.kaldata.com/it-%D0%BD%D0%BE%D0%B2%D0%B8%D0%BD%D0%B8/10-%D0%BF%D1%80%D0%B8%D0%BC%D0%B5%D1%80%D0%B0-%D0%B7%D0%B0-%D1%82%D0%BE%D0%B2%D0%B0-%D0%BA%D0%B0%D0%BA-%D0%B8%D0%B7%D0%BA%D1%83%D1%81%D1%82%D0%B2%D0%B5%D0%BD%D0%B8%D1%8F%D1%82-%D0%B8%D0%BD%D1%82%D0%B5-421251.html> [Accessed: Jan. 17, 2024].
- [6] How teachers can use artificial intelligence in school with examples.[Online]. Available: <https://cpcreativity.com/%D0%BA%D0%B0%D0%BA-%D1%83%D1%87%D0%B8%D1%82%D0%B5%D0%BB%D0%B8%D1%82%D0%B5-%D0%BC%D0%BE%D0%B3%D0%B0%D1%82-%D0%B4%D0%B0-%D0%B8%D0%B7%D0%BF%D0%BE%D0%BB%D0%B7%D0%B2%D0%B0%D1%82-%D0%B8%D0%B7%D0%BA%D1%83/> [Accessed: Jan. 23, 2024].
- [7] Artificial intelligence in education. [Online]. Available: <https://bg.khanacademy.org/khan-for-educators/ii-ai-v-obrazovanieto> Accessed: Jan. 23, 2024].
- [8] ChatGPT. [Online]. Available: <https://openai.com/chatgpt> [Accessed: Jan. 23, 2024].
- [9] Genimi (Bard). [Online]. Available: <https://gemini.google.com/> [Accessed: Jan. 23, 2024].
- [10] Bing Chat. [Online]. Available: <https://www.bing.com/chat> [Accessed: Jan. 25, 2024].
- [11] Claude. [Online]. Available: <https://claude.ai/login?returnTo=%2F> [Accessed: Jan. 25, 2024].
- [12] ChatGPT.[Online]. Available: <https://www.techtarget.com/whatis/definition/ChatGPT> [Accessed: Jan. 12, 2024].
- [13] What is artificial intelligence. [Online]. Available: <https://digitalmarketing.bg/what-is-artificial-intelligence> [Accessed: Feb. 7, 2024].
- [14] How Ai is used in Education & 10 Ways You Can Too. [Online]. Available: <https://www.classpoint.io/blog/10-ways-how-ai-is-used-in-education> [Accessed: Feb. 12, 2024].
- [15] 10 examples of how artificial intelligence improves education.[Online]. Available: <https://www.kaldata.com/> [Accessed:Feb. 17, 2024].
- [16] USING CHATGPT FOR EDUCATION AND WORK IN IT: PRACTICAL TIPS BASED ON PERSONAL EXPERIENCE. [Online]. Available: <https://career.softserveinc.com/bg/stories/using-chatgpt-in-education-and-work-in-it-practical-tips-from-our-own-experience> [Accessed:Feb. 17, 2024].
- [17] 100 Best ChatGPT prompts to unleash AI potential. [Online]. Available: <https://www.ranktracker.com/bg/blog/best-chat-gpt-prompts-to-unleash-ai-s-potential/> [Accessed: Feb. 25, 2024]
- [18] P. Boyanov, Educational exploiting the information resources and invading the security mechanisms of the operating system Windows 7 with the exploit Eternalblue and backdoor Doublepulsar, a refereed Journal Scientific and Applied Research (Licensed in EBSCO, USA), Konstantin Preslavsky University Press, ISSN 1314-6289, vol. 14, 2018, pp.34-41.
- [19] P. Boyanov, Construction and simulation of optical local area computer networks for the needs of the academic institutions, International Scientific Online Journal, www.sociobrain.com , Publ.: Smart Ideas - Wise Decisions Ltd, ISSN 2367-5721 (online), Issue 54, February 2019, pp. 89-96.
- [20] R. Iliev, K. Ignatova. Software tools to support collaboration. Collection of reports from the International Scientific Conference "Hemus 2018", II-132 - II-141, Plovdiv, 2018.
- [21] M. Kochankov, R. Iliev. Supporting decision-making in command and control systems by applying artificial intelligence. Collection of reports from the International Scientific Conference "Hemus 2020", pp. 106 - 113, Plovdiv, 2020.
- [22] S. Spasov, International academic programs and training models for combating corruption and their application in the UNSS. Scientific works of UNSS, pp. 69-95, 2022.
- [23] S. R. Marinov, I. P. Ivanov, A. A. Kolev, Modeling of a controllable communication environment, Collection of reports from the Scientific Conference "Modern trends in aviation training", NSU "V. Levski", Faculty of "Aviation" - Dolna Mitropolia, 2017, ISBN 978-954-713-110-1в, (in Bulgarian). [Online]. Available: https://www.af-acad.bg/Documents/conference/archive/Sbornik_FA_2017.pdf [Accessed: Jan. 3, 2024].

Integrated Intelligent System for Scientific and Educational Information Retrieval

Mukhammadjon Musaev

Artificial Intelligence

Tashkent University of Information

Technologies named after

Muhammad al-Khwarizmi

Tashkent, Uzbekistan

mm.musaev@rambler.ru

Marat Rakhmatullaev

Library Information Systems

Tashkent University of Information

Technologies named after

Muhammad al-Khwarizmi

Tashkent, Uzbekistan

marat56@mail.ru

Sherbek Normatov

Library Information Systems

Tashkent University of Information

Technologies named after

Muhammad al-Khwarizmi

Tashkent, Uzbekistan

shb.normatov@gmail.com

Kamoliddin Shukurov

Artificial Intelligence

Tashkent University of Information

Technologies named after

Muhammad al-Khwarizmi

Tashkent, Uzbekistan

keshukurov@gmail.com

Malika Abdullaeva

Artificial Intelligence

Tashkent University of Information

Technologies named after

Muhammad al-Khwarizmi

Tashkent, Uzbekistan

m.abdullaeva@tuit.uz

Abstract. The relevance of creating information systems using artificial intelligence methods and tools is dictated by the following reasons: The volume of scientific and educational information is growing; Traditional information retrieval methods have exhausted themselves. Using only deterministic and iteration methods, rigid algorithms don't give the expected results. They require more time to process information and more memory. Significant progress in recent years in the development of artificial intelligence (AI) methods and systems gives hope that their use will significantly reduce the time needed to search for data for scientific research and educational activities. The aim of the research results presented in the article is to increase the efficiency for scientific and educational information retrieval based on the use of AI methods implemented in the integrated intelligent information system "SMART TUIT". The article presents the results of theoretical and applied research obtained by several departments of the Tashkent University of Information Technology (TUIT) in solving the following tasks: Voice recognition for subsequent processing; Pattern recognition in order to identify the users of information; Search and processing of scientific and educational resources in electronic libraries; Analysis of information needs of users depending on the level of competence and type of activity; Evaluation of scientific and educational information to identify the most important data sources; Geoinformation system to solve the problems of the location of the information source. Initially, each research area in the departments was aimed at solving a certain class of

problems related to medicine, linguistics, electronic libraries, corporate networks, information security systems, etc. The TUIT creative group decided to combine efforts to apply the results obtained to solve the important problem of intellectualizing the search for sources of scientific and educational information among a large amount of data.

Keywords: *artificial intelligence, pattern recognition, voice recognition, information retrieval, database, knowledge base.*

I. INTRODUCTION

The relevance of developing information systems for accessing current data through artificial intelligence methods and tools is underscored by several compelling factors:

1. Rapid Growth of Scientific and Educational Information: The volume of scientific and educational data is expanding exponentially, nearly doubling each year. This growth necessitates more efficient means of accessing and managing this wealth of information.

2. Increasing Importance of Access to Information Resources: Access to valuable information is crucial not only for advancements in science and education but also for the overall progress of the economy and society. Scientific and technical solutions drive progress across all sectors, highlighting the critical need for reliable access to pertinent information resources.

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8028>

© 2024 Mukhammadjon Musaev, Marat Rakhmatullaev, Sherbek Normatov, Kamoliddin Shukurov, Malika Abdullaeva.

Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

3. Exhaustion of Traditional Retrieval Methods: Conventional data retrieval methods have reached their limits. Relying solely on classical approaches, which consume extensive time and memory resources, often fails to yield satisfactory results. This underscores the necessity for innovative approaches to information retrieval.

4. Demand for Timely Decision-Making: In today's complex environment, swift decision-making is imperative, particularly in situations where vast amounts of information must be processed. The complexity and sheer volume of information require prompt decision-making to address emerging challenges effectively.

5. Advancements in Artificial Intelligence: Significant advancements in artificial intelligence (AI) methods and systems offer promising prospects for reducing the time required to search for scientific research and educational data. Leveraging AI technologies holds the potential to streamline information retrieval processes, thereby enhancing research and educational activities.

By addressing these pressing needs, the development of information systems utilizing AI methodologies promises to revolutionize the accessibility and utilization of scientific and educational data, fostering progress across various domains.

Since the most objective scientific information remains concentrated within libraries and subscription-based databases, a critical aspect of research is to enhance the efficiency of information retrieval from these repositories. The system-functional approach serves as the methodological foundation for exploring the capabilities of AI technologies across various processes within information and library activities [1].

Information systems encompass a multitude of processes and functions that resist formalization [2], necessitating direct human intervention:

- Evaluating existing information resources and assessing the extracted information.
- Understanding the nature of information needs and identifying these needs within the system.
- Identifying relevant information resources based on information needs.
- Organizing existing information resources and structuring selected information from extracted elements.
- Managing existing information resources and overseeing the extracted information.
- Swiftly searching for and selecting information resources, utilizing extracted information.
- Analyzing information and knowledge.
- Transforming information into knowledge by establishing semantic relationships between data units (the "building blocks" of knowledge).
- Disseminating and transferring information and knowledge.
- Facilitating interaction and exchange of information and knowledge.

These functions underscore the indispensable role of human intelligence in information systems, working in tandem with AI technologies to optimize information retrieval and management processes within library environments.

Of particular significance is the study conducted by [3], which delves into the analysis of diverse intelligent agent technologies within library contexts. The author scrutinizes the application of AI in this domain from two distinct angles:

- Digital Libraries (DL): This perspective encompasses the utilization of intelligent agents for distributed searches of heterogeneous information within digital library environments. Additionally, the author explores the role of agents in supporting the information retrieval process within information library systems (DLS).
- Services in Traditional Libraries: This facet examines the integration of AI technologies into services provided by traditional libraries. It includes the development of user interfaces tailored for DLS, the implementation of automated reference services, and the architecture of library services aimed at enhancing efficiency and accessibility.

By examining these perspectives, the study sheds light on the multifaceted applications of AI within library settings, ranging from digital environments to traditional service delivery models.

Indeed, despite the substantial body of research in this field, there is a tendency to examine factors and tasks related to AI utilization in scientific information retrieval in isolation, rather than addressing the integration of individual subsystems and modules involved in the process. However, adopting a systematic approach that facilitates the integration of heterogeneous modules, encompassing both AI-driven and traditional data processing functions, holds the potential to yield a synergistic effect, thereby enhancing the efficiency of locating critical information resources.

By embracing a holistic perspective that emphasizes integration, researchers and practitioners can capitalize on the complementary strengths of various modules within the information retrieval process. This integrated approach enables seamless coordination and cooperation among disparate components, fostering a more cohesive and streamlined search experience. Furthermore, it facilitates the leveraging of AI technologies alongside conventional methods, thereby maximizing the benefits derived from each approach.

In essence, prioritizing a systematic approach to integration not only enables the efficient utilization of AI in information retrieval but also fosters innovation and optimization across the entire process. By transcending isolated considerations and embracing synergy, researchers can unlock new avenues for advancing the effectiveness and scalability of scientific information retrieval systems.

An information resource (IR) within this context denotes a repository of scientific and educational information, distinguished by its bibliographic description and full-text content. IR encompasses a diverse range of

sources, including books, journals, scientific articles, reports, and other pertinent materials. It's worth noting that IR can extend beyond traditional text-based formats to encompass multimedia sources such as audio and video content. The primary objective revolves around enhancing the efficiency of IR retrieval from vast datasets and presenting it to users in an accessible and user-friendly format.

The objective of this endeavor is to enhance the effectiveness of searching for scientific and educational information, referred to as information resources, by leveraging artificial intelligence (AI) methods integrated into the comprehensive intelligent information system known as "SMART TUIT."

The article presents the outcomes of both theoretical inquiries and practical applications conducted by various departments of Tashkent University of Information Technologies (TUIT), addressing the following key challenges:

- Speech recognition for generating search queries: Research endeavors aimed at developing systems capable of recognizing speech inputs and converting them into search queries for subsequent processing.
- Pattern recognition to identify users of information resources: Investigations focused on implementing pattern recognition techniques to identify and authenticate users accessing information resources.
- Search and processing of scientific and educational resources in electronic libraries: Efforts directed towards optimizing the search and processing capabilities within electronic library environments, enhancing accessibility to scientific and educational materials.
- Analysis of information needs of users: Research initiatives aimed at analyzing the information requirements of users, taking into account their level of expertise and specific areas of activity.
- Assessment of scientific and educational information: Studies aimed at evaluating the quality and relevance of scientific and educational information to identify the most significant sources beneficial to users.
- Geographic information systems: Research activities focused on developing geographic information systems to address spatial-related challenges in locating information sources.
- Information security: Measures undertaken to ensure the security of the system, including protecting databases, especially the full-text information database, and safeguarding user databases from unauthorized access.

Through these comprehensive research efforts, the article contributes to advancing the capabilities of the integrated intelligent information system "SMART TUIT" in effectively addressing the diverse needs of users in accessing scientific and educational information.

Initially, each research area focused on addressing specific problem domains such as medicine, linguistics, electronic libraries, corporate networks, and information

security systems. However, recognizing the potential synergies, the creative team at TUIT opted to consolidate their efforts and apply the accumulated results to tackle the crucial challenge of enhancing the discovery of scientific and educational information sources. Within this article, particular emphasis is placed on elucidating the capabilities of voice recognition subsystems, as well as assessing and retrieving information effectively.

The scope of this article encompasses research materials pertaining to three specific subsystems: "Speech Recognition," "Information Retrieval," and "Evaluation of Scientific and Educational Information." Notably, discussions on other subsystems such as "Pattern Recognition" and "Information Security" are deferred to subsequent articles within the conference collection. Additionally, references are made to previously published articles where more detailed information on these subsystems is available. This approach ensures a comprehensive coverage of relevant topics while facilitating a deeper exploration of specific subsystems in dedicated articles.

II. MATERIALS AND METHODS

The functional structure of the integrated intelligent information system "SMART TUIT" is presented in Fig. 1.

The "Data Input" subsystem of the integrated intelligent information system "SMART TUIT" is primarily responsible for inputting all initial data necessary for creating databases, as well as generating search queries. It features a dedicated interface that facilitates the selection of the relevant section or database into which specific data is to be entered.

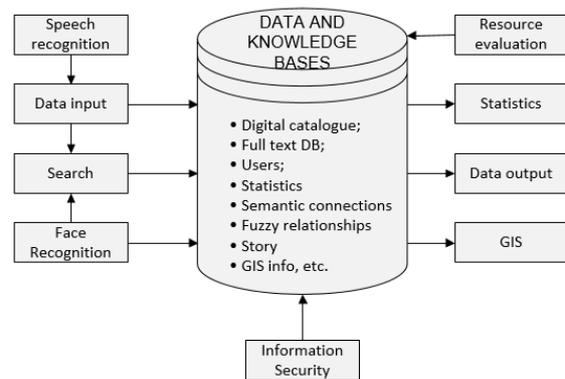


Fig.1 Functional structure of SMART TUIT

This subsystem serves as the initial entry point for populating the system's databases with essential information, streamlining the organization and accessibility of data for subsequent retrieval and analysis tasks.

III. RESULTS AND DISCUSSION

Several databases are formed in the integrated system:

- DB1 "Electronic catalogue";
- DB2 "Full-text electronic literature";
- DB3 "User";
- DB4 "Statistics";

- DB5 “Speech Corpus”;
- DB6 “Assessing information resources”

In the DB1 database, an electronic catalog is established utilizing metadata in the internationally recognized DUBLIN CORE format. This format is widely employed in library activities worldwide [4] for the presentation of electronic resources. Utilizing international communication formats for bibliographic information facilitates swift data exchange between libraries, whether within corporate networks or on an international scale.

The record structure of an information source unit in DB1 is delineated as follows:

DB1::= < Term 1> < Term 2> < Term 3> ...< Term 16>< Term 17>< Term 18>,

Term 1 – this is the information resource ID metadata (ID IR);

Term (2-16) – this is the DUBLIN CORE metadata;

Term 17 – this is an indicator characterizing the Evaluation of an information resource;

Term 18 – indicator of the location(s) of the information resource (for example, the ID of the library where this information resource is available). This information is needed for the operation of the GIS subsystem.

DB2 “Full-text electronic literature” includes an information resource in electronic format:

DB2:: = <ID IR><FT>,

FT – full text file IR.

The DB3 User database is created based on the following metadata:

DB3:: = <ID USER><NAME><SONAME><Face ID> <LIST of keywords><OTHERS>

LIST of keywords – a list of queries submitted by the system user. This important indicator is formed while the user is working with the system. It is needed to analyze user needs.

Face ID is a photo (image) of the user. It is necessary for the functioning of the “Pattern Recognition” subsystem.

OTHERS – this section includes additional information about the user, filled out at his request (for example, phone number, email, etc.).

DB4 “Statistics” includes information about the frequency of use of the information resource, when (date) the resource was downloaded, the ID of the user who used the resource.

DB4:: <ID IR><ID USERS><DATE>

This information allows you to track the relevance of information sources and is used in their evaluation. DATE – information about the date of use of the IR.

DB 5 is a “Speech Corpus of the Uzbek Language” and includes a synchronized text-audio pair.

DB5::= <ID TEXT ><ID USER><AUDIO PATH>

ID TEXT – represents the identification number of each text that is associated with the audio file. This identifier can be used to associate an audio file with the corresponding text that was spoken in that audio file.

ID USER – field contains information about the speaker of the audio file, that is, about the person whose speech is recorded in the audio file. This numeric

identifier associates an audio file with a corresponding user in the database.

AUDIO PATH - Specifies the path to the audio file of the speech corpus, which allows the database to find and access the corresponding audio file.

A. “SEARCH” Subsystem

The “Search” subsystem includes functions for searching scientific and educational information from the DB1 database. It interacts with the subsystems “Speech Recognition” (for entering a query after processing a voice command), “Pattern Recognition” (for searching data in the DB1 and DB3 database corresponding to the user image). This subsystem allows you to increase the efficiency of search through: 1) user identification; 2) reducing registration time; 3) use of search history. In this case, the system gives recommendations to the user on received “fresh” IRs, using previously received requests.

B. “SPEECH RECOGNITION” Subsystem

Numerous methods and tools for processing speech commands have been developed and extensively documented in scientific literature. Valuable results have been achieved particularly in the domain of speech processing for languages such as English, Russian, French, Spanish, Chinese, and others. However, the subsystem discussed below is specifically tailored for processing speech in the Uzbek language. Uzbek differs significantly from other languages, not only in terms of vocabulary but also in sentence structure, phonetics, and other linguistic characteristics. Therefore, specialized approaches are required to effectively process Uzbek speech, taking into account its unique linguistic attributes.

While there exist numerous methods and software tools aimed at enhancing listening, reading, and writing skills in language learning, there is often insufficient focus on methods and information technologies to improve speaking proficiency. It is crucial to emphasize the development of speaking skills as they are fundamental for effective communication in various contexts, including business and industrial relationships. Mastery of correct pronunciation of sounds, words, and sentences is essential for facilitating smooth and clear communication, underscoring the importance of dedicating attention and resources to the enhancement of speaking abilities in language education.

The primary objective of this subsystem is to transform spoken words into formats suitable for subsequent processing by the “Search” subsystem.

In accordance with the functional structure of SMART-TUIT, the speech recognition module is tasked with executing user requests directed towards literary sources. The laboratory of speech technologies has developed speaker-independent programs capable of analyzing continuous Uzbek speech in real time, without any vocabulary constraints [5], [6]. The process of constructing automatic speech recognition programs constitutes a comprehensive technology for preparing and processing information, encompassing the following key stages:

- Creation of a speech corpus: Compilation of a comprehensive collection of speech samples representing various linguistic elements and contexts.
- Selection of informative features of the speech signal: Identification and extraction of relevant features from the speech signal that are indicative of distinct linguistic components.
- Design of acoustic and speech recognition language models: Formulation of statistical models that capture the probabilistic relationships between acoustic signals and linguistic units, facilitating accurate speech recognition.
- Development of neural network architecture for speech recognition: Construction of neural network architectures tailored for speech recognition tasks, leveraging advanced machine learning techniques to enhance performance.
- Creation of automatic speech recognition modules: Implementation of software modules integrating the aforementioned components to achieve robust and efficient automatic speech recognition capabilities.

Through these concerted efforts, the speech recognition subsystem of SMART-TUIT is equipped to effectively process spoken input, enabling seamless interaction with literary sources and facilitating user queries with enhanced accuracy and efficiency.

The creation of a speech corpus involves the collective reading of texts by groups of speakers representing various demographics, including different ages, genders, and pronunciation patterns, utilizing office and web technologies. The corpus comprises texts

sourced from widely accepted materials such as books, magazines, and internet sources.

Text preparation for announcers involved several steps, including the insertion of spaces between sentences, removal of ambiguous characters, conversion of numerical data into text, and segmentation of sentences into manageable lengths.

Algorithms for extracting informative features encompass a range of techniques, including filtering, segmentation, and spectral analysis of speech signals captured from microphones. Additionally, compressed cepstral analysis of selected fragments is performed [5].

For the development of acoustic models for the Uzbek language, deep neural networks have been employed, including recurrent networks, Hopfield networks, and "coder-decoder" processing modes [7-10]. Furthermore, for the implementation of N-gram language models, LSTM-LM networks (Long Short Term Memory networks – Language model) have been utilized, alongside Softmax normalization layers [6]. These advanced techniques enable the creation of robust and accurate models for speech recognition, enhancing the performance and adaptability of the speech recognition subsystem within the SMART-TUIT system.

The automatic speech recognition module allows you to combine the parameters of acoustic and speech models of speech processing. These stages make it possible to implement an automatic recognition mode for continuous input speech spoken directly by the user of the system. The general diagram of the automatic user speech recognition mode is shown in Fig. 2.

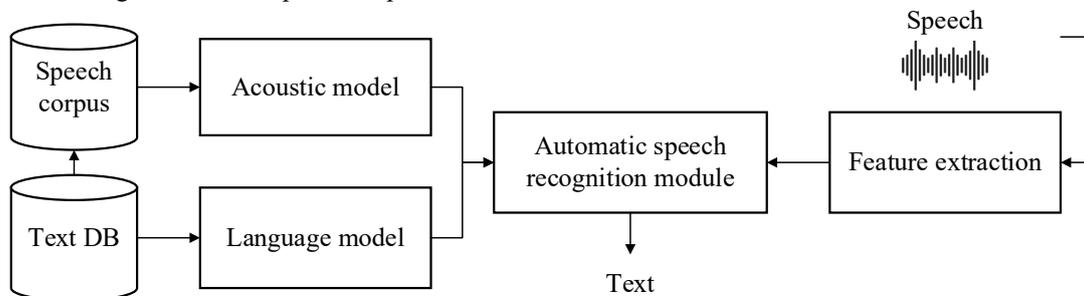


Fig.2. Diagram of speech recognition procedures

The language model of the Uzbek language is implemented on the basis of training a deep neural network Transformer, a detailed architecture of which is given in [6, 11] using a multi-hour speech corpus containing a pair of audio and its corresponding text. To competently form the necessary speech corpus of the Uzbek language, a telegram bot has been developed [11, 12]. The current volume of the generated speech corpus is 1535.3 hours of literary speech by speakers of various genders and ages, who uttered ~3.12 million sentences, of which 206 thousand are non-repeating words.

C. "STATISTICS" Subsystem

The "Statistics" subsystem allows you to generate a summary table of resource use for a period, who uses the database most often, what literature is in greatest

demand, and how many times IR has been downloaded. The subsystem includes standard procedures for processing statistical information widely used in information and library systems and generates DB4. This information is used for library collection management as well as IR assessment.

D. "RESOURCE EVALUATION" Subsystem

The purpose of the information resource assessment subsystem in an integrated intelligent information library system is to extract the most valuable and relevant information resources based on user requests. The variety of purposes for assessing information sources, a large number of parameters reflecting the content and characteristics of information sources, as well as changes in information assessments depending on time complicate

the issue of assessing sources of scientific and technical information.

The assessment of the source of information is carried out according to two types of criteria: objective and subjective [13], [14]. Objective criteria include the following indicators: 1) novelty of information (date of publication); 2) frequency of use of the resource (how many times users accessed the resource; 3) type of

resource (book, scientific article, report, etc.); 4) ease of access (paid, free, open access, etc.). Subjective criteria (assessed by experts): 1) relevance; 2) completeness of information; 3) scientific novelty; 4) the authority of the author (indicators of the author of the publication).

In the SMART TUIT system, the “Evaluation” subsystem is associated with the “Statistics”, “Full-text database” and “Data extraction” subsystems (Fig. 3).

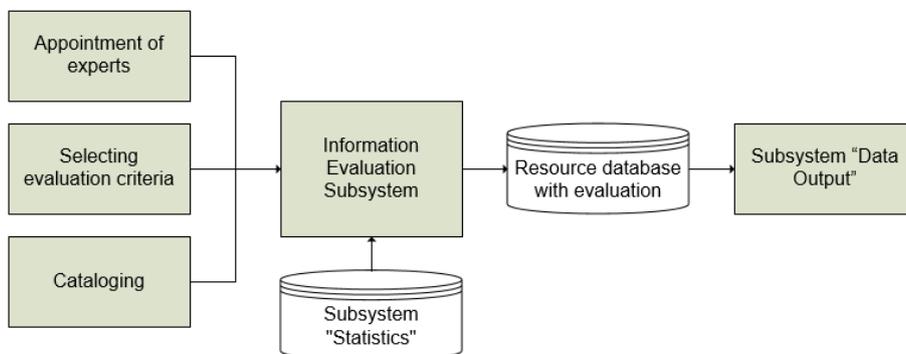


Fig. 3. Functional structure of the subsystem “Assessment of information resources”

Expert review or machine learning algorithms can be used to evaluate library resources. Highly qualified library specialists, as well as scientists, are involved as experts. The process of evaluating information sources can occur during cataloging or later.

Of course, the value of information depends on several factors, such as the purpose, interests, needs and level of knowledge of the recipient. However, you can improve your information retrieval efficiency by assessing the suitability of the information source for your specific area of study or the needs of your user group. For example, to assess the compliance of a library resource with the needs or requests of a certain group of users, a fuzzy variable

Ω_R = “Compatibility of the resource with user needs” is introduced, taking fuzzy values $M = \{M_1, M_2, M_3, M_4, M_5\}$. Here M_1 = “Unsuitable”, M_2 = “Partially suitable”, M_3 = “Moderately suitable”, M_4 = “Almost suitable”, M_5 = “Completely suitable” are the meanings of the term. To determine the support of the set Ω_R , consisting of M thermal values, you can use the point method of expert assessment. This method is described in detail by the authors in [15].

In the SMART TUIT system, the information assessment subsystem works according to the following scheme (Fig. 4).

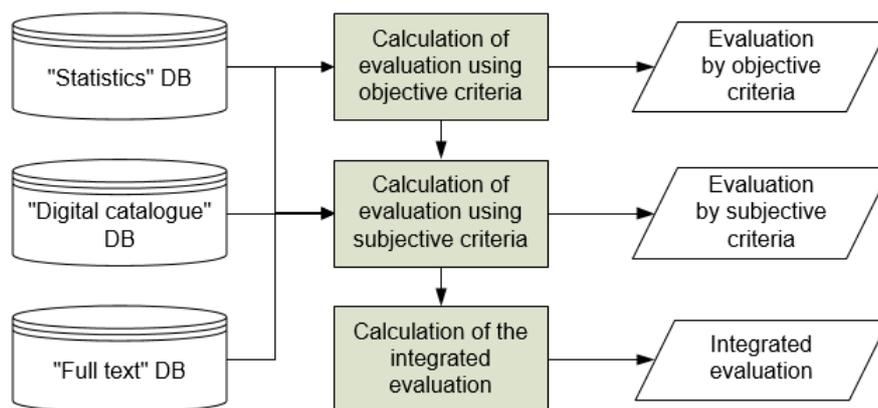


Fig.4. Integrated assessment calculation scheme

Calculation of assessment based on objective criteria. This function works directly with the Statistics subsystem. “Statistics” calculates the number of hits to the source of information and records this data in a special field. (<ID> <number of references>).

Calculation of assessment based on subjective criteria. Experts are invited to evaluate according to the above subjective criteria. Experts are librarians who specialize in cataloging and compiling library collections

in a particular field of knowledge, as well as specialists (scientists, teachers, etc.) working in this field.

Calculation of the integrated assessment. At this stage, all ratings are summed up and divided by the number of evaluation criteria. So we can get an average assessment of the information resource:

$$EoI = \frac{\sum_{i=0}^i s_i + \sum_{j=0}^j o_j}{i+j} \quad (1)$$

where i is the number of subjective criteria; j – number of subjective criteria; s_i – sum of subjective assessments; o_j – sum of subjective assessments; EoI is the overall assessment of the resource.

Subjective assessment of IR is the most complex process. This is because IR is difficult to evaluate unambiguously for the following reasons: 1) scientific and educational information is constantly updated, new methods, models, technologies and, accordingly, new publications appear; 2) it is difficult to regularly attract highly qualified experts to assess IR. To increase the objectivity of assessments, it is necessary to attract more experts to assess the same IR; 3) the volume of information being assessed increases, which complicates the assessment process itself. To process subjective assessment, a fuzzy compositional correspondence model is proposed [16].

In general, the price of information is dynamic and can change depending on changes in the information needs of users, the development of science and the conditions for using information. However, the subsystem makes it possible to improve the efficiency of information retrieval by providing users with valuable information that meets their needs.

IV. CONCLUSION

Research has demonstrated that integrating individual research results and subsystems can lead to a synergistic effect, resulting in overall outcomes that surpass what could be achieved by utilizing separate subsystems in isolation. At each stage of processing and generating a request and acquiring the necessary information, the system yields specific benefits:

- Reduced search time: Integration streamlines the information retrieval process, leading to quicker access to relevant data.
- Increased reliability: The integrated approach enhances the accuracy and correspondence of responses to user queries.
- Enhanced completeness: Users benefit from a wider range of options when selecting from the proposed list of information sources.

Significant progress has been made in the development of individual voice recognition subsystems specifically tailored for the Uzbek language. By leveraging intelligent algorithms for speech analysis and synthesis, computer programs have been devised to facilitate language learning within a comprehensive service delivery framework. This subsystem can be applied across all stages of the learning process, including mastering new material, reinforcement, repetition, and monitoring learning quality.

The "Information Source Evaluation" subsystem plays a pivotal role, particularly when processing large volumes of information and generating extensive results from user queries. Integration with other subsystems enables the identification of the most valuable information sources within the existing database, thereby enhancing the quality of data retrieval.

The ongoing efforts of the creative team focus on various research areas, including processing queries in textual form in addition to keywords, developing methods for semantic analysis of search queries, and enhancing geographic information systems to pinpoint the location of information sources. These endeavors aim to further enhance the capabilities and effectiveness of the integrated intelligent information system, ensuring its continued relevance and utility in meeting user needs.

REFERENCES

- [1] A. I.Kapterev, Cognitive management and artificial intellect in libraries:Possibilities and highlights // Scientific and technical libraries. 2023. No. 6. P. 113–137. <https://doi.org/10.33186/1027-3689-2023-6-113-137>.
- [2] Asefeh Asemi, Andrea Ko and Mohsen Nowkarizi, Published by Emerald Publishing Limited. Intelligent libraries: a review on expert systems, artificial intelligence, and robot. Library Hi Tech Vol. 39 No. 2, 2021 pp. 412–434 Emerald Publishing Limited 0737-8831.DOI 10.1108/LHT-02-2020-0038
- [3] G. Liu, "The application of intelligent agents in libraries: a survey", 2011, Program, Vol. 45 No. 1, pp. 78-97, doi: 10.1108/00330331111107411.
- [4] DCMI Metadata Terms. <https://www.dublincore.org/specifications/dublin-core/dcmi-terms/>
- [5] M. Musaev, I.Khujayorov, M Ochilov, The use of neural networks to improve the recognition accuracy of explosive and unvoiced phonemes in Uzbek language. 2020 Information Communication Technologies Conference (ICTC). China, 2020. -pp. 231-234.
- [6] M. Musaev, S. Mussakhoyayeva, I. Khujayorov, Y. Khassanov, M.Ochilov, H.A. Varol, USC: An Open-Source Uzbek Speech Corpus and Initial Speech Recognition Experiments. Speech and Computer 23rd International Conference, SPECOM 2021. St. Petersburg, Russia, September 27–30, 2021, Proceedings. – pp. 437-447.
- [7] A.V. Sozykin, An Overview of Methods for Deep Learning in Neural Networks.. Bulletin of the South Ural State University. Series: Computational Mathematics and Software Engineering. 2017. vol. 6, no. 3. pp. 28–59. (in Russian) DOI: 10.14529/cmse170303.
- [8] A.Graves, Jaitly, N. Towards end-to-end speech recognition with recurrent neural networks. In Proceedings of the International Conference on Machine Learning, Beijing, China, 21 June–26 June 2014; pp. 1764–1772.
- [9] Yeh, C., Wang, Y., Shi, Y., Wu, C., Zhang, F., Chan, J., & Seltzer, M.L. (2021). Streaming Attention-Based Models with Augmented Memory for End-To-End Speech Recognition. 2021 IEEE Spoken Language Technology Workshop (SLT), pp. 8-14.
- [10] Sak, H.; Shannon, M.; Rao, K.; Beaufays, F. Recurrent Neural Aligner: An Encoder-Decoder Neural Network Model for Sequence to Sequence Mapping. In Proceedings of the INTERSPEECH, ISCA, Stockholm, Sweden, 20–24 August 2017; pp. 1298–1302.
- [11] Mukhamadiyev, A., Mukhiddinov, M. , Khujayorov, I., Ochilov, M., Cho, J., Development of Language Models for Continuous Uzbek Speech Recognition System, Sensors 2023, 23(3), 1145; <https://doi.org/10.3390/s23031145>
- [12] Musaev M., Khujayorov I., Ochilov M., Speech Recognition Technologies Based on Artificial Intelligence Algorithms, 14th International conference intelligent human computer interaction, Tashkent, Uzbekistan, October 20-22, 2022, <https://doi.org/10.1007/978-3-031-27199-1>
- [13] Ramasamy, Ammuthavali & Ali, Nor'ashikin. (2021). High value information for managers in organisations. electronic Journal of Computer Science and Information Technology. 7. 10.52650/ejsit.v7i1.110.
- [14] Bendecheche, Malika & Limaye, Nihar & Brennan, Rob. (2020). Towards an Automatic Data Value Analysis Method for Relational Databases. 10.5220/0009575508330840.
- [15] Rakhmatullaev M., Normatov Sh. Formalizing the processes of evaluating the characteristics of scientific and educational

information resources. International Conference on Information Science and Communications Technologies (ICISCT), Tashkent, Uzbekistan, 2022, pp. 1-4, doi: 10.1109/ICISCT55600.2022.10146831.

[16] M. Rakhmatullaev, S. Normatov, and F. Bekkamov, "FUZZY RELATIONS BASED INTELLIGENT INFORMATION RETRIEVAL FOR DIGITAL LIBRARY USERS", ETR, vol. 2, pp. 80–83, Jun. 2023, doi: 10.17770/etr2023vol2.7218.

Approach to Developing a Maritime Cybersecurity Virtual Training Environment

Borislav Nikolov

Department of Information Technologies

Nikola Vapsarov Naval Academy

Varna, Bulgaria

nikolov@naval-acad.bg

Abstract. The maritime industry is increasingly reliant on digital systems for navigation, communication, cargo management, and other critical functions. As these systems become more interconnected and technologically advanced, they also become vulnerable to cyber threats. A virtual training environment allows maritime personnel to simulate cyber attacks and practice responding to them, enhancing their preparedness and resilience against real-world cyber threats. Cyber attacks targeting maritime assets can have severe consequences, including disruptions to operations, financial losses, environmental damage, and even threats to human safety. By providing virtual training environments, maritime organizations can identify and mitigate cybersecurity risks before they escalate into actual incidents, thereby safeguarding their assets and operations. Regulatory bodies, such as the International Maritime Organization (IMO) and various national maritime authorities, have established guidelines and regulations aimed at enhancing cybersecurity in the maritime sector. Developing a virtual training environment enables maritime organizations to ensure compliance with these regulations by training personnel on cybersecurity best practices and regulatory requirements. Conducting hands-on cybersecurity training in a real-world maritime environment can be logistically challenging and costly. A virtual training environment offers a cost-effective alternative by allowing personnel to engage in realistic cybersecurity scenarios without the need for physical equipment or resources. This paper presents an approach to developing a maritime cybersecurity virtual training environment utilizing open-source software.

Keywords: *cybersecurity, virtual training environment, cyber hygiene, training scenarios, computer virtualization.*

I. INTRODUCTION

The maritime industry is changing rapidly and becoming increasingly digital. Ships, ports, and related infrastructure are increasingly using digital systems to manage crews, cargo, communications, and more [1]. As connectivity and automation grow, so does the potential for cyberattacks. The maritime industry is exposed to a variety

of cyber threats, including hacker attacks, phishing, malware, and more. These threats can pose a risk to the safety of crews, the protection of personal data, the integrity of management systems, and other aspects of maritime transport [2].

International regulations, such as the ISPS Code [3] and the ISM Code [4], impose strict security requirements on the maritime industry. In recent years, new legislative frameworks have emerged specifically dedicated to cyber security in this industry.

Cyber attacks can cause serious damage to the maritime business, from financial losses and data breaches to serious damage to a company's reputation [2]. Cybersecurity training helps crew to understand potential threats and take appropriate protection measures. Training not only provides technical knowledge and skills but also builds a cyber security culture within the company. This means that all employees, from ship crews to port managers, understand the importance of cyber security and are committed to achieving and maintaining security [5].

Cybersecurity training conducted in a virtual training environment (VTE) offers numerous advantages that make it a preferred choice for many organizations and industry participants [6]. The VTE enables the creation of realistic simulations of cyber attacks, threats, and scenarios that can be used for training. Such simulations allow learners to become familiar with different types of threats and develop skills to recognize and deal with them. The VTE provides a secure and controlled platform for conducting cybersecurity training. This allows learners to experience various cyber attack scenarios without the real risks associated with malicious activities on real systems. Virtual cybersecurity training is flexible and accessible to trainees from different locations and at any time. This allows employees, especially those in the maritime industry, to receive training without needing to be physically present in specially equipped training labs or centers [7].

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8039>

© 2024 Borislav Nikolov. Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

Learning in a virtual environment very often offers interactive learning materials including exercises, tests, simulations, and games. These learning elements can improve learner engagement and interest, accelerating their acquisition of new knowledge and skills.

Delivering cybersecurity training in a virtual environment is often more cost-effective than traditional face-to-face courses. This reduces the costs of travel, and rental of premises and equipment, which are usually associated with the organization of training [8].

Conducting cybersecurity training in a virtual environment requires a specialized simulation environment to provide the various training scenarios. Acquiring simulation environments such as Cyber Range is a costly investment for any maritime company or training institution [6]. However, there are also technical solutions based on open-source programs that can have the same efficiency, but at a significantly lower cost. In any case, it should be kept in mind that the instructors and the training materials and scenarios developed by them remain the key elements in conducting cybersecurity training [9], [10].

II. DEFINING CYBERSECURITY VIRTUAL TRAINING ENVIRONMENT

How a virtual training environment will be used depends primarily on the target categories of participating

trainees. These categories define the requirements for the methods to access the virtual environment and what real devices are to be simulated [11].

If the training will be related to cybersecurity, the target groups of trainees are mainly two categories. The first category is related to the users with administrative access to IT systems and has responsibilities for ensuring the general level of cyber security. The second category of users can be broadly described as end-users of IT systems. When the training is focused on cybersecurity in the maritime industry additional requirements arise – the VTE must provide the possibility of remote secure access as well as simulate the ship systems that are quite specific.

Both categories of trainees should be able to remotely and locally access different simulation scenarios based on their daily activities as part of the ship’s crew or employees in the IT support department in the companies’ shore offices [12].

Fig. 1 presents the different access methods for both trainees' categories – “Advanced User” and “Beginner User”. The “Advanced User” represents the users with administrative access to IT systems, and the “Beginner User” represents the end-users of IT systems. It should be noted that the differences between cybersecurity training in the maritime industry and any other industry will be in the type of simulated devices and scenarios from the VTE.

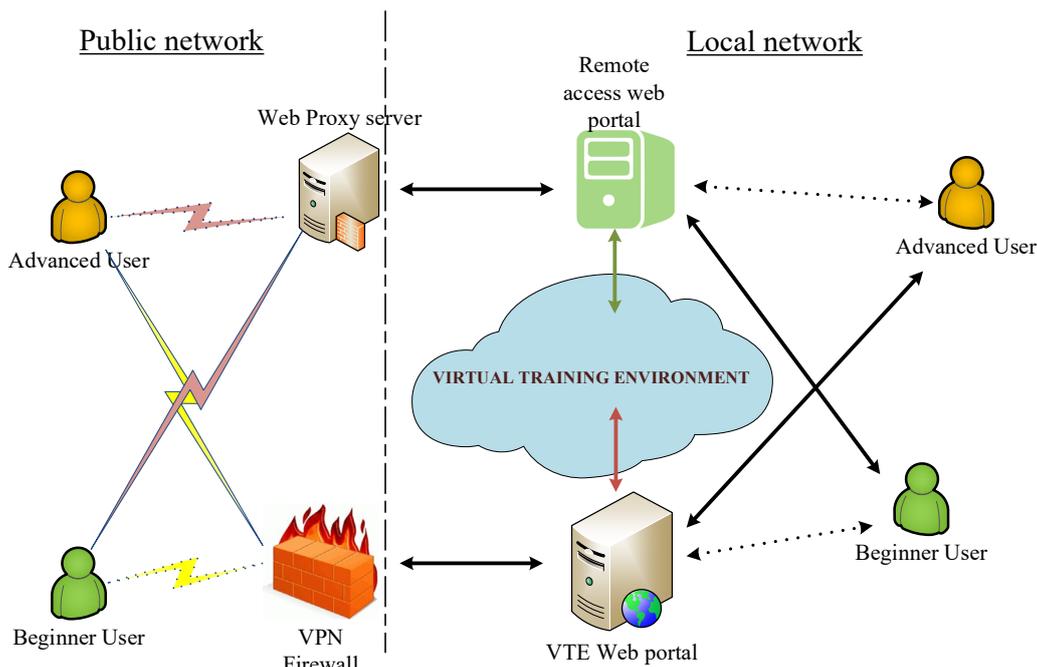


Fig. 1. Remote and local access to the maritime cybersecurity virtual training environment.

The VTE resource access topology presented in Fig. 1 has two main zones – “Public network” and “Local network”. “Public network” represents the ability for remote access to the VTE from anywhere by using an Internet connection. At the same time, the “Local network” represents the ability for local access to the VTE at the training centers where the VTE is installed.

The VTE used for cybersecurity training is most often called “Cyber Range” [13]. This environment consists of multiple virtual machines that represent computers, servers, network equipment, and other IT devices with their

configurations and vulnerabilities. The main access method to the virtual machines is through the internal VTE web portal. However, direct access to virtual machines is possible if they are configured with RDP, SSH, Telnet, VNC, or other remote access protocols. In this case, the access can be simplified using a remote desktop gateway like Apache Guacamole or a similar platform [14].

The two defined trainees’ categories require different access types to the virtual devices. The Beginners need access to a single simulated end-user desktop. This access can be provided by direct access to the VTE web portal.

This scenario is useful only if the trainee is located at the training center, but more useful will be the access through a remote desktop gateway. If the trainee is out of the training center, access should be provided through a remote desktop gateway. That will provide more security. A VPN Firewall or other VPN concentrator can be used if the highest level of security is required for remote access.

Contrariwise, the Advanced trainees will require access to multiple devices at the same time depending on the training scenario. Again, the access can be provided by direct access to the VTE web portal, but only if the trainee is located at the training center. Because access to multiple virtual devices will be required for this type of trainee, the remote access web portal is not recommended due to the peculiarities of simultaneous operation with multiple remote terminals. Remote Advanced trainees will need a VPN connection to perform all tasks in the training scenario.

In any case, access to the remote desktop gateway outside the training center must be provided only through a web proxy server. This will ensure a relatively good level of access security.

In Fig. 1 the main access methods are presented with solid lines. The dotted lines present access methods that should be used as a last resort.

Fig. 2 presents the VTE main functions and modules that are required to support cybersecurity training.

VTE utilizes computer virtualization technology to simulate server and desktop operating systems as well as network or other communication equipment. At least one physical host is the root of the VTE. Different hypervisors or server OS that support containerization can be installed on the physical host.

The VTE software should provide several mandatory functions as follows:

- Virtual Nodes Management;
- Labs Management;
- Account Management;
- User-friendly Web interface.

The Virtual Nodes Management function provides capacity for the simulation of a wide range of server and desktop operating systems, hypervisors, physical hosts (computers or servers), storage systems, network and communication devices and equipment. This function can be determined as one of the two core functions of any VTE. It is required for VTE to have the capacity to simulate as much as possible different types of nodes.

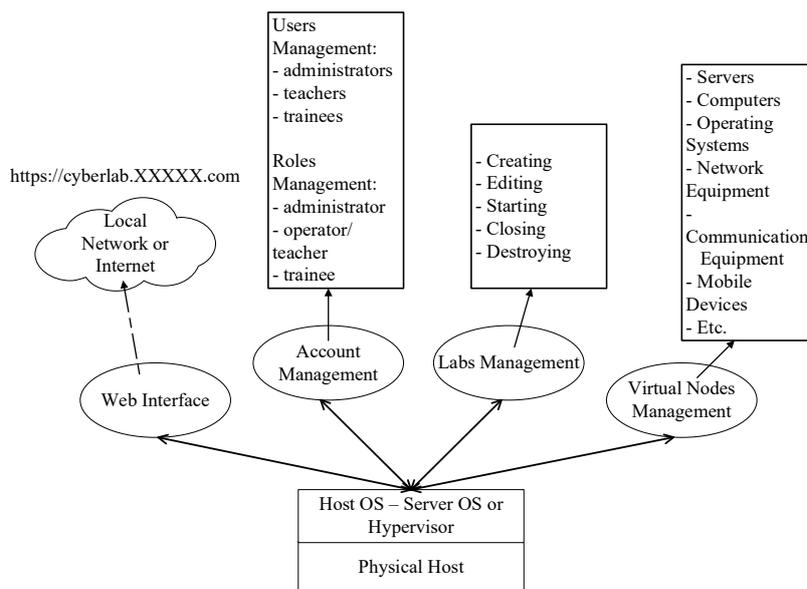


Fig. 2. Cybersecurity VTE main functions and modules.

The Labs Management function is the second core function of any VTE. Utilizing this function VTE administrators (or operators) can develop virtual labs combining virtual nodes. These labs are used in different scenarios during cybersecurity training. Labs are assigned to the trainees. Labs Management must have the ability to restore labs to their initial state after every training.

The Account Management function is required to define VTE users' roles. At least three users' roles should be preset – administrator, operator or teacher, and trainee or student.

Administrators are responsible for the whole VTE system:

- Normal operation of the system and its accessibility from users;
- Managing virtual nodes;
- Managing users and users' roles.

Operators or teachers are responsible for developing the virtual labs and their assignment to the trainees or students.

Trainees or students are the end users of the VTE. Trainees or students use the VTE according to their curriculum or training scenarios. Different trainees' categories were described above.

As already noted, the users access the VTE resources over a computer network, and most often the access is

through the VTE web interface or remote access web gateway. VTE web interface should provide easy access without compromising security.

III. MARITIME CYBERSECURITY VTE AT NIKOLA VAPTSAROV NAVAL ACADEMY

Based on the functions presented in the previous section, Nikola Vaptsarov Naval Academy (NVNA) built a maritime cybersecurity VTE utilizing open-source software. This VTE uses a Moodle learning management system (LMS) to provide different cybersecurity training scenarios [15].

The physical host used to build the VTE has two Intel(R) Xeon(R) CPU E5-2620 processors and 72 GB RAM. The operating system installed on the host is Ubuntu 18.04.6 LTS. The industry-standard container runtime *containerd* version 1.6.12 is installed to support virtual devices used in labs. To ensure the cybersecurity of the IT infrastructure in which VTE is built, isolation of the VTE's

VLANs from the NVNA's computer network has been implemented. Local and remote trainees can access only the virtual machines and data from the VTE. The isolation of the VLANs ensures that a simulated for training purposes cyberattack will not reach the productive environment. The network traffic over public networks uses secured protocols.

The VTE status information page (Fig. 3) presents information about the current load of the system. The built system has enough computing resources to support all running simultaneously labs that are required to provide cybersecurity training at NVNA.

For each training, at least one virtual lab providing the teacher's (instructor's) topology (Fig. 4) and one lab for each student (Fig. 5) are required. In NVNA, a policy was adopted for the practical maritime cybersecurity classes to be held in groups of between 4 and 8 trainees. This means that every training requires between 5 and 9 labs.

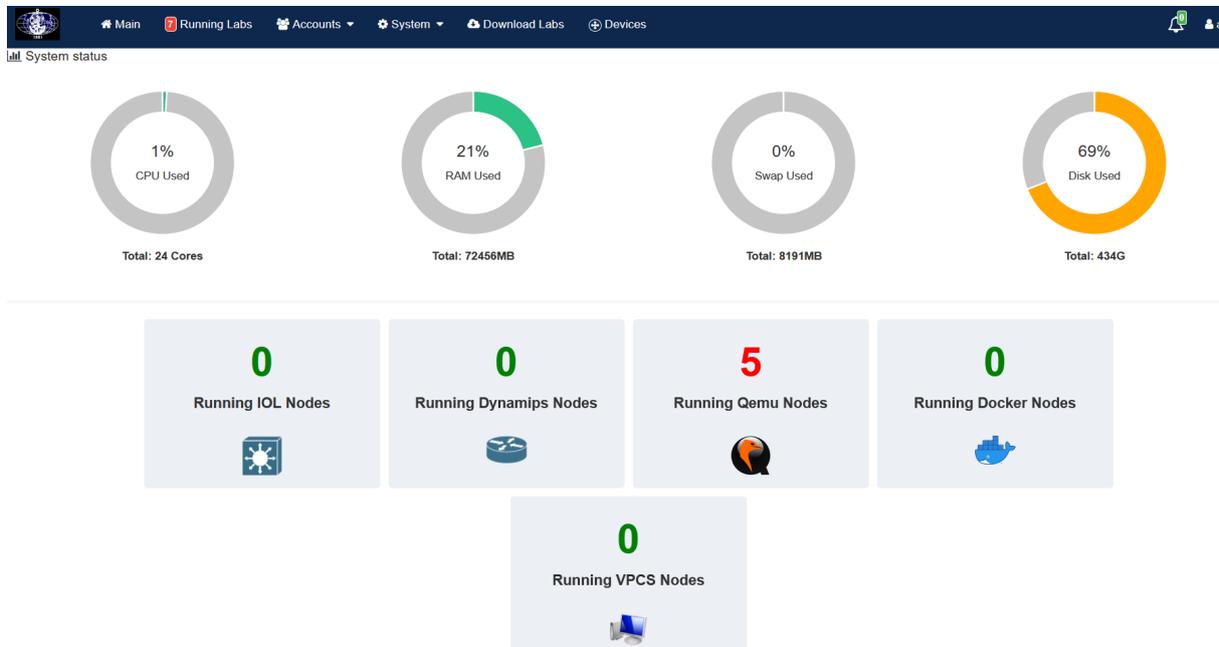


Fig. 3. NVNA cybersecurity VTE system status information page.

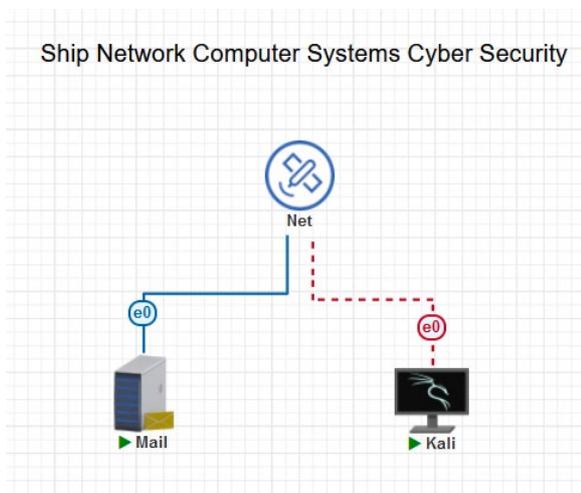


Fig. 4. NVNA cybersecurity VTE teacher's (operator's) virtual topology.

Virtual devices used in the teacher's and student's topologies are different and have different purposes. The teacher's topology has to include the virtual devices that will be used to provide the main part of the training scenario, whereas the student's topology has to include the virtual devices that will perform the role of the "target" machines in a simulated cyber attack.

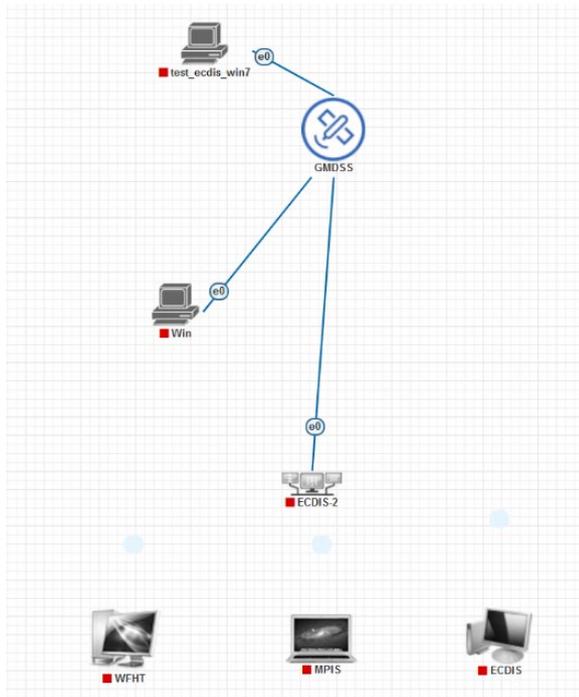


Fig. 5. NVNA cybersecurity VTE trainees' (students') virtual topology.

The NVNA's cybersecurity VTE can provide training under several scenarios as follows:

- End-user device's operating system misconfiguration;
- Sensitive data unauthorized access;
- Phishing emails;
- Malware hidden behind commonly used file extensions;

- Ransomware;
- Privilege escalation;
- Social engineering countermeasures.

The teacher's topology (Fig. 4) consists of three elements – two virtual machines ("Mail" and "Kali") and one virtual network ("Net"). "Net" presents the connectivity to the other devices in the VTE. The virtual machines "Mail" and "Kali" are used to start cyber attacks against the students' topologies (students' labs) based on the training scenario. Other elements can be added to this topology if it is required by the training scenario. It should be noted that one teacher's topology can be used in more than one training scenario.

The student's topology (Fig. 5) consists of more elements because, in one training scenario, it has to provide a simulation of multiple vulnerable devices and systems. On this topology, it seems that some of the virtual devices are not connected to the virtual network "GMDSS". This is only apparent – all virtual devices are connected to the network, but for scenario purposes, it doesn't matter how some of the devices are connected.

A remote access web portal based on Apache Guacamole and HAProxy systems (Fig. 6) is used in NVNA. The purpose of this web portal is to provide access to the VTE's virtual devices for remote trainees. The web portal provides remote desktop access to a single VTE device or multiple VTE devices with a single user login. This web portal in conjunction with the NVNA's Moodle LMS is a complete solution for remote cybersecurity trainees.

A pilot maritime cyber hygiene course was conducted in NVNA with local trainees. Work is underway to organize and conduct a pilot course with remote trainees.

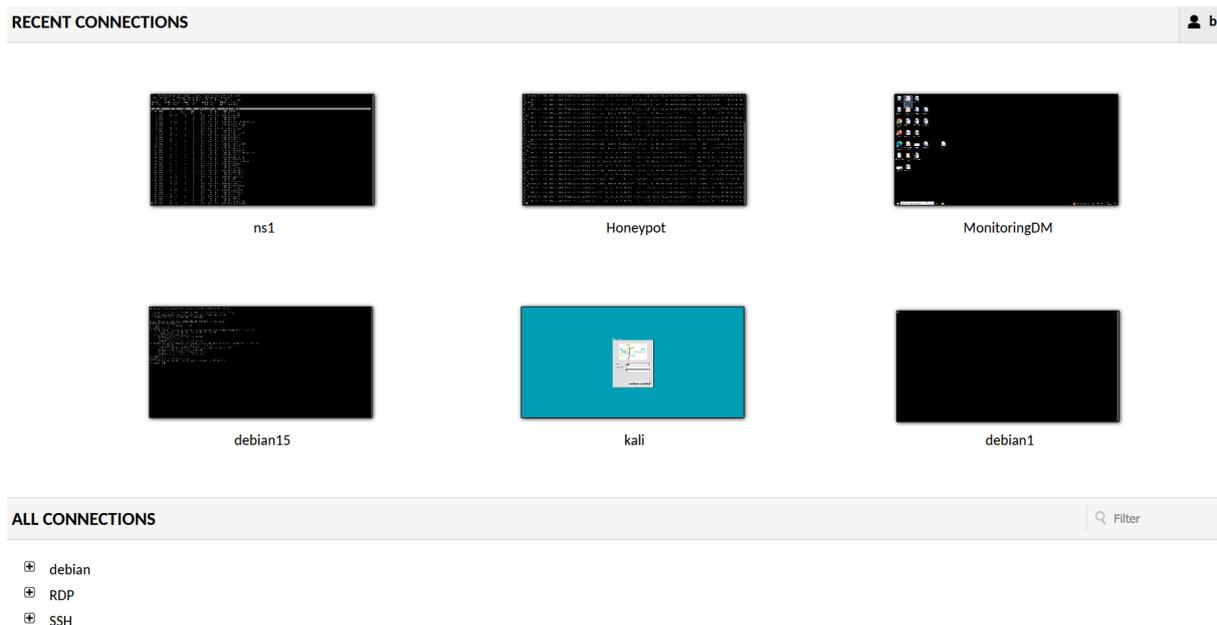


Fig. 6. NVNA's remote access web portal.

IV. CONCLUSIONS

Several open-source platforms have been integrated into NVNA to develop a maritime cybersecurity virtual training environment. This integrated solution has the same functionalities as a full-scale Cyber Range system. The future improvement of the system built in this way should be related to the tools for the automation of training scenarios development. This will enable trainees to perform the training scenarios without the involvement of teachers (instructors).

ACKNOWLEDGMENTS

This work was supported by the National Scientific Program “Security and Defense”, adopted with RMS No. 731/21.10.2021, and financed by the Ministry of Education and Science of the Republic of Bulgaria according to Agreement No. D01-74/19.05.2022.

REFERENCES

- [1] P-L Sanchez-Gonzalez, D. Díaz-Gutiérrez, T.J. Leo, and L.R. Núñez-Rivas, “Toward Digitalization of Maritime Transport?”, *Sensors*, Vol. 19, Iss. 4, 2019. <https://doi.org/10.3390/s19040926>
- [2] C-H Chang, S. Wenming, Z. Wei, P. Changki, and Ch. Kontovas, Evaluating cybersecurity risks in the maritime industry: a literature review. In: Proceedings of the International Association of Maritime Universities (IAMU) Conference, October 29 – November 01, 2019, Tokyo, Japan.
- [3] International Maritime Organization, The International Ship and Port Facility (ISPS) Code, July 1, 2004.
- [4] International Maritime Organization, International Safety Management Code, July 1, 1998.
- [5] M. Canepa, F. Ballini, D. Dalaklis, and S. Vakili, Assessing the effectiveness of cybersecurity training and raising awareness within the maritime domain, 15th International Technology, Education and Development Conference, March 8-9, 2021, INTED2021 Proceedings, pp. 3489-3499. <https://doi.org/10.21125/inted.2021.0726>
- [6] G. Potamos, A. Peratikou, and S. Stavrou, Towards a Maritime Cyber Range training environment, IEEE International Conference on Cyber Security and Resilience (CSR), Rhodes, Greece, 2021, pp. 180-185. <https://doi.org/10.1109/CSR51186.2021.9527904>
- [7] C. Willems and C. Meinel, Online assessment for hands-on cyber security training in a virtual lab, Proceedings of the 2012 IEEE Global Engineering Education Conference (EDUCON), Marrakech, Morocco, 2012, pp. 1-10. <https://doi.org/10.1109/EDUCON.2012.6201149>
- [8] C. J. Bonk, Online training in an online world. Bloomington, IN: CourseShare.com, 2002.
- [9] Ge Jin, Manghui Tu, Tae-Hoon Kim, J. Heffron, and J. White, Game based Cybersecurity Training for High School Students, SIGCSE '18: Proceedings of the 49th ACM Technical Symposium on Computer Science Education, February 2018, pp. 68-73. <https://doi.org/10.1145/3159450.3159591>
- [10] T. van Steen and J. R.A. Deeleman, “Successful Gamification of Cybersecurity Training”, *Cyberpsychology, Behavior, and Social Networking*, 24:9, pp. 593-598, 2021. <https://doi.org/10.1089/cyber.2020.0526>
- [11] V. Krinickij and L. Bukauskas, “Challenges in Cybersecurity Group Interoperability Training”, In: Stephanidis, C., Antona, M., Ntoa, S., Salvendy, G. (eds) HCI International 2023 Posters. HCII 2023. Communications in Computer and Information Science, vol 1834. Springer, Cham. 2023. https://doi.org/10.1007/978-3-031-35998-9_38
- [12] M. Domínguez, D. Pérez, A. Morán, S. Alonso, M. A. Prada, and J. J. Fuertes, Remote training in cybersecurity for industrial control systems, 13th IFAC Symposium on Advances in Control Education ACE 2022: July 24 – 27, 2022, Hamburg, Germany. Vol. 55, Iss. 17, pp. 320-325, 2022. <https://doi.org/10.1016/j.ifacol.2022.09.299>
- [13] M. M. Yamin, B. Katt, and V. Gkioulos, “Cyber ranges and security testbeds: Scenarios, functions, tools and architecture”, *Computers & Security*, Vol. 88, 2020. <https://doi.org/10.1016/j.cose.2019.101636>
- [14] I. Hassan, “Leveraging Apache Guacamole, Linux LXD and Docker Containers to Deliver a Secure Online Lab for a Large Cybersecurity Course”, 2022 IEEE Frontiers in Education Conference (FIE), Uppsala, Sweden, 2022, pp. 1-9. <https://doi.org/10.1109/FIE56618.2022.9962510>
- [15] B. Nikolov and Y. Tsonev, Utilizing Moodle and Apache Open Meetings in a Learning Management System. In: SECOND CONFERENCE ON INNOVATIVE TEACHING METHODS (ITM 2017) June 28-29, 2017, Varna, Bulgaria.
- [16] I. Chakarov, “Cyber Security as Part of the Contemporary Security Environment”, *NRDC-GR Herald Magazine*, Iss. № 8, pp. 7-10, July 2016 – January 2017.

The Use of Generative Artificial Intelligence in Higher Education: University Social Responsibility and Stakeholders' Perceptions

Oļegs Ņikadimovs
EKA University of Applied Sciences
Riga, Latvia
olegs.nikadimovs@eka.edu.lv

Velga Vēvere
EKA University of Applied Sciences
Riga, Latvia
velga.vevere@eka.edu.lv

Abstract. This pilot study assesses the reliability and validity of measurement tools and instrumentation to ensure accurate measurement of the variables and defines possible problems of the follow-up larger-scale research. The study's overall goal is to measure stakeholders' perspectives on the use of generative artificial intelligence (AI) in higher education and its implications for university social responsibility (USR) with the purpose of better understanding how AI technologies are deployed in academic institutions. The primary aim of this pilot study is to evaluate the effectiveness of the designed questionnaire by calculating Cronbach's alpha coefficient of the measurement scales. A questionnaire of 20 items was disseminated to the relevant stakeholders, including students, and academic and administrative staff, with the total number of received valid responses being 101. Cronbach's alpha was used as a measure of internal consistency to test the reliability of the measurement scale that consists of two groups of items: Scale B) perceptions of AI use in higher education of all the relevant stakeholders; Scale C) AI integration into higher education and its implications for USR. Key findings and implications from the study results include good or acceptable internal consistency > 0.7 among the majority of the items in the questionnaire. Specific recommendations for improving some of the items were suggested based on the findings. Modifying language, rephrasing questions, or deleting items that lead to reduced internal consistency are examples of these. The pilot study provides useful insights on the viability of employing the questionnaire in a larger-scale study, and considerations for time and resource allocation to ensure practicality in the subsequent study.

Keywords: generative artificial intelligence; higher education, information technologies; technological integration in academia; university social responsibility

I. INTRODUCTION

The United Nations (UN) Sustainable Development Goals (SDGs) are a collection of 17 interrelated objectives

established by all UN Member States in 2015 as part of the 2030 Agenda for Sustainable Development. The SDGs aim to address many global concerns and create a more sustainable and equitable society by 2030, including poverty, hunger, health, education, gender equality, clean water, sanitation, affordable and clean energy, decent work, industry and innovation, reduced inequalities, sustainable cities, responsible consumption, climate action, life below water, life on land, peace, justice, and strong institutions [1]. The UN define "Quality Education" as ensuring that everyone has access to inclusive, equitable, and high-quality education, as well as encouraging lifelong learning. In the UN 2023 progress report "Quality Education" is not being on track or meeting the target, but rather progressing fairly or showing the signs of stagnation or regress [1].

The COVID-19 pandemic in 2020 exposed vulnerabilities in the current higher education system, as well as the need for more digital technology training for academic staff to respond to the world's rapidly changing educational environment and difficulties. In the post-pandemic era, online learning, digital tools and virtual education seemingly have become an essential component of the higher education system, where universities have the responsibility to address education and research initiatives to ensure student learning outcomes and educational quality [2].

In addition to post-pandemic challenges in higher education, technological developments and the growing rate of adoption of new technologies in higher education, such as artificial intelligence (AI), present certain problems for higher education institutions and student learning in implementing these technologies for teaching, learning, student assistance, and administration [3]. These presented challenges need to be examined to forecast the future models of higher education in a world where AI is integrated into the systems of universities, specifically in

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8015>

© 2024 Oļegs Ņikadimovs, Velga Vēvere. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

the context of university social responsibility (USR). The technological integration of AI with ethical issues in universities is a critical and emerging aspect of higher education, as AI has been widely adopted and employed in higher education, particularly by educational institutions, in a variety of fields such as research, curriculum development, interdisciplinary approaches, ethics, and many others. AI started with computers and computer-related technologies, then moved on to web-based and online intelligent education systems, and finally to the use of embedded computer systems, humanoid robots, and web-based chatbots to perform academic staff duties and functions independently or with instructors [4]. Information technologies are adaptive and non-intrusive, making learning more appealing to the next generation, however, conventional teaching methods may be cautious about integrating current technology and gadgets in the classroom, making it a difficult strategy to use at first [5], [6]. The integration of AI technology in academia creates new teaching techniques and systems, promoting innovation and improving learning results [7]. Some studies propose four areas of AI use in academic assistance, institutional, and administrative services: 1. profiling and prediction, 2. assessment and evaluation, 3. adaptive systems and personalisation, and 4. intelligent tutoring systems; with the results highlighting the nearly complete lack of critical thought on AI's problems and challenges, the limited link to theoretical teaching perspectives, and the need for additional research of ethical and educational methods in the deployment of AI in higher education [8].

While USR is not as commonly used as corporate social responsibility (CSR), there is a growing recognition of the importance of universities taking on social responsibilities. USR in the context of AI entails universities recognising their ethical responsibilities in the creation, implementation, and research of AI technology [9]. Several challenges that fall into the USR domain and have to be addressed can be named including cheating, AI honesty and trustworthiness, academic integrity, privacy, deception, and manipulation of data. USR policies should explore effective techniques for building and implementing AI technologies and assessment of their effects on higher education [10].

This pilot study aims to assess the reliability of a questionnaire prepared for a follow-up larger-scale study on the implementation of generative AI in higher education and the stakeholders' perceptions. The internal consistency method assesses how well the individual items within the questionnaire are correlated and Cronbach's alpha is used as a measure of internal consistency. Based on the study results revisions and modifications of the questionnaire are administered.

II. MATERIALS AND METHODS

The field of AI emerged in the 1950s when computer scientists began to investigate the possibility of developing robots that could learn and think like humans, following McCarthy coining the term "artificial intelligence" in 1956 and organising the Dartmouth Conference, which is widely regarded as the genesis of AI [11]. AI does not refer to a single technology, but rather to a set of technologies and methodologies, including

machine learning, natural language processing, data mining, neural networks, and algorithms, in which computers that perform cognitive functions similar to human minds, such as learning and problem-solving [12]. One of the most widely used AI tools is OpenAI, which is a research tool dedicated to developing user-friendly AI systems that are generally smarter than humans to benefit all of humanity [13]. OpenAI's long-term objective is to develop artificial general intelligence (AGI), often known as "strong AI", AGI refers to robots capable of performing all cognitive activities that humans can [14], [15]. AI technologies in higher education seem to appear to have gone mainstream and the impact on higher education is still in its early stages. It is crucial to monitor and adapt learning, teaching, and assessment methodologies in higher education to this rapidly evolving field of AI [16].

In the age of AI technologies being merged with teaching and learning processes in higher education, ensuring academic integrity and following ethics is of utmost importance [17]. AI tools have the potential to provide a string of benefits to higher education, including enhanced student engagement, cooperation, and accessibility, asynchronous communication, fast feedback, student groups, remote learning, language translation, summarization, question answering, text production, and customized assessments, among other uses. However, AI tools provide issues and concerns, especially with academic integrity, ethics and plagiarism [18]. AI is one of the emerging fields in educational technology seeing a tremendous increase in publication numbers in the span of the last 10 years. According to Scopus abstract and citation database query results using the Boolean operator and the keyword combination "higher AND education AND artificial AND intelligence", the number of published documents grew from 43 in 2013 to 926 in 2023, making it ~21,53 times growth in document count (year range 2013 to 2023). The query results include Document type publications, conference papers, book chapters, conference reviews, editorials and other documents (See Fig. 1).

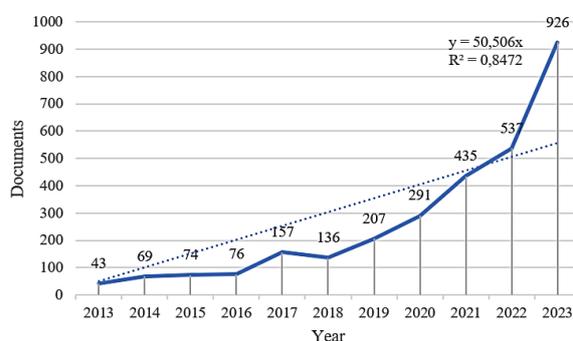


Fig. 1. Search string for artificial intelligence and higher education

The linear regression on a chart represents the general direction of the data points depicting the linear relationship between two variables – independent (year) and dependent (documents). The linear trendline is determined by a linear regression algorithm that minimizes the sum of squared differences between the

observed data points and the points predicted by the line ($R^2 = 0,8472$).

Academic integrity and ethics are the main concerns of the implementation of AI in higher education, despite the potential benefits. AI, as it is known nowadays, is prone to mistakes and information falsification, which can compromise academic integrity, ethics and credibility of the results. These technological limitations provide additional restrictions that limit the usefulness of AI to the users by failing to produce results that meet the required standard [19]. Deliberate academic misconduct by both students and educators is another threat, with several risks identified in higher education and research systems, including cheating on online tests, human-like text production, decreased critical thinking abilities, and difficulty analysing created material [20]. AI has the potential to revolutionise technologies and shift paradigms. Learners would be able to use AI to understand and solve complex problems, improve their reading and writing skills through suggestions, practice exercises, and quizzes, provide personalised guidance to learners during discussions, and use speech-to-text and text-to-speech, among other things. Lesson preparation, personalized learning support, responding to learners' questions, fast assessment and evaluation, and many more opportunities for educators thus saving a substantial amount of time [21]. Information technologies and their integration into academia have significantly impacted the educational systems and the Covid-19 pandemic has boosted the use of digital technology in education. Digital tools such as AI have caused a paradigm change across the education sector, where AI can serve not only as a mentor and assessor but also knowledge provider and co-creator of information [22].

According to the World Business Council for Sustainable Development (WBCSD), CSR is a company's ongoing commitment to ethical behaviour and economic development while improving the quality of life of its employees and their families, as well as the local community and society as a whole [23]. While defining CSR is challenging, defining USR is much more complicated, as the goal is to foster civic commitment and active citizenship through volunteering, ethical behaviour, and encouraging students and faculty to provide social services to their community or promote sustainable development in universities [24]. There have been several definitions of USR produced in the academic setting, "the capacity of the university to disseminate and implement a body of principles and general and specific values, utilizing four key processes—management, teaching, research, and community engagement—to respond to the needs of the university community, and in this framing, their "country" as a whole" [25, p. 710]; "a concept whereby a university integrates all of its functions and activities with the society needs through active engagement with its communities in an ethical and transparent manner which aimed to meet all stakeholders' expectations" [26, p. 275]; "a policy of ethical quality of the performance of the university community (students, faculty and administrative employees) via the responsible management of the educational, cognitive, labour and environmental impacts produced by the university, in an interactive dialogue with society to promote a sustainable

human development" [27, p. 2]. From the selected definitions it can be concluded that USR refers to universities incorporating ethical, social, and environmental values into their core operations, with a focus on meeting stakeholder expectations. It has become crucial to evaluate the role of CSR and thus USR as well in the age of AI technologies being integrated into the very fabric of organizations, companies and higher education establishments. Both CSR and USR include aspects of managing conflicts of interest, such as present and long-term interests of stakeholders, ethics, local and global interests, and sustainable development, among others, including raising stakeholders' awareness of social responsibility, rethinking social responsibility, and reconsidering ethical behaviour standards [28].

Cronbach's alpha is a widely used statistic in research on test development and usage [29]. It is commonly used in studies with multiple-item measures [30]. Cronbach's alpha (α) is a commonly used statistic method that evaluates the internal consistency and reliability of a questionnaire or measuring scales in this study. It assesses how closely the items on a scale or questionnaire correlate with one another. Cronbach's alpha spans between 0 and 1, with higher values suggesting more internal consistency [31].

The formula for Cronbach's alpha is as follows:

$$\alpha = \frac{k\bar{c}}{\bar{v} + (k - 1)\bar{c}} \quad (1)$$

Where:

- k represents the number of items in the measure
- \bar{v} represents the average variance
- \bar{c} represents the average inter-item covariance.

The key interpretations of Cronbach's alpha values:

- Cronbach's Alpha > 0.9: *Excellent internal consistency*
- 0.8 < Cronbach's Alpha < 0.9: *Good internal consistency*
- 0.7 < Cronbach's Alpha < 0.8: *Acceptable internal consistency*
- Cronbach's Alpha < 0.7: *Consideration for improvement in the scale's reliability*

To achieve the main goal of the study, the authors created a three-part questionnaire, where:

- respondents' occupation question – PART A
- stakeholders' perceptions of AI – PART B
- stakeholders' perceptions of USR role – PART C

TABLE 1 THE STRUCTURE OF THE QUESTIONNAIRE

Part	Main question	Types, responses, scales
A	Respondents' profile	Occupation, dummy variables
B	Perceptions on AI in higher education	10 questions. Likert scale: (1 - absolutely disagree; 5 - absolutely agree)
C	Perceptions of USR role in regards of AI in higher education	10 questions. Likert scale: (1 - absolutely disagree; 5 - absolutely agree)

Table 1 shows the structure of the questionnaire. The responses for Part A are categorized using dummy variables (coded 1 - 0), that represent categorical data with two categories - different occupations within a dataset, student (1) or academic/admirative staff (0) [32]. The proportion of the respondents' occupation is 42,02%/57,98%, where 42,02% are academic/ administrative staff, 57,98% are students.

Items from Part B are included in the questionnaire based on the theoretical study of the importance of the perceptions of AI use in higher education of all the relevant stakeholders. The questions are concerned with the general perceptions of students and academic and administrative staff on AI regarding the quality of education, job competitiveness, curriculum, support, learning experience, engagement, and effectiveness among others. The questions of the B scale and their labels are presented in Table 2.

TABLE 2 PART B SCALE ITEMS AND THEIR LABELS

Questions Part B	Label
How would you describe your overall perception of the use of generative AI in higher education?	AI Perception in Higher Ed
Do you agree that generative AI is a revolutionary technology that is going to be widely used in all industries, and employee competitiveness on the labour market will depend on the AI usage skills?	AI and Job Competitiveness
How do you evaluate the use of generative AI will impact the overall quality of education in higher institutions?	AI Impact on Education Quality
How do you perceive the impact of generative AI on the overall learning experience for students in higher education?	AI Impact on Learning Experience
To what extent generative AI positively influences student engagement in higher education?	AI Influence on Student Engagement
How concerned are you about ethical and privacy issues associated with the use of generative AI in higher education?	AI Privacy Concerns
How effective generative AI is in providing academic support and resources to students, academic staff, and administrative staff in higher education?	AI Effectiveness in Academic Support
Do you agree that students, academic staff, and administrative staff are embracing the integration of generative AI in higher education?	Embracement of AI Integration
How well prepared is your institution to integrate generative AI into higher education?	Readiness for AI Integration
How easily generative AI can be integrated into existing educational systems?	AI Integration Ease

Items from Part C are concerned with the incorporation of AI into higher education and making sure it is consistent with the concepts of USR, such as academic integrity and ethics, inclusivity and access to resources, institutional responsibility, stakeholder awareness, training and guidelines, and overall influence of AI on social responsibility. The questions of the C scale and their labels are presented in Table 3.

TABLE 3 PART C SCALE ITEMS AND THEIR LABELS

Questions Part C	Label
Integration of AI into higher education would have a positive outcome on academic integrity?	AI Impact on Integrity
The use of AI in higher education will create certain challenges and threats to the academic ethics and integrity?	Threats to Academic Ethics
Institutions should ensure that ethical considerations are taken into account when using AI products in higher education?	Institutional Responsibility for AI use
Please rate the ethical considerations associated with the use of AI in higher education according to your perceptions.	Ethical Considerations for AI Use
Stakeholders in higher education (e.g., academic staff, students, administrators) are aware of the ethical implications and applications of AI?	Stakeholder Awareness of AI Ethics
Universities have established clear ethical guidelines and oversight mechanisms for the responsible use of AI in higher education?	University Guidelines for AI
Integration of AI aligns with the principles of University Social Responsibility in higher education?	AI Integration and USR
How do you perceive the impact of AI on promoting inclusivity and improving access to educational resources within the framework of University Social Responsibility?	Impact on Inclusivity in USR
How adequate do you find the training and support programs provided by universities to faculty and staff for effectively using AI in higher education?	USR and Training for AI Use
How much positive impact generative AI technologies can have on the university social responsibility initiatives?	Impact of AI on Social Responsibility

Before dissemination, the questionnaire was discussed within different focus groups of students providing additional information and definitions on AI and USR. The focus groups totalled an excess of 100 students from bachelor's and master's programmes in EKA University of Applied Science, programmes "Management", "Business Management" and "Marketing". Clarity, cohesion, and overall understating of the questionnaire items were discussed. In addition to students, academic and administrative staff were provided with the same guidance and clarifications of key definitions. Following the adjustments and needed corrections, the questionnaire was disseminated via the QuestionPro platform to the relevant stakeholders. The return rate of the filled-in questionnaires is ~33%, with 101 completed questionnaires submitted in the QuestionPro platform. The questionnaires were processed and the internal consistency and reliability of the questionnaire and measuring scales of this study were evaluated.

III. RESULTS AND DISCUSSION

Reliability analysis was performed in SPSS to test the measurement instrument of internal consistency. The results of Cronbach's Alpha statistics analysis for the questionnaire's Part B and Part C internal consistency and reliability of measuring scales have produced the results presented in Table 4. Overall results present acceptable or

good internal consistency with some items considered for improvement in the scale's reliability.

TABLE 4 RELIABILITY STATISTICS

Scale	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
Part B	,683	,692	10
Part C	,730	,722	10

Alpha value of ,683 indicates moderate internal consistency for the Part B scale. Researchers often strive for a Cronbach's alpha of 0.70 or above, which indicates good reliability. However, the acceptable range can vary based on the context and measurement aims. For the Part C scale, Cronbach's alpha value is ,730 and suggests that the measuring instrument's set of standardised items has a good level of internal consistency. A Cronbach's alpha of 0.70 or greater is commonly accepted for most research purposes, implying that the items in the instrument reliably measure a common underlying concept.

TABLE 5 INTERNAL CONSISTENCY TEST RESULTS FOR THE SCALE B

Nr.	Part B	Cronbach's Alpha if Item Deleted
Q.B1	AI Perception in Higher Ed	,632
Q.B2	AI Revolution and Job Competitiveness	,675
Q.B3	AI Impact on Education Quality	,618
Q.B4	AI Impact on Learning Experience	,642
Q.B5	AI Influence on Student Engagement	,651
Q.B6	AI Privacy Concerns	,749
Q.B7	AI Effectiveness in Academic Support	,657
Q.B8	Embracement of AI Integration	,630
Q.B9	Readiness for AI Integration	,657
Q.B10	AI Integration Ease	,656

To increase the internal reliability of Cronbach's alpha value for the Part B scale to ,749 it is suggested to delete or modify the following item from the questionnaire – item Q.B6: *How concerned are you about ethical and privacy issues associated with the use of generative AI in higher education*, label: *AI Privacy Concerns* (See Table 5). Removal of this questionnaire item would lead to a small improvement in Cronbach's alpha, where corrected item-total correlation would present only ,137 value for this item.

Although the Part C scale Cronbach's alpha value is ,730 and is considered to be a good level of internal consistency, to slightly increase it to ,756 the following item from the questionnaire should be deleted or modified – item Q.C3: *Institutions should ensure that ethical considerations are taken into account when using AI products in higher education*, label: *Institutional Responsibility for AI use* (See Table 6). Removal of this questionnaire item would lead to a small improvement in

Cronbach's alpha, where corrected item-total correlation would present only ,005 value for this item.

TABLE 6 INTERNAL CONSISTENCY TEST RESULTS FOR THE SCALE C

Nr.	Part C	Cronbach's Alpha if Item Deleted
Q.C1	AI Impact on Integrity	,688
Q.C2	Threats to Academic Ethics	,755
Q.C3	Institutional Responsibility for AI use	,756
Q.C4	Ethical Considerations for AI Use	,695
Q.C5	Stakeholder Awareness of AI Ethics	,682
Q.C6	University Guidelines for AI	,692
Q.C7	AI Integration and USR	,686
Q.C8	Impact on Inclusivity in USR	,696
Q.C9	USR and Training for AI Use	,693
Q.C10	Impact of AI on Social Responsibility	,724

Based on the analysis and results, researchers have decided to modify the Part B scale questionnaire item labelled *AI Privacy Concerns*. No deletions will take place in both scales, since it would lead only to an insignificant improvement in Cronbach's alpha value.

IV. CONCLUSIONS

This pilot study presents the interim findings of a planned larger-scale study on stakeholders' perceptions of the use of AI in higher education and its implications for USR. The study aims to evaluate the effectiveness of the designed questionnaire intended for a larger-scale study on the use of generative AI in higher education by calculating Cronbach's alpha coefficient and measuring the internal consistency and reliability of the questionnaire items. Two items from both scales B and C (item Q.B6 and item Q.C3) are adjusted to achieve higher alpha values and improve the questionnaire's internal consistency, providing that both scales have a good level of internal consistency – scale B ,749 and scale C ,756. Researchers have also reviewed and revised the wording of the questionnaire items, and identified and modified terminology and phrases that may be confusing or subject to interpretation to ensure that respondents understand exactly what is being asked. The final review of the questionnaire included a discussion with the group of experts to validate items and improve overall clarity and cohesion.

The limitations of this study would include that stakeholders only from one university were participating - EKA University of Applied Science, bachelor's and master's programmes students as well as academic and administrative staff.

Future directions for this pilot study would include dissemination of the questionnaire in more universities, including at least one foreign university. Conducting structured pre-survey interviews with a selection of participants to acquire qualitative insights into their comprehension of the questions and identify any problems. Increasing the sample size to receive more diverse replies and a better representation of the target

audience's perceptions and include more diverse stakeholders in the sample population, such as employers and NGO representatives.

REFERENCES

- [1] United Nations, "The Sustainable Development Goals Report Special edition," New York: United Nations Publications, 2023. [Online]. Available: United Nations Reports Online, <https://unstats.un.org/sdgs/report/2023/>. [Accessed January 24, 2024].
- [2] S. Rashid and S. Yadav, "Impact of Covid-19 Pandemic on Higher Education and Research," *Indian Journal of Human Development*, vol. 14(2), pp. 340-343, 2020. doi: 10.1177/0973730320946700
- [3] S. Popenici and S. Kerr, "Exploring the impact of artificial intelligence on teaching and learning in higher education," *Research and Practice in Technology Enhanced Learning*, vol. 12, n. pag., 2017. doi: 10.1186/s41039-017-0062-8.
- [4] L. Chen, P. Chen and Z. Lin, "Artificial Intelligence in Education: A Review," in *IEEE Access*, vol. 8, pp. 75264-75278, 2020. doi: 10.1109/ACCESS.2020.2988510.
- [5] B. Cavas, P. Cavas, B. Karaoglan and T. Kislal, "A Study on Science Teachers' Attitudes Toward Information and Communications Technologies in Education," *Turkish Online Journal of Educational Technology*, vol. 8(2), n. pag., 2009.
- [6] I.O. Biletska, A.F. Paladieva, H.D. Avchinnikova and Y.Y. Kazak, "The use of modern technologies by foreign language teachers: developing digital skills," *Linguistics and Culture Review*, vol. 5 (S2), pp. 16-27, 2021. doi: 10.21744/lingcure.v5nS2.1327
- [7] M.L. Owoc, A. Sawicka and P. Weichbroth, "Artificial Intelligence Technologies in Education: Benefits, Challenges and Strategies of Implementation," *ArXiv abs/2102.09365*, 2021, n. pag.
- [8] O. Zawacki-Richter, V.I. Marín, M. Bond and F. Gouverneur, "Systematic review of research on artificial intelligence applications in higher education – where are the educators?," *International Journal of Educational Technology in Higher Education*, vol. 16, n. pag., 2019. doi: 10.1186/s41239-019-0171-0
- [9] M.L. Jorge and F.J. Peña, "Analysing the Literature on University Social Responsibility: a Review of Selected Higher Education Journals," *Higher Education Quarterly*, vol. 71, pp. 302-319, 2017.
- [10] A. Tlili, B. Shehata, M.A. Adarkwah, et al., "What if the devil is my guardian angel: ChatGPT as a case study of using chatbots in education," *Smart Learning Environments*, vol. 15, pp. 1-24, 2023. doi: 10.1186/s40561-023-00237-x.
- [11] S. Russel and P. Norvig, *Artificial intelligence - a modern approach*. New Jersey: Pearson Education, 2010.
- [12] T. Baker and L. Smith, "Educ-AI-tion Rebooted? Exploring the future of artificial intelligence in schools and colleges," (2019). London: Nesta Foundation, 2019. [Online]. Available: Nesta Foundation report https://media.nesta.org.uk/documents/Future_of_AI_and_education_v5_WEB.pdf. [Accessed January 29, 2024].
- [13] OpenAI, "Our vision for the future of AGI," 2024. Available: <https://openai.com/about>. [Accessed February 20, 2024].
- [14] K. Grace, J. Salvatier, A. Dafoe, D. Zhang and O. Evans, "Viewpoint: When will AI exceed human performance? Evidence from AI experts," *Journal of Artificial Intelligence Research*, vol. 62, pp. 729-754, 2018.
- [15] N. Bostrom, *Superintelligence: paths, dangers, strategies*. Oxford University Press, 2017.
- [16] J. Rudolph, S. Tan and Sh. Tan, "ChatGPT: Bullshit spewer or the end of traditional assessments in higher education?," *Journal of Applied Learning & Teaching*, vol. 6(1), pp. 342-362, 2023. doi: 10.37074/jalt.2023.6.1.9
- [17] M.R. King, chatGPT, "A Conversation on Artificial Intelligence, Chatbots, and Plagiarism in Higher Education," *Cellular and Molecular Bioengineering*, vol. 16, pp. 1-2, 2023. doi: 10.1007/s12195-022-00754-8
- [18] D.R.E. Cotton, P.A. Cotton and J.R. Shipway, "Chatting and cheating: Ensuring academic integrity in the era of ChatGPT," *Innovations in Education and Teaching International*, vol. 61:2, pp. 228-239, 2024. doi:10.1080/14703297.2023.2190148
- [19] G.M. Currie, "Academic integrity and artificial intelligence: Is ChatGPT hype, hero or heresy?," *Seminars in Nuclear Medicine*, vol. 53(5), pp. 719-730, 2023. doi: 10.1053/j.semnuclmed.2023.04.008
- [20] M. Tight, "Challenging cheating in higher education: a review of research and practice," *Assessment & Evaluation in Higher Education*, pp. 1-13, 2024. doi: 10.1080/02602938.2023.2300104
- [21] M.M. Rahman and Y. Watanobe, "ChatGPT for Education and Research: Opportunities, Threats, and Strategies," *Applied Sciences*, vol. 13(9), pp. 57-83, 2023. doi: 10.3390/app13095783
- [22] H. Abid, J. Mohd, Q. Mohd and S. Rajiv, "Understanding the Role of Digital Technologies in Education: A review," *Sustainable Operations and Computers*, vol. 3, pp. 275-285, 2022. doi: 10.1016/j.susoc.2022.05.004.
- [23] R. Holme, Watts P. and World Business Council for Sustainable Development, "Corporate Social Responsibility: Making Good Business Sense," World Business Council for Sustainable Development; 2000.
- [24] R. Vasilescu, C. Barna, M. Epure and C. Baicu, "Developing university social responsibility: a model for the challenges of the new civil society," *Procedia Social and Behavioral Sciences*, vol. 2, pp. 4177-4187, 2010.
- [25] R. Garde, M.P. Rodríguez and A.M. Lopez, "Online disclosure of university social responsibility: A comparative study of public and private US universities," *Environmental Education Research*, vol. 19(6), pp. 709-746, 2013. doi: 10.1080/13504622.2012.749976
- [26] A. Esfijani, F. Hussain and E. Chang, "University Social Responsibility Ontology," *International Journal of Engineering Intelligent Systems*, vol. 4, pp. 271-281, 2013.
- [27] J. Reiser, "University Social Responsibility definition," 2008. Available: http://www.usralliance.org/resources/Aurilla_Presentation_Session6.pdf. [Accessed February 20, 2016].
- [28] W. Zhao, "How to improve corporate social responsibility in the era of artificial intelligence?," *IOP Conference Series: Earth and Environmental Science*, vol. 186(6), 012036, 2018. doi: 10.1088/1755-1315/186/6/012036.
- [29] J.M. Cortina, "What is coefficient alpha? An examination of theory and applications," *Journal of Applied Psychology*, 78(1), pp. 98-104, 1993. doi: 10.1037/0021-9010.78.1.98.
- [30] N. Schmitt, "Uses and abuses of coefficient alpha," *Psychological Assessment*, vol. 8(4), pp. 350-353, 1996. doi: 10.1037/1040-3590.8.4.350.
- [31] K.S. Taber, "The Use of Cronbach's Alpha When Developing and Reporting Research Instruments in Science Education," *Research in Science Education*, vol. 48, pp. 1273-1296, 2018. doi: 10.1007/s11165-016-9602-2
- [32] P. Balestra, "Dummy Variables," in J. Eatwell, M. Milgate and P. Newman (eds) *Econometrics*. London: The New Palgrave. Palgrave Macmillan, 1990. doi: 10.1007/978-1-349-20570-7_9

Research of Different Turbo Code Speeds, Types of Modulations, Decoding Methods and their Compatibility with Encryption Techniques

Stanimir Parvanov

National Military University "Vasil Levski",
Faculty "Artillery Air Defense and
Communication and Information Systems"
Shumen, Bulgaria
ssparvanov@gmail.com

Abstract. Turbo codes are widely used to perform reliable information transfer over noisy communication connections with limited bandwidth or latency. The focus of the report is the analysis of different turbo encoder speed of the code, types of modulations, decoding methods and their joint use with information covert transmission methods. Realization of the communication channels is realized via Matlab/Simulink software. The effectiveness of communication systems is a matter of constant analysis and research by experts in the field of communication technologies.

Keywords: turbo codes, error correction, encryption, communication systems.

I. INTRODUCTION

Turbo codes do a simple but incredible thing: they let engineers design systems that come extremely close to the so-called channel capacity - the absolute maximum capacity, in bits per second, of a communications channel for a given power level at the transmitter. This threshold for reliable communications was discovered by the famed Claude Shannon, the brilliant electrical engineer and mathematician who worked at Bell Telephone Laboratories in Murray Hill, N.J., and is renowned as the father of information theory [1]. Nowadays, Turbo codes are widely used from the ground or terrestrial systems of data storage, Asymmetric Digital Subscriber Line (ADSL) modems and fiber optic communications. Subsequently, it moves up to the air channel applications by employing to wireless communication systems, systems operating on the principle of secondary radar systems, [9] and then flies up to the space by using in digital video broadcasting and satellite communications. Undoubtedly, with the excellent error correction potential, it has been selected to support data transmission in space exploring system as well [2],[3]. Also, communication over the public network

infrastructure like Internet brings potential threat which necessitating the use of encrypted algorithms [4], [5], [6].

The main purpose of this study is to build different communication models, with different speed of the turbo encoders, precisely different generating polynomial, with different codeword length, to combine them with different types of modulation, and examine and summarize the results obtained with different types of algorithms to decode in to decoders [11].

II. MODEL AND METHODS

There are many ways to implement a communication channel, but in most case's, this requires a large amount of funds. In this report, the focus is on communication simulation models implemented in the Simulink simulation environment.

Figure 1 depicts the first communication model considered. Its composition includes the following blocks. Message Source, Matrix Interleaver, Turbo Encoder, 64-QAM Modulator, AWGN Channel, 64-QAM Demodulator, Turbo Decoder, Matrix Deinterleaver, Bit Error Rate Calculator, Display, Spectrum Analyzer and Constellation Diagram Block. The specific thing about this simulation model is that, unlike standard turbo encoders, a matrix interleaver is added before it, which adds a percentage of hiddenness in the task of secret transmission of the information, which, in principle is achieved by encrypting the message. The phase manipulated (PM) signals, possessing a crest factor equal to one and a thumbtack autocorrelation function (ACF), are very important for many types of radio-communication systems (RCSs), because they provide the maximal possible resolution of the objects and diminish the negative effects, caused by the multipath spread of the electromagnetic waves [12].

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8037>

© 2024 Stanimir Parvanov. Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

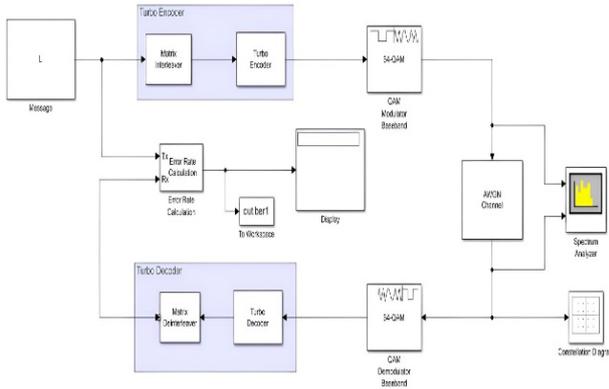


Fig. 1. Communication channel with Turbo coding and 64-QAM modulation

The communication channel of Figure 1 works as follows: From the message source, a text is generated, which is encrypted via RSA algorithm and converted into a binary form containing a cryptotext and a public key from a written code in the command window of Matlab (code is almost similar as in source [5]), the binary message is passed through a matrix interleaver, where an additional shift by rows and columns takes place, then the series of 0's and 1's is encoded with the turbo encoder with different generating polynomials (different length and code rate), then the encoded ciphertext is modulated by 64-QAM modulator, the modulated signal is received at AWGN channel, where noise is added, after that the signal is demodulated, decoded and received by bit error calculator, which compare the real message with the received one and, also the send signal is received by "ber1" block which is connected with Matlab environment and the final result can be decrypted from the written RSA code. More about RSA algorithm in [6].

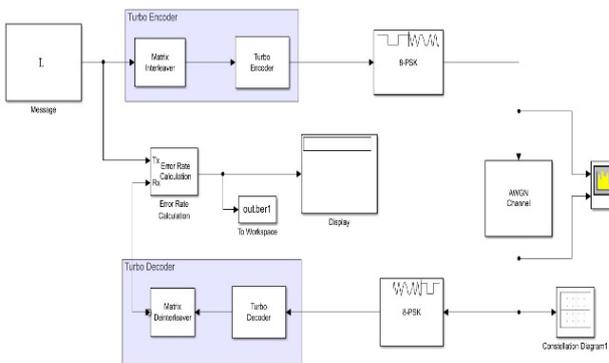


Fig. 2. Communication channel with Turbo coding and 8-PSK modulation

For the simulations are made 2 more models shown in fig.2 and fig.3 that are similar to the one illustrated in fig 1, the difference being that the modulation blocks are set to: different modulations and the poly2trellis structure in turbo encoder/decoder, are also other. Table 1 shows the parameters of the simulation models.

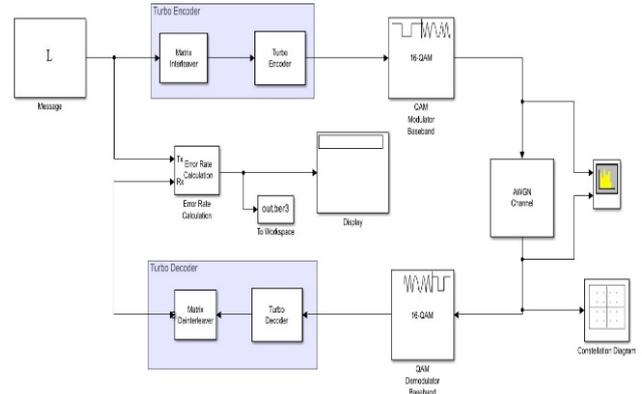


Fig. 3. Communication channel with Turbo coding and 16-QAM modulation

- Adds White Gaussian noise channel (AWGN)

The relationship between Ratio of symbol energy to noise power spectral density (E_s/N_0) and Ratio of bit energy to noise power spectral density (E_b/N_0), both expressed in [dB], is as follows:

$$E_s / N_0 (dB) = E_b / N_0 (dB) + 10 \log_{10}(k) \quad (1)$$

where "k" is the number of information bits per symbol.

In a communications system, "k" might be influenced by the size of the modulation alphabet or the code rate of an error-control code. For example, in a system using a rate 1/2 code and 8-PSK modulation, the number of information bits per symbol "k" is the product of the code rate and the number of coded bits per modulated symbol. Specifically,

$$(1/2) \log_2(8) = 3/2 \quad (2)$$

in such a system, three information bits correspond to six coded bits, which in turn correspond to two 8-PSK symbols [6].

- Encoder/Decoder Trellis structure

Trellis construction = poly2trellis (Constraint Length, Code Generator, Feedback Connection) returns the trellis structure description corresponding to the conversion for a rate k/n feedback encoder. "k" is the number of input bit streams to the encoder, and "n" is the number of output connections. Constraint length specifies the delay for the input bit streams to the encoder. Code Generator specifies the output connections for the input bit streams to the encoder. Feedback connection specifies the feedback connection for each of the "k" input bit streams to the encoder. You can find more information about trellis structures in [8].

TABLE 1 PARAMETERS OF THE MODELS

№	Parameters of the models		
	<i>poly2trellis structure</i>	<i>modulation n</i>	<i>R, K</i>
1.	poly2trellis(4,[13,15],13)	8-PSK	1/2, 4
2.	poly2trellis(4,[13,15,17],13)	8-PSK	1/3, 4
3.	poly2trellis(7,[23,12,7],170)	8-PSK	1/3, 7
4.	poly2trellis(4,[13,15],13)	16-QAM	1/2, 4
5.	poly2trellis(4,[13,15,17],13)	16-QAM	1/3, 4
6.	poly2trellis(7,[23,12,7],170)	16-QAM	1/3, 7
7.	poly2trellis(4,[13,15],13)	64-QAM	1/2, 4
8.	poly2trellis(4,[13,15,17],13)	64-QAM	1/3, 4
9.	poly2trellis(7,[23,12,7],170)	64-QAM	1/3, 7

III. RESULTS AND DISCUSSION

The first results shown in (fig. 4, 5, 6) claim from a simulation model with 8-PSK modulation, with parameters shown in table 1.

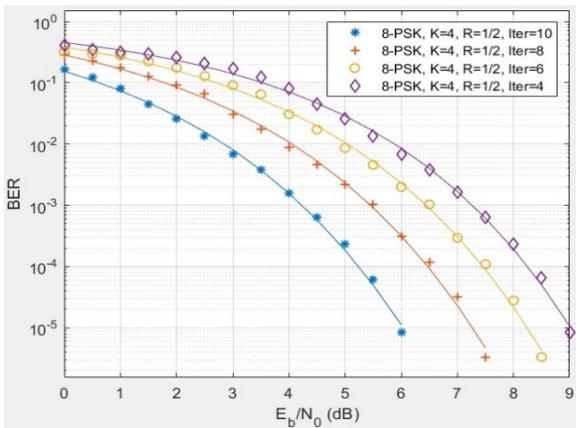


Fig. 4. Communication channel with Turbo coding and 8-PSK modulation and poly2trellis(4,[13,15],13), R = 1/2, K = 4

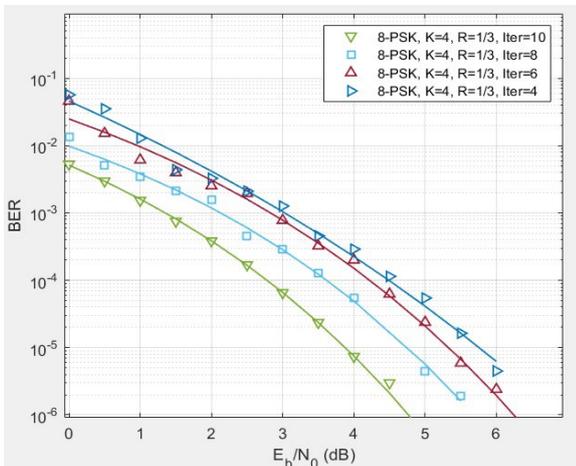


Fig. 5. Communication channel with Turbo coding and 8-PSK modulation and poly2trellis(4,[13,15,17],13), R = 1/3, K = 4

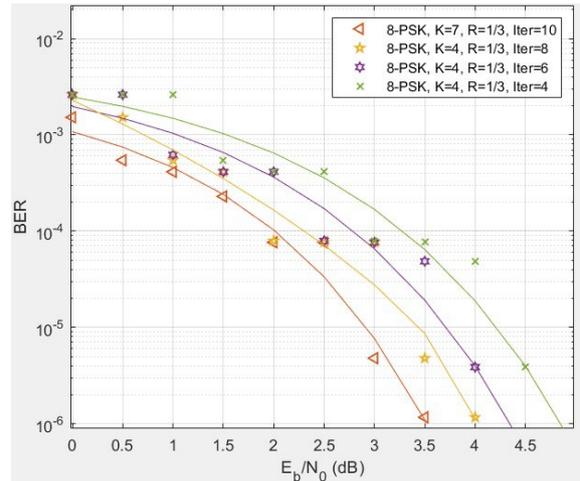


Fig. 6. Communication channel with Turbo coding and 8-PSK modulation and poly2trellis(7,[23,12,7],170), R = 1/3, K = 7

The model with 8-PSK modulation give the following results: for poly2trellis (7, [23,12,7],170), R=1/3, K=7 and 10 iterations in turbo decoder as the best signal to noise ratio is 3,5 [dB]. The lowest score was obtained with poly2trellis (4, [13,15],13), R=1/2, K=4 and 4 iterations in decoder and signal to noise ratio 9 [dB].

The second results (fig. 7, 8, 9) that are illustrated are obtained from a simulation model with 16-QAM modulation, with parameters shown in table 1.

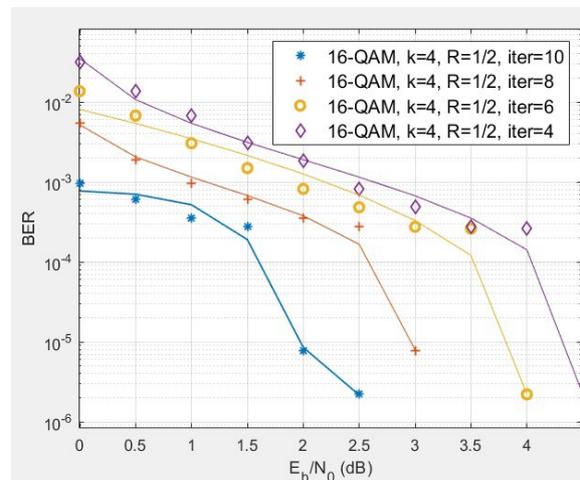


Fig. 7. Communication channel with Turbo coding and 16-QAM modulation and poly2trellis(4,[13,15],13), R = 1/2, K = 4

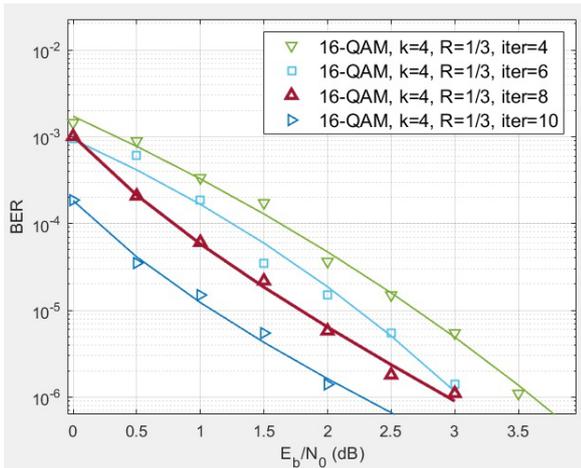


Fig. 8. Communication channel with Turbo coding and 16-QAM modulation and poly2trellis(4,[13,15,17],13), $R = 1/3$, $K = 4$

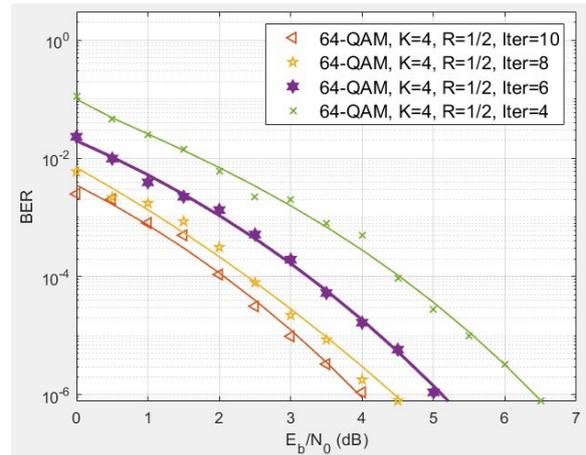


Fig. 10. Communication channel with Turbo coding and 64-QAM modulation and poly2trellis(4,[13,15,17],13), $R = 1/2$, $K = 4$

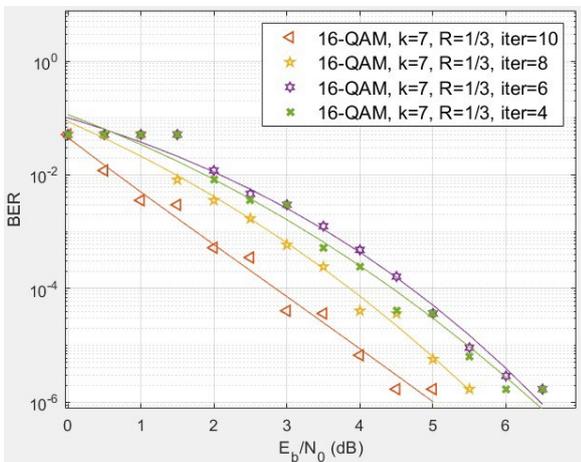


Fig. 9. Communication channel with Turbo coding and 16-QAM modulation and poly2trellis (7,[23,12,7],170), $R = 1/3$, $K = 7$

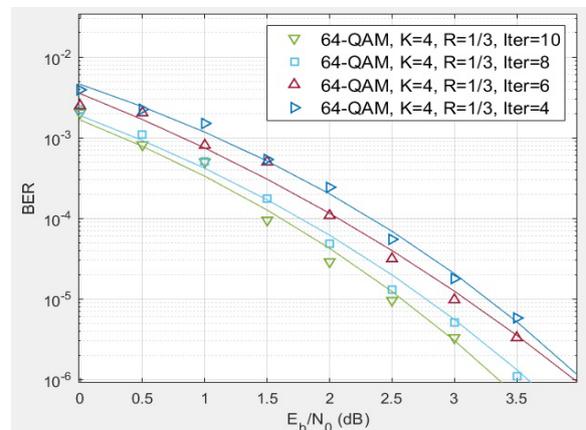


Fig. 11. Communication channel with Turbo coding and 64-QAM modulation and poly2trellis(4,[13,15,17],13), $R = 1/3$, $K = 4$

The best results are for model with 16-QAM modulation and parameters: poly2trellis (4, [13,15,17],13), $R=1/3$, $K=4$ and 10 iterations in turbo decoder as the best signal to noise ratio is 2,5 [dB]. The worst results were obtained with poly2trellis (7, [23,12,7],170), $R=1/3$, $K=7$, $K=4$ and 4 iterations in turbo decoder and $SNR = 6,5$ [dB].

The last results (fig. 10, 11, 12) which is simulated was from a model with 64-QAM modulation, with settings specified in table 1.

The best indicators for model with 64-QAM modulation is for: poly2trellis (4, [13,15,17],13), $R=1/3$, $K=7$ and 10 iterations in turbo decoder as the best signal to noise ratio is 2,3 [dB]. The worst results were obtained with poly2trellis (4, [13,15],13), $R=1/2$, $K=4$, $K=4$ and 4 iterations in turbo decoder and $SNR = 6,5$ [dB].

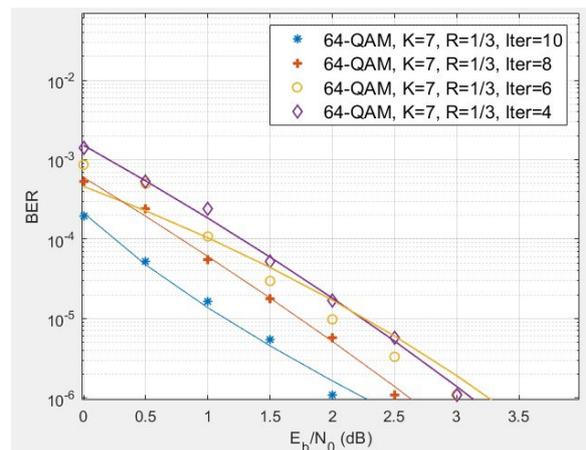


Fig. 12. Communication channel with Turbo coding and 64-QAM modulation and poly2trellis (7,[23,12,7],170), $R = 1/3$, $K = 7$

IV. CONCLUSION

The following conclusions can be drawn from the examined results:

1. As the length of the codeword increases, the chance of correcting erroneous bits increases.
2. Increasing the code rate improves the signal-to-noise ratio.

3. As the codeword length, code rate, and iterations in the decoder increase, the data rate slows down significantly.

4. To increase the data transfer rate, it is necessary to use a shorter code word, a smaller code rate and fewer iterations in the turbo decoder.

If you need a streaming communication system you should use short code word length and low code rate, if signal to noise ratio is need to be optimal then the longer the code word is, the faster the code rate and more iterations in the decoder are needed at the expense of the data transfer rate, or if you want to keep the data transfer rate you must use more powerful computing device such as a system of multiprocessor systems consisting of a number of independent processors connected to each other by a system of buses, organized in a certain way with a single operating system, shared operative memory and external devices [10], if this is cost effective.

ACKNOWLEDGMENT

This paper is supported by the National Scientific Program "Security and Defense", approved with Decision № 171/21.10.2021, task 3.1.9 of the Ministry Council of Republic of Bulgaria.

REFERENCES

[1] Erico Guizzo, "Closing In On The Perfect Code", [Online], Available: <https://spectrum.ieee.org/turbo-codes>, [Accessed March 1, 2004].

[2] Keattisak Sripimanwat, "Turbo Code Applications - A Journey from a Paper to Realization", National Electronics and Computer Technology Center (NECTEC), Pathumthani, Thailand, 2005;

[3] K. O. Slavyanov, "Contemporary Synthetic Aperture Radar Systems. Market Situation", International Scientific Conference

"Defense Technology" at "Artillery, Aircraft Defense and CIS" Shumen, Bulgaria, 2017;

[4] L. Nikolov, R. Dimov, B. Zlatinov, "Malware in Social Engineering", "Scientific-Technical Union Of Mechanical Engineering - Industry 4.0", Borovets Winter Resort, Bulgaria, 2020;

[5] Suriyanath, RSA algorithm, MATLAB Central File Exchange, [Online], Available: <https://nl.mathworks.com/matlabcentral/fileexchange/46824-rsa-algorithm>; [Accessed: April 12, 2024];

[6] Z. J. Luo, R. Liu, A. Mehta, "Understanding the RSA algorithm", 2023;

[7] Mathworks support centre, Documentation, [Online], Available: <https://nl.mathworks.com/help/comm/ug/awgn-channel.html>, [Accessed: 1994-2024 The MathWorks, Inc.]

[8] Mathworks support centre, Documentation, [Online], Available: https://nl.mathworks.com/help/comm/ref/poly2trellis.html?searchHighlight=poly2trellis&srchtitle=srchtitle_support_results_1_poly2trellis, [Accessed: 1994-2024 The MathWorks, Inc.]

[9] D. Dimitrov, M. Kirov, "Methods For Increasing Information Authenticity by Knowing Objects for Identification System "IFF"", Scientific Session - Part I, National Military University "Vasil Levski", V. Tarnovo, 2010;

[10] T. G. Peshev, "Types of processor architectures for signal processing in inverse antenna aperture synthesis radar", Scientific Session - Part I, National Military University "Vasil Levski", V. Tarnovo, 2010;

[11] J. Kenea, K. Kulatb, "Soft Output Decoding Algorithm for Turbo Codes Implementation in Mobile Wi-Max Environment", "2nd International Conference on Communication, Computing & Security", [Online] Available: <https://www.sciencedirect.com/science/article/pii/S2212017312006251>, [Accessed: November 12, 2012 [ICCCS-2012], DOI: 10.1016/j.protcy.2012.10.080;

[12] B. Bedzhev, D. Dimitrov, "Application Of Quasi Complementary Pairs Of Phase Manipulated Signals In Radio-Communication Systems", Proceedings of "International Scientific Conference - Defense Technologies", DefTech, Shumen, Bulgaria, 2023.

Analysis and application of CRM systems in the field of education

Pavel Petrov

Department of Computer Systems
and Technologies
St. Cyril and St. Methodius
University of Veliko Turnovo
Veliko Turovo, Bulgaria
p.v.petrov@ts.uni-vt.bg

Vassil Milev

Department of Computer Systems
and Technologies
St. Cyril and St. Methodius
University of Veliko Turnovo
Veliko Turovo, Bulgaria
v.milev@ts.uni-vt.bg

Abstract. In practice, a customer relationship management (CRM) system is considered as application software, which is designed for organizations and enterprises, with the aim of facilitating the organization and successful implementation of relationships with current and future customers, i.e. CRM systems are mainly referred to business. The purpose of this paper is to research and represent the integration/deployment and benefits of CRM-systems in non-profit organizations such as universities and other higher education institutions, thereby contributing to increasing their competitiveness. The appropriate communication and streamlined processes are the key steps to attracting and retaining more students, as well as staying competitive, therefore an adequate using of CRM system can support taking advantage of these success factors. The paper proposes a comparative analysis of existing leading CRM systems in the field of Higher Education, a summarization of the benefits and the need for their deployment.

Keywords: CRM system, educational CRM system Education.

I. INTRODUCTION

The term CRM (customer relationship management) [16] is an umbrella term that includes strategies, practices and technologies whose ultimate goal is to improve the understanding and philosophy of a business's customers by focusing on the human factor, regardless of whether it refers to customer, service user or merchant. The ultimate goal is to build strong relationships with customers to increase business profits. The following "Fig. 1" presents a common model of CRM system [11].

Nowadays, CRM systems are the information systems which provide effective market orientation.

These systems are aimed at creating an extensive database of current and future users, the creation of which gives a competitive advantage.

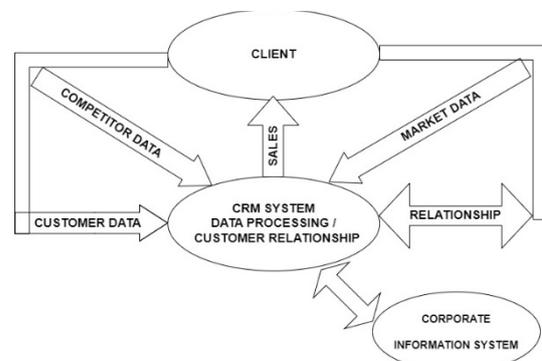


Fig. 1. Common model of CRM system.

The purpose of a CRM system is to bring together the various sources of data on customers, sales, competitors, responses to marketing campaigns and market trends in order to build close relationships with customers.

A. Principles and processes of a CRM system Basic principles of a CRM system:

- Availability of a single database in which data can be quickly, easily and efficiently stored and information retrieved for “
- Synchronization of management of multiple interaction channels. It is obvious that regardless of the method of contact with the customer, it is necessary to store the relevant data and then use it.
- Constant analysis of collected customer information and adoption of relevant organizational decisions.

Information processes in a CRM system are presented in “Fig. 2”.

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8029>

© 2024 Pavel Petrov, Vassil Milev. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

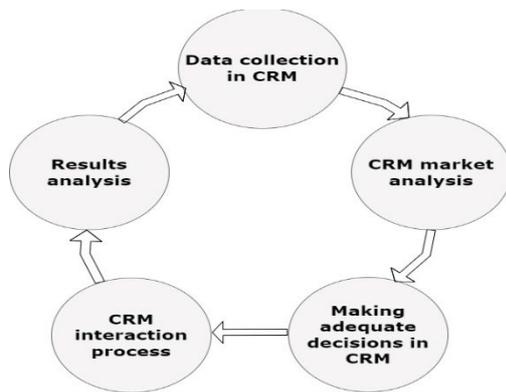


Fig. 2. Information processes in a CRM system.

- Data collection in CRM.
- CRM market analysis.
- Making adequate decisions in CRM.
- CRM interaction process.
- Results analysis.

B. Application areas of CRM

Every business has its own specifications and every owner runs their business differently. As a result, there are many different ways to develop the perfect CRM system [13]. Some of the industries using CRM systems are:



Fig. 3. Industries using CRM systems.

- Retail Industry - such an advanced software allows companies selling goods and services to personalize the shopping experience towards the users as the software can collect and analyze the data, through the websites of the companies or through the social media and thus identify the exact audience.
- Hospitality - this sector provides its customers with various types of services, and these systems allow staff to quickly access information related to current and future hotel guests, in an adequately organized way that is at the same time easy to understand.
- Financial industry - uses CRM software thanks to which it can better understand the wishes of its customers and create more attractive offers. By analyzing customer information, CRM software can attract more prospective customers in a short period of time.
- Healthcare - users can use the CRM to find a doctor, book an appointment, add to the schedule and notify the patient in advance of the doctor's visit. Various

planning can be done with the use of artificial intelligence.

- Manufacturing – using CRM software helps forecast demand, which can be crucial for high-tech and electronics companies. An integrated CRM module can compare data collected in different production departments with sales-based information and develop accurate forecasts related to product demand.
- Education - the digital age we live in is the reason CRM systems for education are quickly becoming mainstream applications used by educational institutions, regardless of the size, location and type of institution.

The current paper is motivated by the dynamics in the development of systems used in the field of education, the large set of input data, as well as the need for communication between educational institutions. These are major problems that CRM systems have the resources to deal with.

II. CRM IN HIGHER EDUCATION

CRM software in education has the ability to manage all interactions of the institution using it with prospective and current students. It maintains the management of communications with alumni, staff and other members of the educational sector at the given institution.

The educational software gathers meaningful information from a variety of sources and stores it in a convenient database. This CRM system can collect and include various data that serve to personalize the relationship between the institution and the learners in all possible channels [8].

The use of such a system can significantly reduce the problems faced by the educational institution, such as errors in the data of an individual student. With this system, the personnel can easily track changes in information and systematize it. In the case of inefficiencies in the system, there is a risk of communication problems that slow down other important institutional processes and lead to problems such as missing important deadlines. The right CRM software provides ample communication tools combined with customization options. This personalized approach ensures that all changes and announcements reach all affected students on time. CRM systems developed and used in education are specialized for its needs [1].

A higher education CRM system is a part of software that manages all interactions between the institution and all the various stakeholders. It is primarily used to optimize and manage relationships with current and prospective students, as well as school staff, partners, alumni and others. A CRM system can also help create and maintain these relationships.

An effective CRM system collects and archives all essential data about students and other participants. Among the information it may include are their names, gender, educational history, age, contact information, etc. This data about the people the organization interacts with is stored in one consolidated and easily accessible database. This provides an opportunity to simplify and personalize communication while improving relationships.

Features that should be present in a higher education CRM system include:

- Management of inquiries and acceptance.
- Integrated means of communication.
- Document management.
- Automation of the work process.
- Real-time analysis and reporting.
- Integration.

A. Leading CRM systems in higher education

Salesforce Education Benchmark - This specialized CRM system is aimed at universities, colleges, schools and other educational institutions [15]. It provides an opportunity to improve relations with learners, staff, and everyone involved in the educational process. Some of its features are:

- Student Relationship Management.
- Course and program management.
- Marketing and recruitment.
- Automation of processes.
- System for face-to-face education and online education.
- Collaboration and communication.
- Analytics and reporting.
- Integration with the Salesforce ecosystem.
- Accessibility and mobility.

Microsoft Dynamics 365 for Education - an educational platform that covers the management of student relationships, administrative processes and other important elements in educational institutions [12, 9]. Some of its features are:

- Student relationship management.
- Marketing and recruitment.
- Administrative processes and course management.
- Online education.
- Collaboration and communication.
- Analytics and reporting.
- Integration with Office 365.
- Accessibility and mobility.

Ellucian CRM Advance - specially developed for higher education. Part of Ellucian, a leading provider of applications in education [2, 14]. It is intended to support higher education institutions. The main goal is improving interaction with sponsors, alumni and other interested parties. Some of its features are:

- Relationship management.
- Marketing and communication.
- Analysis and reporting.
- Integration with other system.
- Student and Alumni Management.
- Security and regulatory compliance.
- Accessibility and easy management.

CampusNexus - Created to help institutions improve their communication with potential and current students [4, 7]. The system offers a comprehensive overview of student data, empowering staff to maintain relations with students permanently and eternally. Some of its features are:

- Management of potential students.
- Student and Alumni Management.
- Analyzes and reports.
- Integration with other systems.

Blackbaud - a system designed specifically for the needs of non-governmental organizations, charitable foundations and various institutions in the field of education [6, 10] - Some of its features are:

- Sponsor relationship management.
- Marketing and recruitment.
- Management of educational institutions.
- Event control.
- Integration with other systems.
- Analysis and reporting.
- Security and regulatory compliance.
- Communication and collaboration.

HubSpot for Education - uses the HubSpot CRM system in the field of education and manages to apply specific settings and solutions to problems in educational institutions [5]. Its main features are:

- Student Government.
- Marketing and recruitment.
- Donation and fund activity.
- Alumni management.
- Event controls.
- Accountability and analysis.
- Integration.

B. Criteria for comparative analysis of crm systems for education

The criteria on which the analysis is made aim to show the advantages of the systems. Due to the different processes in the field of education, it is the advantages and the opportunity to work with numerous and important tools that the systems have, that are essential for choosing the right one for educational institutions. The selection criteria are as follows:

- Working with the platform.
- Integration with other systems and applications.
- Tracking the students' learning path.
- Data security.
- System management costs.

III. COMPARATIVE ANALYSIS OF CRM SYSTEMS FOR EDUCATION

Table 1 presents a comparative analysis between the reviewed CRM systems in the field of education.

Table 1 Comparative analysis of CRM systems for education.

CRM systems in Education	Advantages	Disadvantages
Salesforce Education	1. A flexible platform with numerous applications. 2. Integration of various aspects in the educational process. 3. Personalization of education.	1. Higher cost. 2. Higher starting point relative to the configuration.
Microsoft Dynamics 365 for Education	1. Integrated with MS Office and other company products. 2. Flexibility through additional extensions.	1. More complex configuration. 2. Higher starting point relative to the configuration.

Ellucian CRM Advance	<ol style="list-style-type: none"> 1. Specialized in higher education. 2. Integration with the management systems of educational institutions. 3. Focus on student and alumni management. 	<ol style="list-style-type: none"> 1. More complex configuration for integration with other systems. 2. More complex managing large educational institutions.
CampusNexus	<ol style="list-style-type: none"> 1. Integrated student and administration management platform. 2. Monitoring and maintaining the student life cycle from recruitment to graduation. 3. Analytical tools for student success. 	<ol style="list-style-type: none"> 1. Complex integration with systems. 2. Complex for configuration.
Blackbaud	<ol style="list-style-type: none"> 1. Specialized software for educational institutions. 2. Donation management and financial support. 3. Tools for analysis and reporting of the finances of educational institutions. 	<ol style="list-style-type: none"> 1. More focused on charity and resource management. 2. Complexity in implementation and integration.
Hubspot for Education	<ol style="list-style-type: none"> 1. Intuitive software that is easy to use. 2. Integration with various marketing tools. 3. Analytical tools for tracking marketing campaigns. 	<ol style="list-style-type: none"> 1. Lack of some functionalities used in educational institutions. 2. Limited possibilities for integration with other systems.

The comparative analysis shows that most systems have the possibility of integration to work with other applications or systems. This helps the functionality of the systems themselves, as well as expanding the set of tools. All of the systems listed are applicable in the field of education, with Ellucian CRM Advance and Blackbaud specializing in higher education. Ellucian CRM Advance also has a special focus on alumni processes.

The problem with integrating with other systems is that the process is not easy with most software. HubSpot for Education lacks some functionality used in educational institutions. With Ellucian CRM Advance comes the complexity of managing larger institutions, and the main disadvantage of Salesforce is the high cost compared to other CRM systems.

The existing CRM systems in the field of education provide a good basis for the continued development and work with this type of systems. Of the listed systems, Salesforce Education, Microsoft Dynamics, and Ellucian CRM Advance are the systems that can provide connectivity between school-to-university educational institutions. The important thing here is to pay attention to whether the functionalities meet the needs of the institutions and whether the systems can be adapted and applicable to the particular educational institution.

On the other hand, there are CRM systems that connect education with business. Such type of systems supports cooperation between educational institutions and different companies.

Two of them - Campus Nexus and Salesforce Education provide this opportunity for student management that allows educational institutions to collaborate with businesses.

The need for the development of this type of CRM system, which tracks a person's development from

education to business, and that is aimed directly at education in Bulgaria, is connected with two main reasons:

- Providing functionalities to track the completion of education in several different stages.
- The opportunity to improve the conversion rate of graduates.

IV. BENEFITS OF IMPLEMENTING CRM IN EDUCATION

Nowadays, there are a lot of technologies and resources that make life easier for students, teachers, and school administrators. Here are the main advantages that a CRM system can offer for the competitiveness of an educational institution:

- Improved record keeping.
- Perfect tracking of payments, acceptance and other activities.
- Simplified process for processing group requests.
- Improved acceptance numbers with automated marketing.
- Sophisticated teamwork.
- Real-time insights into organizational processes.
- Correct analyses.
- Increasing student participation.
- Better retention.

V. CONCLUSION

From the survey of existing papers on the implementation of CRM systems in higher education institutions, it can be concluded that the main motive is to improve competitiveness by helping to solve problems related to attracting and retaining students. Dealing with these problems, requires interaction with students to be aimed at increasing their success rate, perception of satisfaction with the studied courses and administrative service, and perception of loyalty to the institution. In order to increase the efficiency of this interaction, ways of extracting additional information based on prediction based on the available data are being sought [3].

REFERENCES

- [1] Kosovac, Amel & Research, Teaching & Assistant, & Kalem, Aida & Medić, Adisa. Proposal of crm conceptual model/framework to optimise relations among stakeholders of higher education, 2022, doi: 10.17818/emip/2022/2.15, [online], https://www.researchgate.net/publication/365182900_proposal_of_crm_conceptual_model_framework_to_optimise_relations_among_stakeholders_of_higher_education.pdf, [Accessed February 14, 2024].
- [2] T. van Vugt, Customer Relationship Management (CRM) Systems in Higher Education, [Online], <https://www.studyportals.com/wp-content/uploads/2015/12/CRM-Systems-in-Higher-Education-main-report.pdf>, [Accessed February 14, 2024].
- [3] Ц., Георгиева-Трифорова, Управление на взаимоотношенията с клиентите и добиване на данни – мотивация и ползи от прилагането им във висшите училища Списание „Известия“, Списание на Икономически университет – Варна, том 63, брой 1, 2019, с. 87-100, ISSN (Online): 2367-6949, ISSN (Print): 1310-0343, http://journal.ue-varna.bg/uploads/20190516100900_7401051985cdd36bc5219e.pdf, [Accessed February 14, 2024].
- [4] CampusNexus Architecture Designed for Higher Education in the 21st Century, [Online], Available: https://www.immagic.com/eLibrary/ARCHIVES/GENERAL/CMC_US/C151118N.pdf, [Accessed February 14, 2024].
- [5] A Quick Guide to a CRM for Education, [Online], Available: <https://www.hubspot.com/products/crm/education?fbclid=IwAR13YrXs4BUFGwV7EhotelwqjeLqRScpnhsXbJkVTkssURZBQUxcGbNEak>, [Accessed February 14, 2024].

- [6] About Blackbaud K-12 Solutions, [Online], Available: <https://www.softwareadvice.com/school-management/blackbaud-k-12-profile/>, [Accessed February 14, 2024].
- [7] CampusNexus® Constituent Relationship Management, [Online], Available: <https://www.cebex3.com/index.php/en/talisma-crm>, [Accessed February 14, 2024].
- [8] Custom CRM System for Higher Education: Key Features, Budget, and Steps, January 10, 2024, [Online], Available: <https://bg.rayhaber.com/2024/01/yukse-ogrenim-icin-ozel-crm-sistemi-temel-ozellikler-butce-ve-adimlar/>, [Accessed February 14, 2024].
- [9] Education Industry, [Online], Available: <https://www.dynamics-square.com.au/industry/education/>, [Accessed February 14, 2024].
- [10] Education Management for K-12 Schools, [Online], Available: <https://www.blackbaud.com/solutions/organizational-and-program-management/education-management/k-12>, [Accessed February 14, 2024].
- [11] H. Tudjarov, Common model of a CRM system, CRM 2008 [Online], Available: <http://tuj.asenevtsi.com/CRM/indexCRM.htm>, [Accessed February 14, 2024].
- [12] How Dynamics 365 for Education is Streamlining Administrative Tasks for Schools and Universities, April 22, 2023 — By Dynamics Square UK / Dynamics ERP for Education, ERP Software Information, [Online], Available: <https://erpsoftwareblog.com/2023/04/dynamics-365-for-education/>, [Accessed February 14, 2024].
- [13] M. Rouse, What is Customer Relationship Management (CRM)?, September 8, 2023, [Online], Available: What is Customer Relationship Management (CRM)? (techopedia.com), [Accessed February 14, 2024].
- [14] R. Winthrop, 7 Ellucian Alternatives & Competitors for Student Management, by Rita Winthrop, [Online], Available: <https://element451.com/blog/7-ellucian-alternatives>, [Accessed February 14, 2024].
- [15] What does Salesforce do?, [Online], Available: <https://www.salesforce.com/products/what-is-salesforce/?d=70130000000i7zF>, [Accessed February 14, 2024].
- [16] What is CRM?, [Online], Available: <https://www.softone.bg/what-is-crm/>, [Accessed February 14, 2024].

Applied Methodological Essence of Project Management in Transport Through Artificial Intelligence

Irena Velinova Petrova

Department of Technology, Organization
and Management of Transport
Todor Kableshkov University of Transport
Sofia 1574, 158 Geo Milev St.
ipetrova@vtu.bg

Abstract. Modern transport projects are complex, multi-stage and long-term, associated with significant calculations, changing schedules, matching resources, analyzing different scenarios for their impact on the development of transport systems and infrastructure. These projects are implemented in a dynamic external environment with a great influence of rapidly changing political, social and natural factors. This objectively requires the application of flexibility in the planning and determination of the various options for development and the search for new approaches to managing transport projects and ensuring the necessary dynamics. Through the application of artificial intelligence, the flexibility in planning and implementation of these transport projects can be improved.

This article examines the possibility of using artificial intelligence in transport project management. More specifically, the methodological essence is emphasized from the point of view of using artificial intelligence in the design and implementation of these projects.

Keywords: Artificial intelligence, methodology, project management, transport projects.

I. INTRODUCTION

Project management in transport is a relatively new approach that is used in planning, construction, rehabilitation, investment, modernization and other activities. Projects in the transport sector can be for traffic management, improving infrastructure safety, building intelligent transport systems, building new infrastructure, etc. They are very diverse and unique to the particular case.

During the processes of design, implementation, commissioning and monitoring, modern information technologies are used in transport projects. However, these projects have seen a serious breach of deadlines, often quality. The causes leading to these violations are not the subject of this article.

Managing transport infrastructure in critical situations as a result of disasters also generates huge amounts of data. Building of an online disaster response system is described in [1].

The latest technology in the management of transport projects is the application of artificial intelligence (AI). Progress in the development of artificial intelligence in the last 3 years has entered the field of project management and at a slower pace in the transport sector. Programmers have created numerous AI-based tools for project management in transport, most of which are cloud solutions. This makes them accessible from anywhere if there is internet. The use of transport project management tools allows large volumes of data to be processed to optimize project planning, implementation and monitoring processes. Many tasks can also be automated, which would reduce the time for the realization of the project and optimize the budget. With these tools, forecasts and scenarios can be generated, thus reducing risk. While transport project management tools may be in the early stages of development, they can be used to reduce costs and increase team communication [2], [3].

II. MATERIALS AND METHODS

In the scientific literature, many attempts can be found to define the concept of artificial intelligence (AI). According to which AI is a system of algorithms that mimic human intelligence to some extent and offer a course of action without being programmed to do so. AI is a program or algorithm that draws conclusions or predictions using a dataset [4].

AI works with huge data sets that are used for training or to solve specific problems. The data it uses can be structured and unstructured. Structured data is organized in tables, by rows and columns, while unstructured data is not organized (example: videos, images, and text).

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8047>

© 2024 Irena Petrova. Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

Synthetic data, which is artificially generated information when there are too few real-world data, are also used.

An AI model trained with large amounts of structured data is more accurate and efficient. It can be trained to perform one task, and then adapt to perform another task. The most used models are described in [5].

New types of AI are constantly being developed using new algorithms. AI finds application in new areas. Models are being developed which are a combination of two or more architectures. Figure 1 presents a summary of the types of AI by different indicators.

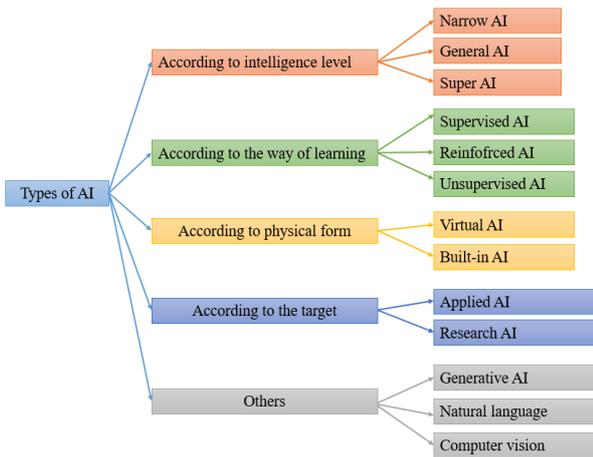


Fig. 1. Types of AI by different indicators.

Generative Artificial Intelligence is the most widely used as it is applicable in many fields and easy to use. From input data in the form of text, image, video or voice, generative AI creates new content. It can generate new project ideas and optimize existing ones [6].

In project management software, in addition to Generative AI, machine learning, natural language, computer vision and intelligent solutions are used to automate processes.

Machine learning based on historical data predicts project deadlines and costs, identifies potential risks, and sets personalized tasks. Computer vision finds application to analyse the progress of the project by using images.

Intelligent AI applications are used to automate tasks, support customers, and answer questions.

When developing the structure of a database, knowledge base, etc. parallel design technology is used. This technology provides a link between the current and transition stages [7].

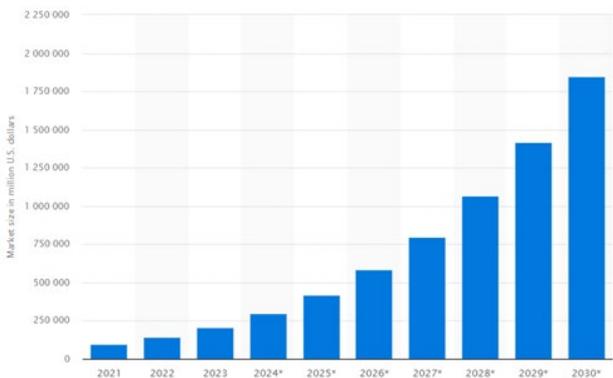


Fig. 2. Forecast for market growth for AI for the period 2021-2030 [8].

An indicator of the development and implementation of AI until 2030 is the forecast of a twenty-fold growth of the market (Figure 2). Everyone will accept and use AI in some way in business and personal life [8].

III. RESULTS AND DISCUSSION

Projects are unique ventures that are limited in terms of scope, time, budget. This makes them difficult to manage based on historical data from transitional projects, as no two projects are exactly the same. They can only be similar. The development of each project goes through seven phases: adoption, initiation, planning, product selection, implementation, monitoring and completion. With data accumulation, AI has the ability to analyze, reason, and solve problems. The quality of the solutions depends mostly on the amount of data available to the AI. It takes longer to build an infrastructure to collect and classify data to power the algorithm. From the main data source we get the collected raw data. Filtered and processed data are obtained from a secondary source. Data that are digital objects and can be reused to train AI are called digital assets [2], [9]. Data-driven project management is an approach that uses data to make decisions. The framework for the use of digital assets includes the following 4 steps [2], [4], [9], [10].

- Creation of digital assets: a set of data and other materials.
- Storage of digital assets: should be easy to find and use.
- Sharing of digital assets.
- Use of digital assets.

The application of digital assets provides the basis for the use of AI in transport project management.

The applications of AI in construction project management are described in [11], [12]. The use of AI allows predicting project costs with greater accuracy, optimizing the project schedule and identifying potential problems, managing resources more efficiently, monitoring performance and detecting deviations from the plan, detecting risks and mitigating them.

AI offers a new approach to project management that is more effective than traditional tools. With the help of AI, project managers can analyze previous data and anticipate potential issues that may affect the project. This reduces the risk of unexpected situations involving people, suppliers, organizations and other factors. AI can also use current and historical data to create different project scenarios and evaluate and rank them according to their meaning. AI helps to plan project costs and time frames more accurately in the early stages [13].

The project manager is the one responsible for making decisions. According to The International Project Management Association (IPMA), it defines the competences that a project manager must possess and publishes them in the Individual Competence Baseline (ICB4). Competence is a combination of knowledge, skills and abilities. With the help of AI, one will have a constant insight and ready-made solutions for any situation that arises [14].

The standard project management methods used are: Gantt Diagram; Critical Path Method; PERT Analysis,

Approaches to Cost Estimation, Progress Reporting and in recent years attempts are seen to implement Agile Methods.

A. Waterfall

This project management methodology is characterized by successive phases, with the next phase beginning after the completion of the preceding one. When using artificial intelligence, you can achieve task automation, report generation and progress tracking.

B. Agile

This methodology is applied to dynamic projects where requirements change frequently. AI achieves task optimization, risk forecasting and resource optimization. A methodology for the use of AI in the management of infrastructure transport projects has been developed [15].

C. Application Of Artificial Intelligence In The Management Of Transport Projects

Project management in the transport sector with AI is not equally developed in different countries. There are more advanced countries that can share experience and knowledge. When implementing AI to manage projects in transport, there is often a lack of database, as well as skilled employees to work with the software. The new channels for data collection should be included and the logic in the application of AI should be sought. Whether the new AI software will be usable by current managers and employees needs to be explored. The latter must be trained to work with the application and, if necessary, be trained to understand AI mechanisms and algorithms. Other issues that are observed are related to security, control, access and data management [16].

A detailed overview of the use of information technology in rail transport is given. The use of various software to automate tasks shows that the sector is ready to move to the next stage – the implementation of AI [17].

Projects in the field of transport are of different types: for construction, rehabilitation, modernization of the transport fleet, construction of intelligent transport systems, logistics and many others. When choosing the right AI software for project management, the type of project is taken into account.

Each project is described by five elements: time, budget, scope, quality and risk, distributed in the project triangle. The project triangle is used to manage the constraints of the project. Optimizing all elements at the same time is impossible,

Transport projects are usually mega projects with huge scope and budget. Budget management is a key activity for its success, which requires constant monitoring and adjustment of costs in all phases, from design to implementation. The expected cost of the project is the result of a preliminary cost estimate, based on historical data for similar projects. At the next stage, an economic assessment of the usefulness of the project is made. A successful transport project ends within the set scope, schedule, budget and according to standards and societal expectations in terms of quality [16], [17].

Quality management of transport projects is an important and responsible task that can be improved with the use of AI. Using the project's data, AI can generate

recommendations on how to improve quality significantly faster than humans. AI can also define the quality requirements of the project and monitor their compliance.

The fifth element of any project is risk. Risk identification, assessment and prioritization is a priority in AI software development. By using statistics and machine learning methods, computer vision and neural networks, early detection of risk is achieved and solutions are proposed on how to reduce their impact [18].

Managing resources in a transportation project can be done with AI and besides optimizing them, it can improve the performance of human resources. With AI, an optimal project schedule can be achieved. Any change in the scope, performance of tasks or use of resources shall be accounted for by AI and the timetable shall be revised [19].

The areas of AI development in project management in the next 10 years are described. These are: cost estimation, schedule management and risk management. The authors propose in the future to look for solutions to integrate AI with other technologies, develop hybrid models, build trust and cooperation between humans and AI [20].

The areas of AI development in project management in the next 10 years are described. These are: cost estimation, schedule management and risk management. The authors propose in the future to look for solutions to integrate AI with other technologies, develop hybrid models, build trust and cooperation between humans and AI [21], [22].

The described proposals for the implementation of AI in the management of transport projects define the technology as a necessity for the implementation of a successful project. However, certain risks can be identified:

- Security risk.
- Risk of violation of the right to confidentiality.
- AI can gain autonomy and control the project entirely.
- Risk related to data quality or missing data.
- Staff skill issue where the AI can assign a task to an incompetent human.
- At this point, AI is not creative.

D. Methodology For the Creation of AI For the Management of Transport Projects

Figure 3 presents the methodology for creating AI software for transport project management.

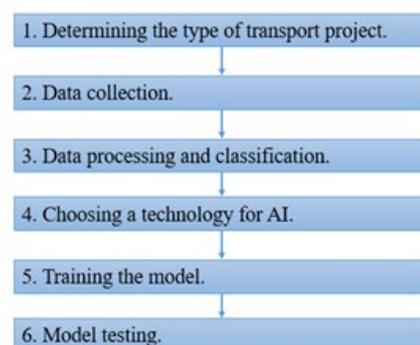


Fig. 1. Methodology for the creation of AI for the management of transport projects.

Step 1. Determining the type of transport project is essential for the selection of AI technology and for building infrastructure for data collection.

Step 2. The quality of AI transportation project management software depends on the data it is trained with. It is important that the data is relevant, correct and comprehensive. In the transport sector, a lot of data is generated, in a different form. There is a huge amount of data in text form, and their analysis would improve the management processes. At this stage, textual data analysis methods work in three languages – English, French and Chinese, and data in different countries are collected in the local language.

Step 3. Before the data classification process, incomplete data should be cleaned and organized. This is followed by uploading the data and training AI. Every time the data changes, the AI model needs to be trained.

Step 4. AI technology is selected from the known: machine learning, voice recognition, natural language processing, etc.

Step 5. Model training is the most complex process and requires the work of specialists. AI platforms have been developed in which we provide data and the platform trains the AI model without writing code [23].

Step 6. After building and training the model, testing follows.

Creating AI software to manage transport projects is a challenging process.

IV. CONCLUSION

Deploying AI in transportation project management is transforming current practices in many aspects which is why it faces severe challenges. In the future, a much wider application of AI in the management of transport projects is expected, as the benefits for its users are:

- Saving valuable time for routine tasks.
- Improving the communications and work of the project team.
- Helps make decisions about which project to invest in.
- Improves project budget management.
- Improves the ability of the project to be completed within the originally set deadline.
- Project quality management.

A key point in introducing and using AI applications in project management is a change in employee thinking and culture. It's not enough for employees to be well informed. They need to be competent and capable.

This study was funded by a grant from the Internal Research Projects Program of the Ministry of Education in the Republic of Bulgaria (Project Title: “Intelligent Transport Systems: Problem Areas and Advanced Solutions”). The grant covered both the research costs and the fees associated with open access publication.

V. ACKNOWLEDGMENTS

This study was funded by a grant from the Internal Research Projects Program of the Ministry of Education in

the Republic of Bulgaria (Project Title: “Intelligent Transport Systems: Problem Areas and Advanced Solutions”). The grant covered both the research costs and the fees associated with open access publication.

VI. REFERENCES

- [1] D. Dimitrov, P. Zlateva, "Information Model for the Registration of Disasters Affecting the Road Infrastructure," *World Science, RS Global*, vol. 1, no. № 1(29), January 2018.
- [2] D. Dimitrov, Z. Trendafilov, "About the Need for Performing Training and Increasing the Qualification of Dispatchers and Movement Managers in Railway Transport," *World Science, RS Global, International Journal of Innovative Technologies in Economy*, vol. 2, no. 5(17), June 2018.
- [3] Dimitrov, D.; Zlateva, P.; Velez, D., "A Methodology for Designing an Information System for Road Infrastructure Monitoring and Traffic Management in Disasters," *IOP Conference Series: Earth and Environmental Science*, vol. 167, p. 012044, June 2018.
- [4] A. M. Sadou, E. T. Njaya, "Applications of Artificial Intelligence in the Air Transport Industry: A Bibliometric and Systematic Literature Review," *Journal of Aerospace Technology and Management*, no. DOI:10.1590/jatm.v15.1312, 2023.
- [5] D. Dimitrov, I. Manchev, „Research and analysis of models for digital management of transport systems,“ *Mechanics Transport Communications*, том 21, № 3, 2023.
- [6] G. Strobel, L. Banh, F. Möller and T. Schoormanm, "Exploring Generative Artificial Intelligence: A Taxonomy and Types," *Hawaii International Conference on System Sciences (HICSS) At Honolulu, Hawaii, 2024*, pp. At Honolulu, Hawaii, 2024.
- [7] K. Ткацхенко, О. Ткацхенко, "Modeling of management of intelligent systems in transport," *Збірник наукових праць ДУИТ. Серія «Транспортні системи і технології»*, vol. Вип. 39, no. DOI:10.32703/2617-9040-2022-39-24, 2022.
- [8] Thormunadsson, B., "Global artificial intelligence market size 2021-2030," 2023. [Online]. Available: <https://www.statista.com/statistics/1365145/artificial-intelligence-market-size/>. [Accessed 26 February 2024].
- [9] Ficzer, P., "The role of artificial intelligence in the development of rail transport," no. DOI:10.55343/cogsust.81, 2023.
- [10] Kuolo, M., "Artificial Intelligence and project management," no. https://www.academia.edu/49328172/Artificial_Intelligence_and_project_management.
- [11] Elrajabi, S., *Artificial Intelligence in Project Management*, LIGG UNIVERSITY USA, 2019.
- [12] I. Merdzanovic, M. Vukomanovic, D. Ivandicvidovic, "A Comprehensive Literature Review Of Research Trends Of Applying Ai To Construction Project Management," in *6th Ipma Senet Project Management Conference: Digital Transformation And Sustainable Developmen in Project Management*, Dubrovnik, 2022.
- [13] O. Balli, I. Guven, "Artificial Intelligence in AEC Industry: Construction Project Management Processes," in *1 st International Conference on Innovative Academic Studise: Turkey*, 2022.
- [14] Miller, G., "Digital assets for project –based studies and data-driven project management," in *15th Conference on Computer Science and Information Systems (FedCSIS)*, Sofia, Bulgaria, 2020, pp. 591-594, doi: 10.15439/2020F94, 2020.
- [15] D. Dimitrov, I. Petrova I., P. Zlateva, D. Velez, "Artificial Intelligence Application in Agile Transport Project Management," in *Digitalization and Management Innovation II*, DOI:10.3233/FAIA230717, Seoul, South Korea, 2023.
- [16] Binova, H., "Methodology of transportation project management," *Journal of Systems Integration*, vol. 3, no. <https://www.researchgate.net/publication/309742397>, 2013.
- [17] D. Dimitrov, K. Lalov, „Review and analysis of intelligent rail transport management systems,“ *Mechanics Transport Communications*, том 21, № 3, 2023.

- [18] T. N. Academies, *Guidance for Transportation Project Management*, Washington : DOI: <https://doi.org/10.17226/23028>, 2029.
- [19] P. Korke, R. Gobinath, M. Shewale, B. Khartode,, "Role of Artificial Intelligence in Construction Project Management," in *E3S Web of Conferences* 405, 04012 (2023), <https://doi.org/10.1051/e3sconf/202340504012>, 2023.
- [20] Ç. Elmas, J. Babayev, "Artificial Intelligence Techniques Used in Project Management," *Advances in Artificial Intelligence Research (AAIR)*, vol. 1 (No.1, no. <http://www.dergipark.com/aaair/>), pp. 1-5, 2021.
- [21] C. Mariani, M. Mancini:, "Artificial Intelligence Adoption In Project Management: Are We Still Far From Practical Implementation?," in *Digital Transformation And Sustainable Development In Project Management*, Dubrovnik, 2022.
- [22] "What is ICB?," [Online]. Available: <https://t2informatik.de/en/smartpedia/icb/>. [Accessed 26 February 2024].
- [23] D. Dobrev, D. Dimitrov, "Metro Traffic Management Scheme Based on Wagons Travelling in Autonomous Mode," *Transport for Today's Society, 2nd International Conference, University "St. Kliment Ohridski", Faculty of Technical Sciences*, pp. 439-445, 17-19 May 2018.

Determine the Location of Nodes in Wireless Sensor Network by Using Genetic Algorithm

Milen Simeonov

Faculty of Aviation

Georgi Benkovski Bulgarian Air Force Academy

Dolna Mitropoliya, Bulgaria

msimeonov@af-acad.bg

Marin Marinov

Faculty of Aviation

Georgi Benkovski Bulgarian Air Force Academy

Dolna Mitropoliya, Bulgaria

mmarinov@af-acad.bg

Abstract. Wireless sensor networks (WSNs) are widely used in the modern world. An important requirement for the optimal operation of the network is the determination of the location of the sensor nodes. When building the network, various positioning methods are used, providing the necessary level of accuracy in determining the location of the sensor nodes. It makes it possible to adjust the transmission power of the nodes, to determine which sensors should be in standby mode and which ones to be in working mode, and also to determine the best route for transmitting information. The Angle of Arrival (AoA) method is a method of positioning with respect to the location of the mobile station, which is determined by triangulation of received information collected at multiple access points. The Time of Arrival (ToA) method, also known as the telemetry method, provides one-way measurements of the time difference of signal propagation from the exact time the signal is sent by the transmitter and the exact time the signal is received at the receiver. The Time Difference of Arrival (TDoA) method is based on the concept that a mobile station transmits a message that has been received by at least three access points that are synchronized with other access points. Most of these methods involve approximation and/or linearization, which introduce additional errors. In the present work, an algorithm is proposed for calculating the location of the sensor nodes by the ToA method using a genetic algorithm (GA). An objective function is derived, based on the distances from the reference nodes and the mobile sensor node whose location is sought. This objective function is minimized using a GA, resulting in the desired node coordinates. Investigations of the accuracy of determining the location of the sensor nodes at different accuracy of distance measurement have been made.

Keywords: genetic algorithm, node positioning, wireless sensor networks

I. INTRODUCTION

Wireless sensor networks (WSNs) are used in a wide range of applications. A critical requirement for many of these applications is the self-determination of the sensor

nodes location in WSNs [1]. Sensor devices need to be cheap and with low power consumption, which is determined by the fact that sensor networks can be composed of hundreds to thousands of devices. To achieve the desired accuracy for determining the location of each device, various positioning methods are used [2] – [4].

WSNs are used to measure different spatial and/or temporal parameters of some systems or devices. They can measure natural phenomena like temperature, sound, pressure or other non-natural parameters of some objects like coordinates, velocity, etc., and transmit this data via formed network to a given control centre [1]. To obtain information about the relative or absolute coordinates of the searched node, different methods are used [2] – [4].

Some nodes are usually chosen as the ‘reference’ in the analysis of a sensor network. The reference sensor nodes are used to obtain the location of the nearby nodes [4], [5]. The coordinates of the farther nodes are determined, using some nodes that have already self-determined their locations. These late nodes are called ‘main’ further in this paper [6].

Usually, a node associated with the largest number of branches is chosen as a reference node [7], [2] – [4]. Determining the position of main sensor nodes in a network is an important part of solving mobile object positioning tasks. One of the goals of using sensor networks is to eliminate the need for detailed network topology planning, thereby reducing the need for data on the exact location of a particular node when it is deployed in the network [8], [9].

A wireless sensor network is composed of directly connected deployed nodes. Each node can communicate directly with adjacent sensor nodes within its radio range. An ideal case is when the node coverage is a circle [1], [10] – [12].

There are three basic methods that are widely used nowadays. One of them is the Angle of Arrival (AoA)

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8059>

© 2024 Milen Simeonov, Marin Marinov. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

method which is a method measuring the angle between direction of received signal and some reference direction or orientation [13]. Another way to implement this method is by measuring the angle between the dumb node and a main node. This technique requires at least three reference or main nodes with known locations to be used. The coordinates of the dumb node are determined by triangulation of received information from main nodes [7], [2] – [4]. This method possesses some disadvantages as deployment of special antennas, the use of more sophisticated and precise hardware, as well as shadowing and multipath fading conditions lead to bigger errors in the estimated position [8], [9]. Because of this, the AoA method is not often used for localization in WSNs.

The second one is the Time Difference of Arrival (TDoA) method which is based on the concept that a mobile sensor receives messages from at least three main or reference sensor nodes. It is necessary to measure time difference between the receiving signals from at least two pairs of sensor nodes (three nodes) [14]. Advantage of this method is that the impact of errors in time difference measurement on the accuracy of mobile sensor positioning is not so critical. Therefore, less complex hardware is required for the measurements. Disadvantage of the method is that the system of hyperbolic equations has to be solved [4], [5].

The Time of Arrival (ToA) method, also known as the telemetry method, provides one-way measurements of the time difference of signal propagation from the time the signal is sent by the transmitter and the time the signal is received at the receiver [15] – [17]. On the one side, it is easier to linearize the equations, describing the relation between measurements and unknown sensor node coordinates, than in TDoA method. On the other side, this method requires time synchronization between nodes [15], [18]. One possible way is to use a GPS receiver for synchronization. Many applications of WSN, need to know when a given event occurred. In such sensor network, the nodes are accurately synchronized and an algorithm for a sensor node positioning can use this time synchronization [15] – [18].

Communications via Wi-Fi technology is a method widely used for data transfer. In this method, a mobile multifunction device (e.g. smartphone, tablet, laptop; sensor) is connected to a Wi-Fi network over which communications have a limited range and may be affected by interference from other Wi-Fi networks. This method is suitable for mobile devices that operate in a limited range and in areas with a stable Wi-Fi network [1], [19].

The mobile sensor node can be a ground-based unmanned vehicle (rover) whose coordinates can be determined via the WSN. This will allow the WSNs that already exist to be used in different application of rovers [19].

In the present work, an algorithm is proposed for calculating the location of the nodes by the ToA method using a genetic algorithm (GA). An objective function is derived, based on the distances from the reference nodes and the mobile sensor node whose location is sought. This objective function is minimized using a GA, resulting in the desired node coordinates without using any approximation or linearization. Investigations of the accuracy of determining the location of the nodes at

different accuracy of distance measurement have been made.

II. MATERIALS AND METHODS

In this research, the ToA method is utilized to obtain an estimation of a mobile sensor node's coordinates. This method uses the measured distances between the mobile sensor node and some main nodes. The coordinates of main nodes are either exactly known or their estimations are known. In the first stage, the time of arrival of the signal from each main node is measured in the mobile sensor node. Then the time of radio wave propagation between the mobile sensor node and each main node is calculated:

$$\Delta t_i = tr_i - t_i, \quad (1)$$

where: tr_i is the time of receiving of the signal from the i^{th} main node to the mobile sensor node; t_i is the time of signal emitting from the i^{th} main node.

Using (1) the measured distance from the mobile sensor node to the i^{th} main node is obtained by the equation:

$$R_i = c\Delta t_i = D_i + \Delta R_i, \quad (2)$$

where: c is the speed of light; D_i is the true distance; ΔR_i is the measurement error.

The true distance is given by the equation:

$$D_i = \sqrt{(x - x_i)^2 + (y - y_i)^2}, \quad (3)$$

where: x and y are the unknown coordinates of the mobile sensor node; x_i and y_i are the true coordinates of the i^{th} main node.

In the current paper is presented an algorithm which seeks such coordinates x and y that minimize the following objective function:

$$f_{obj} = \sum_{i=1}^N (\sqrt{(x - xm_i)^2 + (y - ym_i)^2} - R_i)^2, \quad (4)$$

where: N is the number of main nodes; i is the main node number; xm_i and ym_i are true or estimated coordinates of main nodes.

The algorithm, proposed in this paper, uses standard GA, included in MATLAB version 2016a, to minimize the formulated objective function (4). The output of the algorithm are the coordinates x and y for which the objective function has minimal value. The proposed algorithm for estimation of the mobile sensor node coordinates is shown in Fig. 1.

First, the surveillance region in which the unknown coordinates will be searched is set. Next, the parameters of GA are set and a random initial population of individuals is created (Generation Zero). The objective function (4) is calculated for each individual. The GA checks if the individual with the minimal objective function value in current generation meets the stopping condition. If it is not fulfilled, the GA creates next generation and the previous two steps are repeated. If the condition is met, then the GA outputs this individual

(coordinates x and y) in current generation for which the objective function value is minimal.

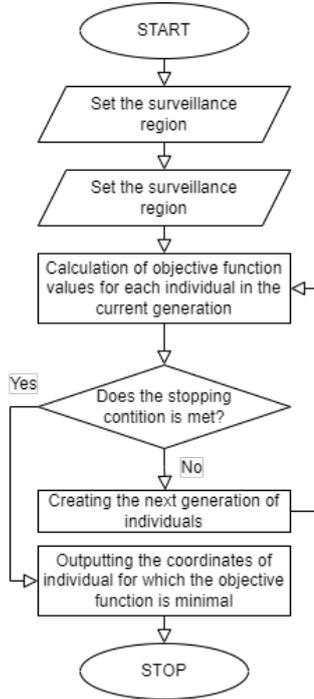


Fig. 1. Algorithm for estimation of mobile sensor node coordinates.

In this article, the rectangular surveillance region is used:

$$\begin{aligned} x_{min} \leq x \leq x_{max} \\ y_{min} \leq y \leq y_{max} \end{aligned} \quad (5)$$

The parameters of GA are as follow:

- population size – 50;
- number of elite individuals – 2;
- number of crossover children – 40;
- number of mutation children – 10;
- stopping condition (6);

$$\frac{1}{50} \sum_{i=n-50}^{n-1} \frac{f_{obj}(i) - f_{obj}(i-1)}{2^{n-i} f_{obj}(i)} < 10^{-6}, \quad (6)$$

where: n is the number of current generation; $f_{obj}(i)$ is the minimal objective function in i^{th} generation.

In fact, the left-hand side of inequality (6) represents the weighted average relative change in the objective function value over the last 50 generations. The population size is chosen after simulations of the algorithm for 30, 50 and 100 individuals in each generation have been done. The rest of the parameters are chosen based on previous studies carried on by the authors using this particular GA. The results obtained in the course of these studies, using the mentioned values of GA parameters, were very good.

The nodes in the WSN are identified by a level, depending on the main nodes, which are used for determination of their coordinates. The first level sensor

nodes determine their coordinates, using only reference nodes as main sensor nodes. The coordinates of reference nodes are exactly known. The second level sensor nodes determine their coordinates, using only first level nodes as main sensor nodes. So, the nodes of given level use only nodes of the previous level to determine their coordinates. For the first level nodes, the true coordinates (x_i, y_i) of reference nodes are used as main nodes coordinates (xm_i, ym_i) in objective function (4). For the higher-level sensor nodes, the estimated coordinates are used in (4). The estimated coordinates of the nodes are obtained during the self-determination of WSN.

Some research results are shown in Section III. It is assumed that the proposed algorithm is used to determine coordinates of main nodes.

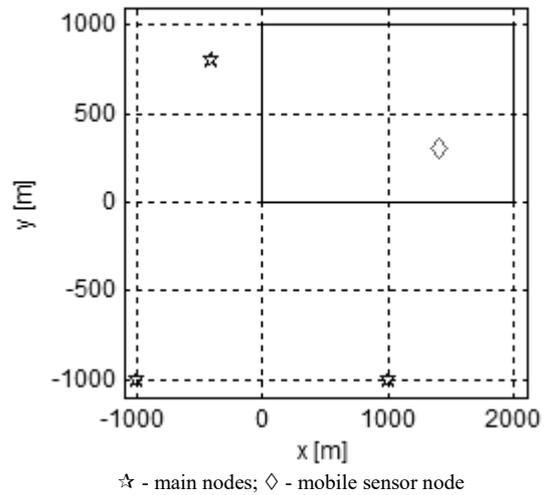
III. RESULTS AND DISCUSSION

The studies are performed at 10 different values of mean squared error (MSE) of the distance measurement. The positioning accuracy of sensor nodes of Level 1 to 5 is evaluated. One thousand simulation of positioning estimation are done for each MSE of the distance measurement and for a given node level.

Fig. 2 shows the true geometric position of the main nodes and the mobile sensor node. The rectangular area, shown in Fig. 2, is the surveillance region where the mobile sensor node is expected to be. The true coordinates (x_i, y_i) of the main nodes are:

- $x_1 = -1000 \text{ m}, y_1 = -1000 \text{ m};$
- $x_2 = -400 \text{ m}, y_2 = 800 \text{ m};$
- $x_3 = 1000 \text{ m}, y_3 = -1000 \text{ m}.$

The coordinates of the mobile sensor node are $x = 1400 \text{ m}$ and $y = 300 \text{ m}$.



☆ - main nodes; ◇ - mobile sensor node

Fig. 2. Location of the sensor nodes.

First, the simulations for mobile sensor node of Level 1 at 1 m MSE of the distance measurement $\sigma_d = 1 \text{ m}$ are done. Since in this case the reference nodes are used, the true coordinates of the main sensor nodes are used in the objective function (4).

The distance measurements are simulated, using the following equation:

$$R_i = \sqrt{(x - x_i)^2 + (y - y_i)^2} + \Delta R_i, \quad (7)$$

where: ΔR_i are normally distributed errors with zero mean and variation σ_d^2 .

The proposed algorithm is used to estimate the mobile sensor node's position in each simulation. The errors between the estimated coordinates and the true coordinates of the node are found:

$$\begin{aligned} \Delta x_n &= x - x e_n \\ \Delta y_n &= y - y e_n \end{aligned} \quad (8)$$

where: $\Delta x_n, \Delta y_n$ are the errors in the n^{th} simulation; $x e_n, y e_n$ are the estimated coordinates of the mobile sensor node in n^{th} simulation.

The mean and MSE (σ_x, σ_y) of all 1000, estimated coordinates are obtained and the MSE of the estimated position is calculated:

$$\sigma_{p1} = \sqrt{\sigma_x^2 + \sigma_y^2}, \quad (9)$$

The new simulations for nine other values of σ_d (from 2 m to 10 m) are done and MSEs of the estimated positions are calculated.

In the higher-level mobile sensor node, simulations deviated coordinates instead of the true coordinates of the main nodes are used in the objective function (4):

$$\begin{aligned} x m_i &= x_i + \Delta x_{ki} \\ y m_i &= y_i + \Delta y_{ki} \end{aligned} \quad (10)$$

where: Δx_{ki} and Δy_{ki} are normally distributed errors with zero mean and variation $0.5\sigma_{p(k-1)}^2$; $k = 2 \div 5$ is the mobile sensor node level.

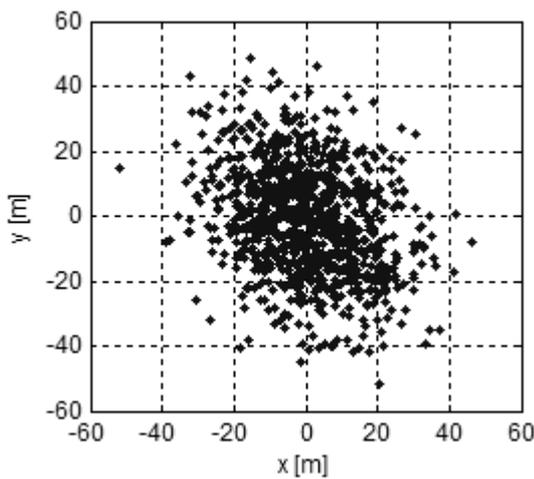


Fig. 3. The errors in estimated position for Level 5 and $\sigma_d = 10$ m.

The errors in estimated mobile sensor node position in the simulations for the node Level 5 and $\sigma_d = 10$ m are shown in Fig. 3. Fig. 3 shows that the errors are grouped around the zero, which points that the estimation of the

mobile sensor node position, using proposed algorithm, is unbiased.

Some comparisons between the proposed algorithm, which uses GA, and one proposed in [1] that uses a least mean square (LMS) algorithm, are made. The obtained MSEs of first level sensor node positioning for the two algorithms are shown in Fig. 4. Fig. 4 shows that the proposed algorithm provides higher accuracy than the LMS algorithm. The improvement in accuracy is observed for all values of MSE of distance measurement.

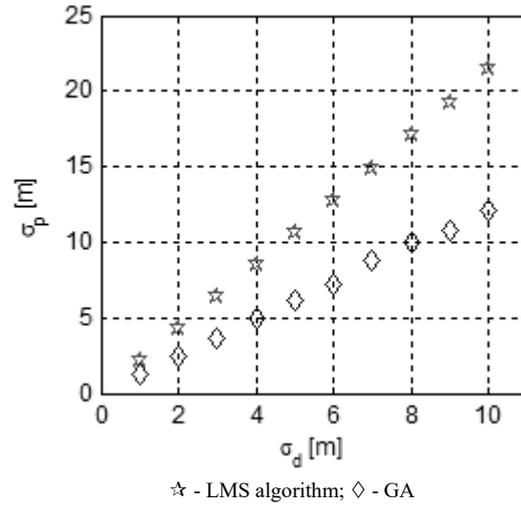


Fig. 4. MSEs of first level sensor node positioning.

The obtained MSEs of third level sensor node positioning for the two algorithms are shown in Fig. 5.

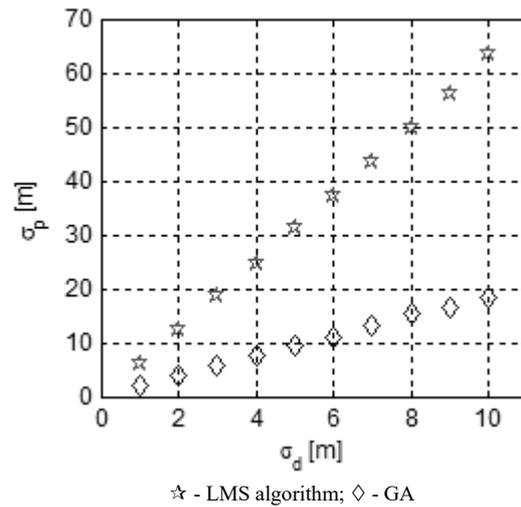


Fig. 5. MSEs of third level sensor node positioning.

Fig. 5 shows that the trends are the same as these in Fig. 4 but the improvement in accuracy of third level node positioning is higher than for first level node positioning.

The obtained MSEs of fifth level sensor node positioning for the two algorithms are shown in Fig. 6. Fig. 6 shows that the improvement in accuracy for fifth level node is significant compared with the first and the third level nodes. The analysis shows that the MSE of node positioning, when the proposed algorithm is used, decreased in comparison with the LSM algorithm 1.70 times for first level node, 2.33 times for second level

node, 3.22 times for third level node, 4.55 times for fourth level node and 6.66 times for fifth level node. It is obvious that the relative improvement of accuracy increases when the level of node is higher.

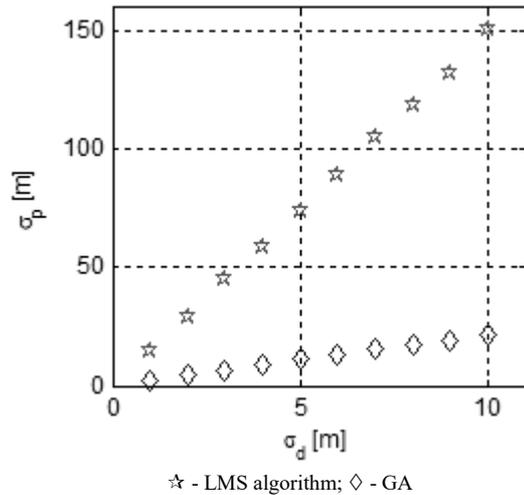


Fig. 6. MSEs of fifth level sensor node positioning.

The graphics of obtained MSEs of node positioning, using proposed algorithm are shown in Fig. 7.

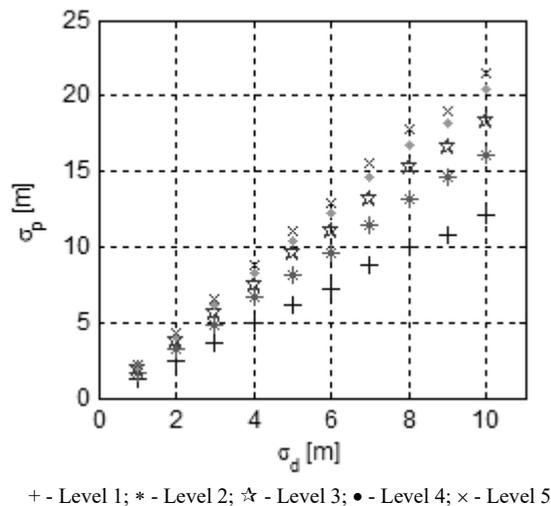


Fig. 7. MSEs of node positioning, using GA.

Fig. 7 shows that the increasing of MSE of positioning is the biggest between Level 1 and Level 2 nodes. The increase in MSE of positioning when moving from a node of a given level to a node of the next level decreases.

The study results for MSE of mobile sensor node positioning are summarized in Table 1 [1]. The analysis of the results in Table 1 shows that the relative sensor node positioning errors σ_{pk}/σ_d can be assumed to be a constant for any given node level. The relative positioning error for first level node is less than 1.25. This points that the accuracy achieved by using the proposed algorithm is high. The MSE of node positioning for Level 5 is less than 1.82 times higher in comparison with Level 1. This proves that the algorithm provides good accuracy even for higher-level sensor nodes.

TABLE 1. MEAN SQUARED ERROR OF SENSOR NODE POSITIONING.

MSE of distance measurement	MSE of mobile sensor node positioning				
	Level 1	Level 2	Level 3	Level 4	Level 5
1 m	1.23	1.65	1.94	2.10	2.20
2 m	2.44	3.26	3.77	4.03	4.30
3 m	3.68	4.89	5.68	6.11	6.55
4 m	4.96	6.66	7.51	8.22	8.78
5 m	6.09	8.17	9.53	10.40	11.04
6 m	7.24	9.53	11.10	11.19	11.91
7 m	8.75	11.50	13.19	14.62	15.60
8 m	10.00	13.21	15.27	16.73	17.74
9 m	10.84	14.58	16.60	18.18	19.00
10 m	11.13	16.03	18.33	20.46	21.43

The results in Table 1 show that there are two ways to ensure that the MSE of positioning is smaller than a predefined value. The first one is to implement better algorithms for distance measurement, but the type of signals, used in WSN, may put limits to their accuracy. The second one is to use the lower-level sensor nodes, which means that more reference nodes have to be placed inside the WSN.

Simulations and studies described in this paper are also done when the population size in GA is 100. The obtained results show that they are not significantly different from the ones discussed in this section. The differences in MSE of the mobile sensor node positioning are less than 5.2%.

IV. CONCLUSIONS

The proposed algorithm uses the ToA method to determine the coordinates of the mobile sensor node. The core of the proposed algorithm is GA, which allows the formulation of an objective function without using approximation and/or linearization. In such way the errors in sensor node positioning are reduced.

The analysis of the research results shows that the proposed algorithm provides much higher accuracy than LMS algorithm. The increase in positioning errors for higher level sensor nodes is relatively small, being less than two times between Level 1 and Level 5 sensor nodes for all values of the MSE in distance measurement. The studies show that it is worth further research to be done for proposed algorithm.

The future studies must include the case when the heights of the nodes in WSNs are not equal, i.e. the coordinate z must be taken into account in the algorithm equations. The impact of the geometry of the main sensor nodes deployment on the positioning accuracy must also be studied. These additional research would give more clarity about conditions and applications in which the proposed algorithm is appropriate for use.

ACKNOWLEDGMENTS

This work was supported by the NSP SD program, which has received funding from the Ministry of Education and Science of the Republic of Bulgaria under the grant agreement no. Д01-74/19.05.2022.

REFERENCES

- [1] M. D. Simeonov, Zh. B. Petrov, "Determining the Location of Mobile Objects in Wireless Sensor Networks", in *Proc. of Annual International Scientific Conference of Bulgarian Air Force Academy*, '10, 2022, pp. 118-122. (in Bulgarian)
- [2] Y. T. Chan, H. Y. C. Hang, and P. C. Ching, "Exact and Approximate Maximum Likelihood Localization Algorithms", *IEEE Transactions on Vehicular Technology*, vol. 55, no. 1, pp. 10-16, Jan. 2006, doi: 10.1109/TVT.2005.861162.
- [3] G. Mao, B. Fidan, and B. D. O. Anderson, "Wireless Sensor Network Localization Techniques", *Computer Networks: The International Journal of Computer and Telecommunications Networking*, vol. 51, no. 10, pp. 2529-2553, July 2007, <https://doi.org/10.1016/j.comnet.2006.11.018>.
- [4] J. Bruck, J. Gao, and A. Jiang, "Localization and Routing in Sensor Networks by Local Angle Information", *ACM Transactions on Sensor Networks*, vol. 5, no. 1, Article No. 7, pp. 1-31, Feb. 2009, <https://doi.org/10.1145/1464420.1464427>.
- [5] M. S. Marinov, V. P. Peneva, "An Algorithm Optimizing the Geometric Distribution of the Stations in Aeronautical Multilateration Systems", *Aeronautical Research And Development*, vol. 1, pp. 43-57, April 2022.
- [6] R. H. Hussain, "Determine The Location Of Nodes In Wireless Sensor Network By Using GA", *Journal of Education for Pure Science*, vol. 7, no. 3, pp. 84-93, Sept. 2017.
- [7] V. Kumar, R. Arablouei, F. de Hoog, R. Jurdak, B. Kusy, and N. W. Bergmann, "Pseudo-linear Localization Using Perturbed RSSI Measurements and Inaccurate Anchor Positions", *Pervasive and Mobile Computing*, vol. 52, '01, 2019, pp. 46-59, <https://doi.org/10.1016/j.pmcj.2018.11.004>.
- [8] J. N. Ash and R. L. Moses, "On the Relative and Absolute Positioning Errors in Self-Localization Systems," *IEEE Transactions on Signal Processing*, vol. 56, no. 11, pp. 5668-5679, Nov. 2008, doi: 10.1109/TSP.2008.927072.
- [9] A. Savvides, W. L. Garber, R. L. Moses, and M. B. Srivastava, "An Analysis of Error Inducing Parameters in Multihop Sensor Node Localization", *IEEE Transactions on Mobile Computing*, vol. 4, no. 6, pp. 567-577, Nov.-Dec. 2005, doi: 10.1109/TMC.2005.78.
- [10] G. Di Stefano, A. Petricola, "A Distributed AOA Based Localization Algorithm for Wireless Sensor Networks", *Journal of computers*, vol. 3, no. 4, pp. 1-8, April 2008.
- [11] N. Patwari and A. O. Hero, "Signal Strength Localization Bounds in Ad Hoc and Sensor Networks when Transmit Powers are Random", in *Proc. of Fourth IEEE Workshop on Sensor Array and Multichannel Processing*, '07, 2006, pp. 299-303, doi: 10.1109/SAM.2006.1706141.
- [12] D. Niculescu and B. Nath, "Ad Hoc Positioning System (APS) Using AOA", in *Proc. of IEEE INFOCOM 2003. Twenty-second Annual Joint Conference of the IEEE Computer and Communications Societies (IEEE Cat. No.03CH37428)*, '04, 2003, vol. 3, pp. 1734-1743, doi: 10.1109/INFCOM.2003.1209196.
- [13] K. Doğançay, H. Hmam, "Optimal Angular Sensor Separation for AOA Localization", *Signal Processing*, vol. 88, no. 5, pp. 1248-1260, April 2008, <https://doi.org/10.1016/j.sigpro.2007.11.013>.
- [14] G. C. Pătru, L. Fluerațu, I. Vasilescu, D. Niculescu, and D. Rosner, "FlexTDOA: Robust and Scalable Time-Difference of Arrival Localization Using Ultra-Wideband Devices", *IEEE Access*, vol. 11, pp. 28610-28627, March 2023, doi: 10.1109/ACCESS.2023.3259320.
- [15] G. Shen, R. Zetik, and R. S. Thoma, "Performance Comparison of TOA and TDOA Based Location Estimation Algorithms in LOS Environment", in *Proc. of 5th Workshop on Positioning, Navigation and Communication*, '05, 2008, pp. 71-78, doi: 10.1109/WPNC.2008.4510359.
- [16] S. Tomic, M. Beko, "Target Localization via Integrated and Segregated Ranging Based on RSS and TOA Measurements", *Sensors*, vol. 19, no. 2:230, '01, 2019, <https://doi.org/10.3390/s19020230>.
- [17] R. Zekavat, R. M. Buehrer, Eds., "Fundamentals of Received Signal Strength - Based Position Location", *Handbook of Position Location: Theory, Practice, and Advances*, IEEE, 2019, pp. 369-404, doi: 10.1002/9781119434610.ch11.
- [18] M. Lin, W. Wang, and C. Liu, "Preventing Hostile TOA/TDOA Localization with AF Relay", *IEEE Communications Letters*, vol. 27, no. 4, pp. 1085-1089, April 2023, doi: 10.1109/LCOMM.2023.3247871.
- [19] G. V. Stanchev, "Analysis of Communications, Control and Data Transfer Methods in Unmanned Aircraft Systems", in *Proc. of Annual International Scientific Conference of Bulgarian Air Force Academy*, '10, 2023, pp. 166-173. (in Bulgarian)

Data Leakage Prevention and Detection in Digital Configurations: A Survey

Svetlana Syarova
CS Department
ULSIT
Sofia, Bulragia
s.syarova@unibit.bg

Stefka Toleva-Stoimenova
CS Department
ULSIT
Sofia, Bulragia
s.toleva@unibit.bg

Aleksandar Kirkov
CS Department
ULSIT
Sofia, Bulragia
a.kirkov@unibit.bg

Samuel Petkov
ULSIT
Sofia, Bulragia
46732r@unibit.bg

Krasimir Traykov
ULSIT
Sofia, Bulragia
k.traykov@unibit.bg

Abstract. As a result of the development of information and communication technologies (ICT) and Internet electronic interaction at all levels in the organizations and the use of various electronic services has become part of our everyday life. The past few decades have been characterized by a tremendous growth in the amount of data generated. At the same time, digital data are subject to malicious and accidental threats, due to the presence of vulnerabilities in the protection of information systems. Unauthorized access, malware, zero-day attack, data leakage, denial of service (DoS), and phishing have increased exponentially in recent years. Data leakage occurs when sensitive data and confidential information is revealed to unauthorized parties. Data leakage is one of the main targets of any insider threat. Over the last few years, the challenge of dealing with insider threats has been recognized and various methods have been proposed to address such problems. Therefore, most proposed internal threat detection methods work towards data leakage prevention (DLP).

This paper addresses the data leakage prevention and detection (DLPD) as some of the most critical cybersecurity issues nowadays. The used DLP techniques and technologies have been explored briefly. As the study aims to reveal the scientific interests in the DLP domain we tried to provide a comprehensive overview of academic publications. Finally, the paper focuses on what drives the DLP domain, the challenges and opportunities the digital configurations are faced in the context of data flow monitoring, prevention and detection.

Keywords: data, leakage, prevention, security.

I. INTRODUCTION

Recent decades are characterized by an increased growth in data generated by humans and machines. It is a result of advances in information and communication technologies (ICT), the digitalization of production processes, the increasing use of electronic devices and networks, including the Internet of Things, cloud computing, etc. Simultaneously, the challenge of dealing with data leakage has been recognized and various methods have been proposed to address related insider threats.

“Insiders” are defined by the Cyber Security and Infrastructure Agency (CISA) [1] as: “any person who has or has had authorized access to or knowledge of an organization's resources, including personnel, facilities, information, equipment, networks and systems.” An “insider threat” is defined by CISA as: “the threat that an insider will use their authorized access, knowingly or unknowingly, to harm the mission, resources, personnel, facilities, information, equipment, networks or systems” Insiders have all the necessary knowledge about internal systems and their topology and have legitimate access to sensitive and valuable information assets [2], [3]. As such, they can inflict much more damage than outsiders [4], [5]. A joint study by the U.S. intelligence community was presented, which included characterizing and analyzing the methods used to counter malicious insider threats [6]. It has proposed a general model of malicious internal behavior, distinguishing motivations, actions, and relevant observables. In [7] authors focused their study on the risks of insider threats in the field of information technologies (IT) through an organization's external partners. This study suggests reducing these risks by using non-deceptive techniques such as

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8045>

© 2024 Svetlana Syarova, Stefka Toleva - Stoimenova, Alexander Kirkov, Samuel Petkov, Krasimir Traykov.

Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

intrusion detection systems, but also fraudulent techniques such as honeypots. In 2023, Rosenthal estimated the average cost of an insider threat incident to be \$11.45 million, up from \$8.76 million in 2018. Organizations are rightly concerned about this threat because insiders can threaten their survival [8].

This paper addresses the DLP domain as one of the most challenging cybersecurity issues today that help identifying, monitoring, protecting and reducing the risks of sensitive-data leakage. A lot of scientific interests have been shown and many related scientific works have been published in academic literature. Various technical approaches have been used in different causes of data leaks. This study is based on a systematic literature review in a way to provide a comprehensive analysis of the current state, challenges and opportunities of data flow monitoring, prevention and detection in the digital configurations. A series of questions arise:

- (1) What techniques and technologies are used?
- (2) What are the most explored research fields?
- (3) What are the challenges and opportunities?

The paper is organized as follows. The second section looks into DLP nature and the techniques and technologies used. The third section explores academic research in the DLP domain and discusses the challenges and opportunities the digital configurations are faced in the context of data flow monitoring, prevention and detection.

II. MATERIALS AND METHODS

According to [9], DLP solution is used to detect and prevent unauthorized attempts to copy or send sensitive data, both intentionally or/and unintentionally, without authorization, by people who are authorized to access the sensitive information. Some of the used DLP's synonyms are: data loss prevention (DLP), information leakage prevention (ILP), information leakage detection and prevention (ILDLP), extrusion prevention (EP), etc. The DLP domain addresses data leaks in the following three states of data throughout their lifecycle by applying specific set of technologies, as shown in Fig. 1 [10], [11]:

- Data-at-Rest (DAR): Data that resides in files system, databases and other storage methods, e.g. a company's financial data stored on the financial application server.
- Data-in-Use (DIU): Data at the endpoints of the network, e.g. USB devices, external drives, MP3 players, laptops, and other highly-mobile devices).
- Data-in-Motion (DIM): Data transmitted on (wire or wireless) network, e.g. customer purchasing details sent over the Internet.

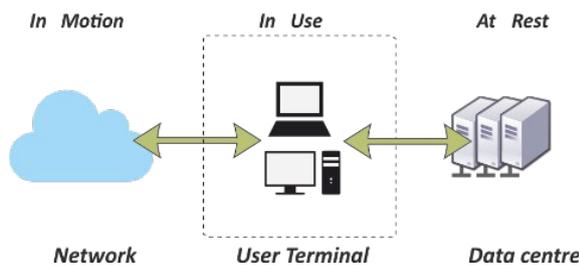


Fig. 1 Data states throughout their lifecycle

DLP solutions can be grouped according to the taxonomy that incorporates the features [12], [13]:

- Data state: DAR, DIU, and DIM.
- Deployment scheme: endpoint and network.
- Leakage handling approach: preventive and detective mechanisms
- Remedial actions: audit, block/remove, notify, encrypt, quarantine.

DLP solutions are used to detect, monitor and protect confidential or sensitive data wherever are stored or used, across endpoint, network, and storage systems. Two main leakage handling approaches - preventive and detective, are shown in Fig. 2:

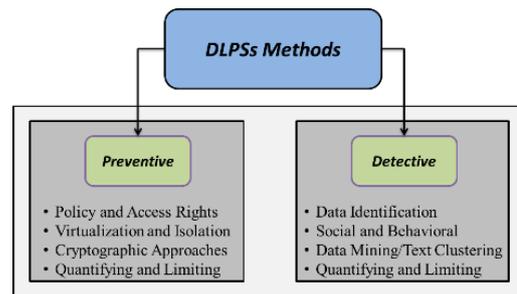


Fig. 2 DLP's methods [13]

Leakage occurrences can be treated by using a detective approach. The system detects any possible leakage incidents and applies the corrective action that is capable of handling the identified leakage incident [12]. Data are categorized as confidential (sensitive) and non-confidential data and subsequently are used for detective purposes. The used techniques are divided into two main groups [13], [14], [15]:

A. Content-based analysis technique

Examines data content to detect sensitive data and protect from accidental exposure and loss in different data states (DAR, DIU, and DIM). In this case, the DLP techniques are mainly based on three content analysis types, which are data fingerprinting, regular expression, and statistical analysis.

B. Context-based analysis technique

Explores only metadata or other properties of the monitored data, for example source, destination, size, recipients, header/metadata information, time stamps, file type, location, format, application, and queries or transactions. Such DLP techniques include social and behavior analysis, data identification, and data mining and text clustering.

The most popular techniques are presented and compared in the following Table 1:

Existing DLP systems, both open source and commercial products, are: Websence DLP, Open DLP, Symantec DLP, Trustwave DLP, MyDLP, RSA DLP, MacAfe DLP, Furtinet DLP, etc. [16].

TABLE 1 SUMMARY OF EXISTING DLP TECHNIQUES

Techniques	Comparison		
	Analysis	Advantage	Disadvantage
Fingerprinting (exact/partial matching)	Content	Simple; Low false positive rate.	Very sensitive to data modification
Regular Expression	Content	Simple; Allow complex pattern matching	High false positive rate
Statistical analysis (N-gram/ Term weighting)	Content	Detect sensitive content in unstructured data	Large amount of data; High false positive rate and high false negative rate
Social and behavior analysis	Context	Proactive prevention technique; Mitigate insider threats	High false positive rate; Administrator involvement
Data mining and text clustering	Context	Perform a complicated task; ML techniques	High false positive rate; Limited scalability; Complicated
Data identification	Context	Very robust to detect unaltered data	Cannot understand data semantics

III. RESULTS AND DISCUSSION

Determining the exact number of academic research papers in the DLP domain is challenging due to several factors:

Volume of Research: The field of cybersecurity, including DLP, is vast, and numerous academic conferences, journals, and research institutions worldwide contribute to the body of knowledge.

Multidisciplinary Nature: DLP research intersects with various disciplines, including computer science, information security, cryptography, data privacy, and behavioral science. As a result, research papers on DLP may appear in a wide range of academic venues covering these areas.

Diverse Topics and Approaches: DLP research encompasses a broad range of topics, including data classification, content inspection, policy enforcement, behavioral analytics, encryption, cloud security, and regulatory compliance. Researchers employ diverse methodologies and approaches to address different aspects of DLP.

Publication Venues: Academic research on DLP may be published in peer-reviewed journals, conference proceedings, workshop papers, technical reports, and dissertations.

As the study aims to reveal the scientific interests related to the DLP techniques and technologies, various data collections organized by publication types such as Conferences, Journals, Magazines, Early Access Articles, and Books have been examined.

For this research, the search was focused on papers in scientific databases such as Google Scholar, Science Direct, IEEE Xplore, Web of Science, Scopus and ACM Digital

Library, as these databases cover relevant scientific information in multiple engineering fields, allowing access to articles published in scientific and academic journals, repositories, archives and other collections. The following keywords were used for the literature search: “Security” AND (“DLP” OR (“Data AND (“Leak” OR “Loss”) AND (“Prevention OR Protection”). These terms are searched in Abstract/Title/Keywords of the papers.

The papers to be analyzed are selected by reading the titles of the results obtained. As selection criteria in the analysis of the abstracts of the papers we used: (1) Studies related to DLP techniques and technologies, (2) Studies related to subdomains of DLP domain, (3) Studies related to challenges and benefits of DLP.

This paper reviews the academic research in the DLP landscape grouped into the following categories:

A. Misuse Detection in Database

Various investigations have been conducted the detection of unusual access to databases. Two approaches are distinguished - syntax-oriented and data-oriented. Both involve mapping between users, searches, and search results. The syntax-oriented approach is based on the syntax of the SQL statements of the query to create a user profile. A data-driven approach focuses on what the user is trying to get, usually by extracting features from the search result set, such as the number of searches as well as the minimum, maximum, and average values of the search attributes.

In [17] authors evaluated a syntax-centric approach to data abuse detection in databases management systems (DBMS) that manage SQL query logs to profile the normal access behavior of users in databases. In [18] proposed a method to create a statistical profile of the normal user's database access pattern to see when the user deviates from his routine. The authors used the data-driven approach and considered its composition an irrelevant search expression to recognize the user's intent, giving importance only to the received data. In [19] also used the data-driven approach to model the knowledge an insider can extract from a given set of records. Given that the insider has legitimate access tables, attributes, and files, he can apply his knowledge to create new knowledge. The method uses dependency graphs based on domain-expert knowledge. Fonseca et al. [20] proposed a Malicious Data Access Detector (MDAD). It aims to protect database applications from data attacks and web applications from SQL injection attacks. This is achieved by representing the profile of valid transactions through a graph that describes different sequences of SQL queries (SELECTs, INSERTs, UPDATEs, and DELETEs), from the beginning of the transaction to the commit or rollback command. The DEMIDS system detects intrusions by building user profiles based on their working scopes which consist of feature/value pairs representing their activities. The system uses audit log data to derive profiles describing typical patterns of accesses by database users [21].

In particular, number of methods and systems have been developed for misuse detection in information

retrieval (IR) systems. In [22] compares user behavior in terms of content rather than in terms of commands issued to a developed user profile, learned through clustering, relevance feedback, and fusion methods. Thus, a new dimension was created to profile-based misuse detection for search systems. In [23] has been proposed a relevance feedback approach based on building a user profile containing both query and feedback terms from prior queries. This method compares user's actions with existing profile.

B. Email Leakage Protection

Many authors concern the aim to study the content and headers of email messages for detecting abuse (e.g., spam) and digital forensic analysis. In [24] the authors propose to use stylometry, the statistical analysis of variations in literary style between users. Using machine learning, they were able to verify the authorship of the emails in a majority of cases. This gives a general idea of the ability to identify and use basic email content to gain insight, and in this case, useful attribution intelligence. Nurse's research [25] investigates the extent to which potentially sensitive information could be leaked, in even blank emails, by considering the metadata that is a natural part of email headers. Through findings from a user-based experiment, we demonstrate that there is a noteworthy level of exposure of organizational and personal identity information, much of which can be further used by an attacker for reconnaissance or develop a more targeted and sophisticated attack. According to [26], an electronic message is identified as a leak based on its content and the likelihood that the recipient of the message will receive it. Messages sent to previous recipients are modeled as message-recipient pairs. Such a pair is considered a potential leak if the message is significantly different from previous messages sent to the recipient. To improve performance, Carvalho and Cohen [27] use various features of social networks. They presented an implementation of their solution in Mozilla Thunderbird. They have also expanded their system to not only detect spam recipients but also suggest recipients that the user may have forgotten to include. In [15] an approach is proposed based on analysis of emails exchange among members of the organization and the identification of groups based on common topics. When a new email is composed and about to be sent, each email recipient is analyzed. A recipient is approved if the email's content belongs to at least one of the topics common to the sender and the recipient.

C. Network / Web-based Protection

In [28] authors introduce a method for computing bandwidth in outbound HTTP traffic that involves discarding expected header fields. However, they use a stateless approach and therefore are unable to discount information that is repeated or constrained from previous HTTP messages. Later researchers present leak measurement algorithms for the Hypertext Transfer Protocol (HTTP), the main protocol for web browsing [29]. Instead of trying to detect the presence of sensitive data, they measure and constrain its maximum volume. They take advantage of the insight that most network traffic is repeated or determined by external information, such as protocol specifications or messages sent by a server. By discounting

this data, true information leakage has been isolated and quantified.

A system called Elicit (Exploit Latent Information to Counter Insider Threats) is presented in [30]. Its aim is to help analysts identify insider threats. This system takes advantage of network traffic and contextual data both. ELICIT uses a naive Bayes detection approach, using 72 features based on the searching, browsing, downloading and printing behavior of users. Examples of features used include the number of remote print jobs, the number of queries made during a suspicious time, and the number of queries that resulted in high document retrievals. They are combined with contextual information and processed by various rule-based and statistical detectors that issue alerts [31].

D. Encryption and Access Control

Cryptography refers to secure information and communication techniques related to the conversion of data from a readable format to an encrypted format. The main purpose is to ensure that content can only be accessed by authorized devices and users. In [32] a framework for protecting sensitive data share between collaborating organizations has been proposed. Their solution is based on trusted computing, which provides a hardware base trust. The trusted computing ensures that the shared data in encrypted form and the encrypted key is accessible only to authorized devices. [33] presented a web-based framework for preventing leakage of confidential information. It is transparent to the user and ensures the safety of confidential data while they are at -rest, in-motion and in-use. Digital Rights Management (DRM) systems refers to a set of policies, techniques and tools that guide the proper use of digital content and ensure vulnerability management in an organization. In [34], [35], [36] the enterprise DRM system is presented, which provides persistent protection for documents using cryptographic methods.

E. Honey Pots for Detecting Malicious Insiders

A honeypot is a unique security resource. It is an information system resource whose value lies in unauthorized or illicit use of that resource [37]. There are two key types of honeypots that play a role in indicating and capturing an advanced insider threat, honeynets and honeytokens. In [38] authors proposed a prototype honeypot to automatically generate signatures for intrusion detections without hard coding any clue in advance to achieve zero-day detections of unknown malware. [37] presented techniques for detecting insider threats using honeypots and honey tokens. Insider threats have challenges different from outsider attacks, as that the malicious insiders are given access to the system and are much more familiar with it. To help catch such malicious insiders, honeypots should be moved into the network and can take up all unused IP addresses. In [39], [40] has been described a procedure of information assurance forensics using honeypots. It consists of network activity analyses, system and file analyses, and evidence gathering. [41] integrated intrusion tolerance into network security forensics using honeypots, called dynamic forensics. The solution makes sure that data gathered for forensic analysis is reliable even if those attacks have tried to modify the data.

In the context of data flow monitoring, prevention, and detection, digital configurations face both challenges and opportunities. Here are some of the key challenges:

Complexity of Digital Environments: Modern digital environments are often complex and dynamic, consisting of diverse systems, applications, and devices interconnected across networks and cloud platforms.

Data Volume and Velocity: Traditional monitoring tools may struggle to keep pace with the continuous flow of data, leading to gaps in coverage and potential security blind spots.

Encryption and Anonymization: Encrypted data traffic obscures the contents of communications, making it difficult to inspect data packets for signs of malicious activity or policy violations. Similarly, anonymized data can obscure the identities of users or devices involved in data transactions, hindering attribution and forensic analysis.

Insider Threats: Employees, contractors, or partners with legitimate access to data may abuse their privileges or inadvertently mishandle sensitive information, leading to data leakage. Detecting and mitigating insider threats requires a combination of technical controls, user monitoring, and behavioral analytics.

Regulatory Compliance Requirements: Organizations must ensure that their monitoring practices comply with relevant regulations such as GDPR, HIPAA, PCI DSS, and others, which often impose strict requirements for data security, privacy, and breach notification.

Some opportunities and trends are:

Advanced Analytics and Machine Learning: Machine learning algorithms can analyze large volumes of data in real-time, identify patterns of normal behavior, and detect anomalies indicative of security threats or policy violations.

Behavioral Analysis: By monitoring and analyzing user behavior patterns, organizations can identify suspicious activities and proactively intervene to prevent data breaches.

Integration with Security Ecosystem: Integration with other security technologies such as SIEM (Security Information and Event Management) systems, endpoint detection and response (EDR) solutions, and threat intelligence platforms, organizations can gain valuable insights into potential security incidents and respond more effectively.

Cloud-Native Solutions: Cloud access security brokers (CASBs), cloud workload protection platforms (CWPPs), and cloud security posture management (CSPM) tools provide centralized monitoring and enforcement of security policies across cloud services and applications.

IV. CONCLUSIONS

This paper summarizes our survey on the recent advances and the current trends in DLP research. We recognized major areas and reviewed the academic research in the DLP domain. Significant progress is seen in DLP techniques and technologies to address related insider threats. Overall, while digital configurations face challenges in data flow monitoring, prevention, and detection, advancements in technology, analytics, and security solutions offer opportunities for organizations to improve their ability to

safeguard sensitive data and protect against emerging threats. By adopting a holistic approach to data security and leveraging innovative solutions, organizations can mitigate risks and ensure compliance with regulatory requirements in an increasingly complex digital landscape.

ACKNOWLEDGMENTS

This work has been supported by the Ministry of Education and Science in implementation of the National Scientific Program "Security and Defense," adopted by RMS No. 731 of 21.10.2021 under Agreement No. D01-74/19.05.2022.

REFERENCES

- [1] Cybersecurity & Infrastructure Security Agency. Defining insider threats, no date. <https://www.cisa.gov/defining-insider-threats> [Accessed 25 February 2024].
- [2] G. Mazzarolo and A.D. Jurcut, "Insider threats in cyber security: The enemy within the gates," *Eur. Cybersecur. Journal*, vol.6, no.1, pp. 57-63, 2019. [10.48550/arXiv.1911.09575](https://arxiv.org/abs/1911.09575) [Accessed 25 February 2024].
- [3] R. Willison and M. Warkentin, "Beyond deterrence: An expanded view of employee computer abuse," *Manage. Inform. Syst. Quart.*, vol. 37, no.1, pp. 1-20, 2013. <https://www.jstor.org/stable/43825935> [Accessed 25 February 2024].
- [4] PWC, "US cybercrime: rising risks, reduced readiness – KEy findings from the 2014 US State of cybercrime survey," <https://www.pwc.com/us/en/increasing-it-effectiveness/publications/assets/2014-us-state-of-cybercrime.pdf> [Accessed 25 February 2024].
- [5] M.R. Randazzo, M. Keeney, E. Kowalski, D. Cappelli, and A. Moore, "Insider threat study: Illicit cyber activity in the banking and finance sector" Technical Report ADA441249, Carnegie-Mellon Univ Pittsburgh Software Engineering Inst, 2005. <https://apps.dtic.mil/sti/citations/ADA441249> [Accessed 25 February 2024].
- [6] M. Maybury, "Analysis and detection of malicious insiders," *Proceedings of International Conference on Intelligence Analysis* 2005.
- [7] P. Gaonjur and C. Bokhoree, "Risk of Insider Threats in Information Technology Outsourcing: Can Deceptive Techniques be Applied?," in *Security and Management*, CSREA Press, p.522, 2006.
- [8] Software Engineering Institute, "Common Sense Guide to Mitigating Insider Threats, Seventh Edition," Carnegie Mellon University, Software Engineering Institute's Digital Library. Software Engineering Institute, 7-Sep-2022 [Online]. Available: <https://insights.sei.cmu.edu/library/common-sense-guide-to-mitigating-insider-threats-seventh-edition/> [Accessed: 25-Feb-2024].
- [9] A.V.Kale, Sh.P. Dubey and V. Bajpayee, "A review on Data Leakage Prevention," *International Journal of Computer Science and Mobile Computing*, vol. 4, no. 4, April 2015, pp. 513-518.
- [10] R. Tahboub and Y. Saleh, "Data Leakage/Loss Prevention Systems (DLP)," 2014 World Congress on Computer Applications and Information Systems (WCCAIS), Hammamet, Tunisia, pp. 1-6, 2014. doi: 10.1109/WCCAIS.2014.6916624.
- [11] S. Peneti and B. P. Rani, "Data Leakage Detection and Prevention Methods: Survey," in *Discovery*, vol. 43, no. 198, pp. 95-100, 2015.
- [12] A. Shabtai, Y. Elovici and L. Rokach, "A survey of data leakage detection and prevention solutions," in *Springer Briefs in Computer Science*, Springer, 2012.
- [13] S. Alneyadi, E. Sithirasenan and V. Muthukumarasamy, "A survey on data leakage prevention systems," *Journal of Network and Computer Applications*, vol. 62, pp. 137-152, 2016. <https://doi.org/10.1016/j.jnca.2016.01.008>. [Accessed 25 February 2024].

- [14] S. Alneyadi, E. Sithirasanen and V. Muthukkumarasamy, "Detecting Data Semantic: A Data Leakage Prevention Approach", pp.910-917, 2015.
- [15] P. Zilberman, S. Dolev, G. Katz, Y. Elovici and A. Shabtai, "Analyzing group communication for preventing data leakage via email", pp.37 - 41, 2011.
- [16] V.O. Waziri, I. Idris, J.K. Alhassan and B.O. Adedayo, "Data Loss Prevention and Challenges Faced in their Deployments", 2017.
- [17] A. Kamra, E. Terzi and E. Bertino, "Detecting anomalous access patterns in relational databases," in *International Journal on Very Large Databases*, vol.17, pp.5, pp.1063–1077, 2008.
- [18] M. Sunu, P. Michalis, N. Hung, and U. Shambhu, "A Data-Centric Approach to Insider Attack Detection in Database Systems", Technical Report, 2009.
- [19] Q. Yaseen and B. Panda, "Knowledge acquisition and insider threat prediction in relational database systems," *Proceedings, 12th International IEEE Conference on Computational Science and Engineering*, pp.450–455, 2009.
- [20] J. Fonseca, M. Vieira and H. Madeira, "Online detection of malicious data access using DBMS auditing," *ACM Symposium on Applied Computing*, pp.1013–1020, 2008.
- [21] C. Y. Chung, M. Gertz and K. Levitt, "Demids: A misuse detection system for database systems," in *Working Conference on Integrity and Internal Control in Information Systems*, pp. 159-178, Boston, MA: Springer US, 1999.
- [22] R. Cathey, L. Ma, N. Goharian and D. Grossman, "Misuse detection for information retrieval systems," in *Proceedings, 12th ACM Conference on Information and Knowledge Management (CIKM)*, 2003.
- [23] L. Ma, N. Goharian, "Using Relevance Feedback to Detect Misuse for Information Retrieval Systems," *ACM CIKM*, 2004.
- [24] O. De Vel, A. Anderson, M. Corney and G. Mohay, "Mining E-mail Content for Author Identification Forensics," *SIGMOD Record*, vol.30, no.4, pp. 55-64, 2001.
- [25] J. Nurse, A. Erola, M. Goldsmith and S. Creese, "Investigating the leakage of sensitive personal and organisational information in email headers," in *Journal of Internet Services and Information Security*, vol.5, 2015.
- [26] V.R. Carvalho, and R. Balasubramanyan, "Information leaks and suggestions: a case study using Mozilla Thunderbird." *Proceedings, 6th Conference on Email and Anti-Spam*, 2009.
- [27] V.R. Carvalho and W. Cohen, "Preventing information leaks in email," in *Proceedings, SIAM International Conference on Data Mining*, 2007.
- [28] K. Borders and A. Prakash, "Web Tap: Detecting Covert Web Traffic," *Proceedings of the 11th ACM Conference on Computer and Communications Security (CCS)*, 2004.
- [29] K. Borders and A. Prakash, "Towards quantification of network-based information leaks via HTTP," *Proceedings of 3rd conference on Hot Topics in Security*, 2008.
- [30] D.D. Caputo., G.D. Stephens and M.A. Maloof, "Detecting insider theft of trade secrets," *IEEE Security and Privacy*, vol.7, no.6, pp.14–21, 2009.
- [31] G. Mazarolo and A. Jurcut, "Insider threats in Cyber Security: The enemy within the gates," *arXiv preprint arXiv:1911.09575*, 2019.
- [32] I.M. Abbadi, and M. Alawneh, "Preventing insider information leakage for enterprises," *International Conference on Emerging Security Information, Systems and Technologies*, pp.99–106, 2008.
- [33] K. Yasuhiro and S. Yoshiki, "A Web-based system for prevention of information leakage," (poster), *Proceedings of 11th International World Wide Web (WWW) Conference*, 2002.
- [34] R.S. Reddy, S.R. Gopu, "Enterprise Digital Rights Management for Document Protection," in *31st International Conference on Advanced Information Networking and Applications Workshops (WAINA)*. pp. 321–326, IEEE, 2017.
- [35] M. Munier, V. Lalanne and M. Ricarde, "Self-protecting documents for cloud storage security," *Proc. of the 11th IEEE Int. Conference on Trust, Security and Privacy in Computing and Communications, TrustCom-2012*, pp. 1231–1238, IEEE, 2012.
- [36] M. Munier, "A Secure Autonomous Document Architecture for Enterprise Digital Right Management," in *7th International Conference on Signal Image Technology & Internet-Based Systems*. pp. 16–23, IEEE, 2011.
- [37] L. Spitzner, "Honeypots: Catching the Insider Threat," *Proceedings of the Computer Security Applications Conference*, pp. 170-179, 2003.
- [38] C. Kreibichi and J. Crowcroft, "Honeycomb – Creating Intrusion Detection Signatures Using Honeypots," *ACM SIGCOMM Computer Communication Review*, vol. 34, no. 1, pp. 51-56, 2004.
- [39] F. Raynal, Y. Berthier, P. Biondi, and D. Kaminsky, "Honeypot Forensics" Part I: Analyzing the Network, *IEEE Security and Privacy*, vol. 2, no. 4, pp. 72-78, 2004.
- [40] F. Raynal, Y. Berthier, P. Biondi, and D. Kaminsky, "Honeypot Forensics" Part II: Analyzing the Compromised Host, *IEEE Security and Privacy*, vol. 2, no. 5, pp. 77-80, 2004.
- [41] T. M. Chen and J. Buford, "Design Considerations for a Honeypot for SQL Injection Attacks," *Proceedings of IEEE Local Computer Networks*, pp. 915-921, 2009.

Application of fuzzy logic in cybersecurity decision making and analysis after a cyber incident detection

Krasimir Slavyanov

Department Computer Systems and Technologies
"Vasil Levski" National Military University
Shumen, Bulgaria
k.o.slavyanov@gmail.com

Radostin Dimov

Department Computer Systems and Technologies
"Vasil Levski" National Military University
Shumen, Bulgaria
rsdimov95@gmail.com

Abstract. This scientific report describes an approach of applying a fuzzy logic decision-making system (Fuzzy Inference System) after detecting a specific cyber incident in a given communication and information infrastructure, supporting the adoption of rapid and adequate measures in the affected systems, both to minimize the consequences for the infrastructure and the functioning of the systems as in general, as well as to support the detailed analysis and prevention of a given cyber incident that has been committed. The cyber security decision-making system was designed in MATLAB's Fuzzy Logic Toolbox, and the input fuzzy variables "Cyber-attack", "Attack Target", "Aim of Attack" were used to select specific action rules. The output fuzzy variables that are designed to produce the result of the operation of the fuzzy rules are: "Hardware actions", "Software actions", "User actions", "Cyber intruder's profile". The purpose of the presented system is to speed up processes after a cyber incident, because delayed and inadequate actions after such an event can lead to an even worse final state of a small or large system, as well as be the cause of great losses for an institution or business. The conducted simulation experiments with different values of the input fuzzy variables prove the approach and the correct decisions that can be made after cyber incidents with different characteristics.

Keywords: *cyber incident, fuzzy inference system, fuzzy logic*

I. INTRODUCTION

Artificial Intelligence systems can successfully work in combination with each other [1] and are increasingly used in modern hybrid warfare. In some contemporary studies, the application of interval type-2 fuzzy logic controller for improving risk assessment model of cyber security is proven [2]. The main perspective approaches in assessing risk from intelligent attack are well studied [3]. After the applications of the linguistic variables and the fuzzy logic complex systems for decision processes, the foundation for

its application in any human area of activity are open [4], [5]. With the experts' experience and deep study of the logical process of the human decision making the steps for synthesis of the fuzzy logic controller can be determined [6]. Implementation of the fuzzy logic rules with weighted attributes from SIEM database for detection of cyber incidents is successfully proven for special information and communication systems [7] and incident management for technological processes and objects [8]. The multi-criteria decision-making process for cyberattacks can be successfully used with artificial intelligence [9] and the experience about it mentioned before with combination with the contemporary programming languages and experimental environments [10]. The computer network vulnerability estimation [11], cybersecurity recommendations [12] and best practices for any digitalization activities [13] can contribute to cyber experts' decision-making process after common cyber incident detection. If the problems with information security in any communication and information devices are thoroughly investigated and well analysed [14] some new solutions, prevention approaches and standard operational procedures can be invented.

Knowledge of the main cyber-attacks, attack targets, and the aims of attack, in this paper is used for tracing the design process of a fuzzy inference system (FIS) to support rapid and adequate decision-making after a cyber incident such as automating the triggering of standard operating procedures.

II. MATERIALS AND METHODS

The proposed fuzzy inference decision-making system aims to support the overall response of the involved persons such as network administrators and cyber security administrators after the recognition of a given cyber incident in the country's business system. The quick and

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8022>

© 2024 Krasimir Slavyanov, Radostin Dimov. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

adequate actions indicated by such a system in this direction can reduce the importance of the subjective factor, panic and stress and mark the main mandatory actions to reduce the consequences of the specific cyber incident and direct prevention and preparation in the right direction. The Fuzzy toolbox of MATLAB was used for the working environment of the simulation studies because it offers a sufficiently, reliable, logical, and visual view of the mathematical operations this kind of a study requires (fig.1).

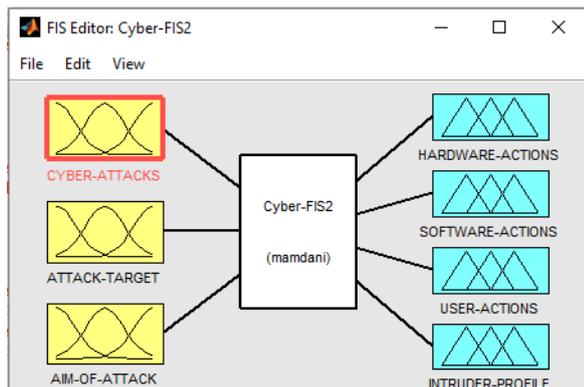


Fig. 1. Fuzzy inference system, designed in MATLAB – Fuzzy Toolbox.

In the selection and summarization of the used input fuzzy variables, the modern state of cyber-attacks, attack targets, aims of attack were described in Table 1.

For the types of cyberattacks, membership functions are selected, named respectively as commonly accepted concepts in cyber security or their generalizations: "Man in the middle", "DoS, DDoS", "Phishing", "Hack device", "Password", "SQL injection", "Cross-site Scripting", "0 Day", "Malware", "Buffer overflow", "Public Service Exploit". Each of these functions is represented by a Gaussian combination membership function [15] (shown on fig. 2) with a shape corresponding to a smooth increase in the membership value in a separate sector for each of the total 11 and at the same time occupying a large space in the region from 0 to 1 along the vertical to obtain a more categorical result (fig. 3).

As described in Table 1, nine membership functions were designed in a similar way for the varieties of attack targets ("Communication Systems", "Energy /Utilities", "Business", "Healthcare/Medical", "Banking /Financial", "Government", "Military /Police", "Education" and "Transport"), as well as 5 membership functions for the fuzzy variable "Aims of attack" ("Data exfiltration", "Recognition", "Ransom", "System Failure" and "Penetration Test").

TABLE 1 INPUT FUZZY VARIABLES

Input Fuzzy Variables					
Cyber attack		Attack Target		Aim of Attack	
1	Man in the middle	1	Comm. Systems	1	Data exfiltration
2	DoS, DDoS	2	Energy /Utilities	2	Recognition
3	Phishing	3	Business	3	Ransom
4	Hack device	4	Healthcare /Medical	4	System Failure
5	Password	5	Banking /Financial	5	Penetration Test
6	SQL injection	6	Government		
7	Cross-site Scripting	7	Military /Police		
8	0 Day	8	Education		
9	Malware	9	Transport		
10	Buffer overflow				
11	Public Service				

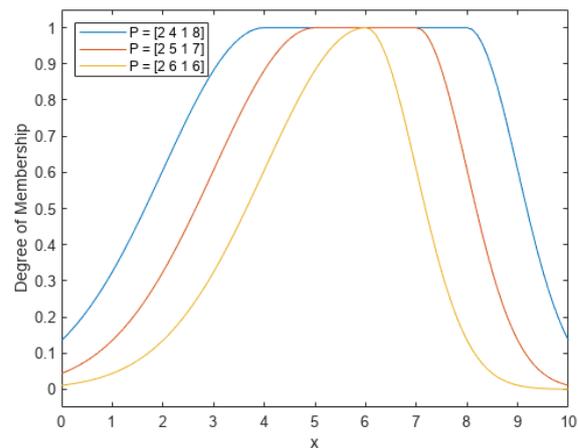


Fig. 2. Gaussian combination membership function [15]

The initial fuzzy variables described in Table 2, may contain several analytical data that can be obtained if the input fuzzy variables discussed are properly analysed. These variables summarize the essential and expertly required actions after the recognition and identification of a cyber incident. The areas of action by the responsible personnel or specialized software are summarized in 3 areas – hardware actions, software actions and user actions.

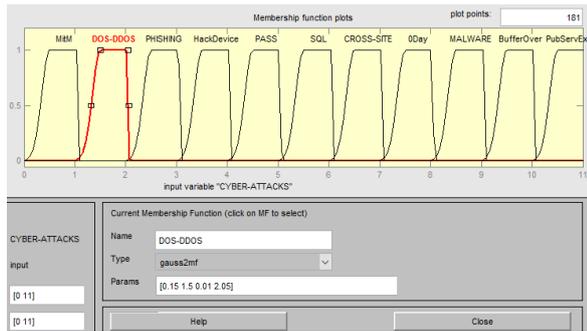


Fig. 3. Membership functions of the fuzzy variable “Cyber attacks”.

TABLE 2 OUTPUT FUZZY VARIABLES

Output fuzzy variables			
Hardware actions	Software actions	User actions	Cyber intruder's profile
1 Physical control	1 Special Software	1 End-User Training	1 Insider
2 Dedicated Systems / DMZ	2 WAF / Network Firewall – reconfiguration	2 Situation Awareness	2 Black hat Hacker
3 Special Technical support	3 SIEM reconfiguration	3 User control update	3 Purple Hat Hacker
4 System Isolation	4 System Update		4 Ethical Hacker
	5 SOP for the attack		5 Cyber Activist
	6 Backup /Restore		

While the first 2 refer to the technical systems, the actions with the users require assistance from the HR structure or the ERP system. In detail, the description of the specific actions is as follows:

A. Hardware actions:

- Physical control – restoration and improvement of physical access control systems to communication and information resources, as well as to specialized equipment.
- Dedicated Systems / DMZ – Designation of Dedicated computer Systems for the specific affected critical systems or construction of a demilitarized zone to restrict access and control.
- Special Technical support – when the intervention of a higher-level specialist is required for the specific system.
- System Isolation – isolation of the affected element from the entire system, if possible, for subsequent thorough analysis of the attack and the affected resources.

B. Software Actions:

- Using specialized software or improving it for its specific activity from the point of view of cyber security.
- WAF / Network Firewall – reconfiguration.
- SIEM reconfiguration.
- System Update - to install the latest security packages.
- SOP for the attack – creation of standard operating procedures (or a software program) to determine the mandatory steps of work in case of repeating an incident of the same type.
- Backup/Restore – Building a reliable system for Backup/Restore, for fast recovery and minimal loss of operational data.

C. Actions with affected user personnel:

- Organization of specialized cyber security training for end users.
- Situation Awareness – correct understanding of the situation and orientation in the new environment.
- User control update – improvement of the employee behaviour control system.

One of the important things that can also be analysed based on the input fuzzy variables described before is the intruder profile - as an output variable of the FIS, which, with certain generalizations can take the following values, designed as membership functions:

- Insider – a person with access to the corporate network and resources and sufficient skills.
- Black hat Hacker – the real criminal.
- Purple hat hacker – people who are only testing and improving their hacking skills.
- Ethical hacker – expert in cybersecurity and cyber defence.
- Cyber activist – someone who uses their skills to hack various systems to practice any type of activism.

For tighter coverage, a membership function of type gbellmf is chosen for all the set possible output values. This function computes fuzzy membership values using a generalized bell-shaped membership function as is shown on fig 4 [16].

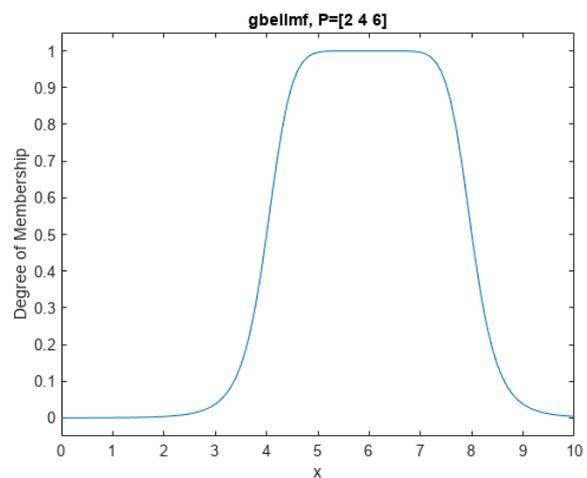


Fig. 4. Gaussian combination membership function [16]

The Membership function of the output fuzzy variable “Hardware actions” is depicted on fig.5.

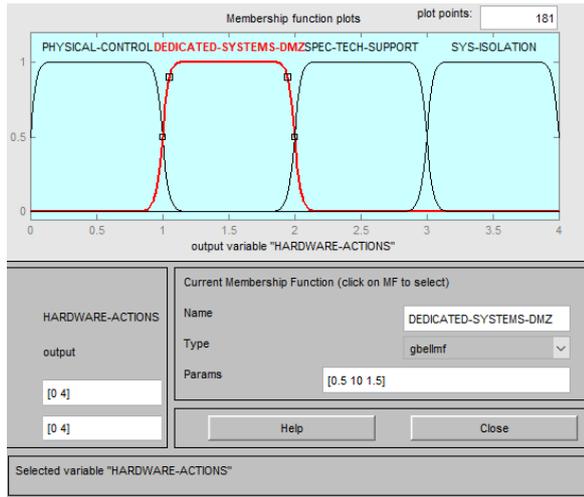


Fig. 5. Membership function of the output fuzzy variable “Hardware actions”.

For this project, the input and output fuzzy variables, a system of 184 example fuzzy rules is created, combining all variables to obtain results for the three categories of FIS output (fig.6 and fig.7). More rules created can lead to computer system limitations being reached.

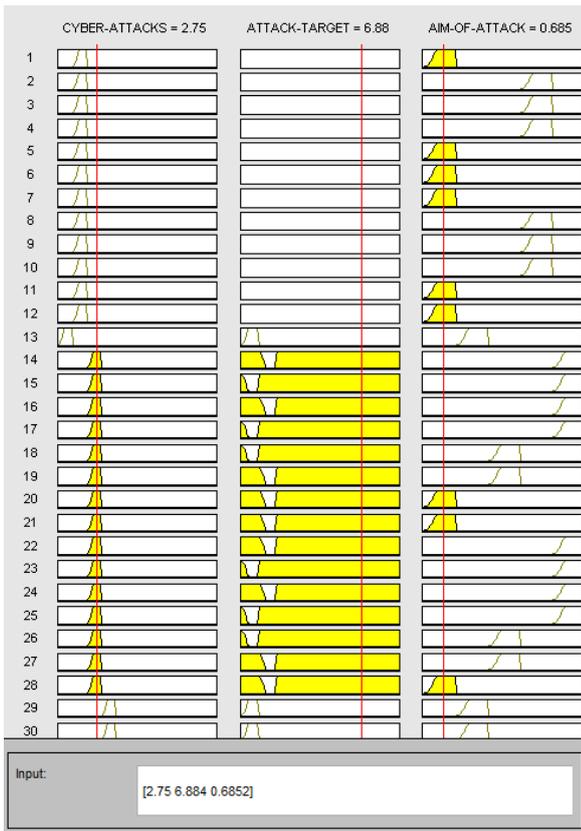


Fig. 6. Input variable values fall in the 184 rules (first 30 are depicted).

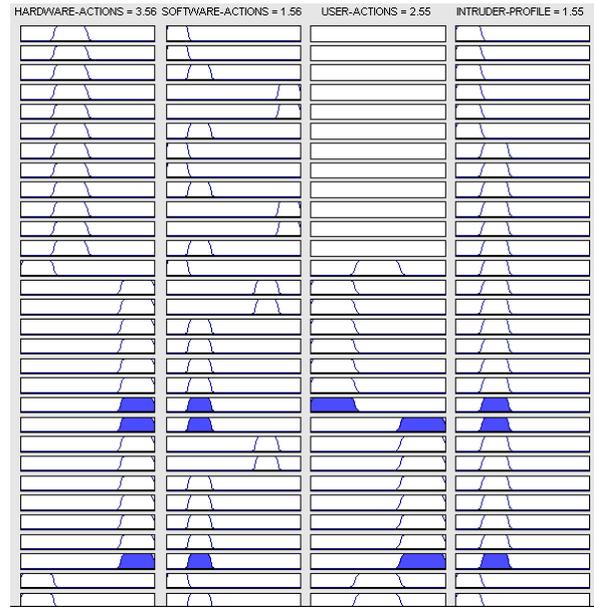


Fig. 7. Output values of variables after running 184 rules (the results of the first 184 rules are shown).

III. RESULTS AND DISCUSSION

The more and more precise fuzzy rules are created, the more precise and definite the results will become. With set implication method = min, aggregation = max type of defuzzification - last of maxima, the obtained results, visible from the surface (Fig. 8), are clearly defined.

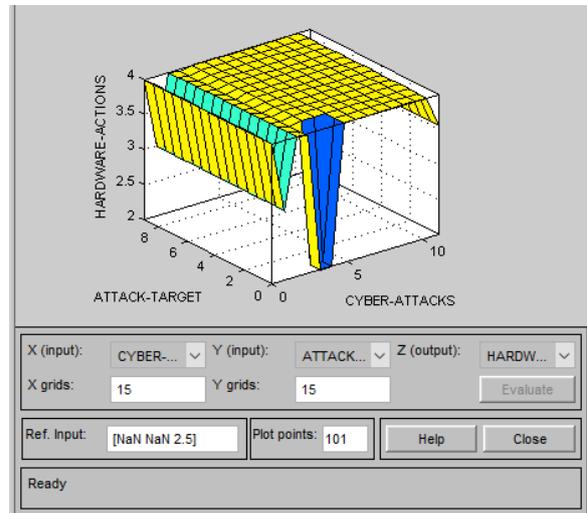


Fig. 8. Output fuzzy variable "Hardware actions".

For the specific example with input fuzzy variables "Cyber-attacks" = 2.75 (Phishing), "Attack targets" = 6.884 (Military Police) and "Aims of attack" = 0.6852 (Data Exfiltration), fuzzy rules form output values of the variables as follows: "Hardware actions" = 3.56 (System isolation), "Software actions" = 1.56 (WAF/Network Firewall – reconfiguration), "User actions" = 2.55 (User control update) and "Cyber intruder's profile" = 1.55 (Black hat Hacker).

IV. CONCLUSIONS

The application of the Fuzzy inference system of the Mamdani type, for the needs of post cyber incident action can be particularly applicable, given the different nature of

the input linguistic variables and the special place that is assigned to systems of this type, namely in solving security crises, as the values of the input variables for a FIS could be fed as outputs from a deep learning system. The structure of a practical approach for a system of standard operating procedures after a cyber incident based on the proposals in this document should be continuously adapted and changed to achieve the set and objectives, given the rapidly changing cyber threats.

ACKNOWLEDGMENTS

This work was supported by the NSP DS program, which has received funding from the Ministry of Education and Science of the Republic of Bulgaria under the grant agreement no. Д01-74/19.05.2022.

REFERENCES

- [1] K. Slavyanov, C. Minchev, „An Algorithm of Fuzzy Inference System for ISAR Image Classification”, *Environment. Technology. Resources, Rezekne, Latvia, Proceedings of the 11th International Scientific and Practical Conference.*, 2017, Volume II, pp 154-158, <https://doi.org/10.17770/etr2017vol2.2599>
- [2] D. K. Jana and R. Ghosh, "Novel interval type-2 fuzzy logic controller for improving risk assessment model of cyber security", *Journal of Information Security and Applications*, 2018, 40, pp. 173–182. <https://doi.org/10.1016/j.jisa.2018.04.002>
- [3] S. D. Guikema and T. Aven, "Assessing risk from intelligent attacks: A perspective on approaches", *Reliability Engineering & System Safety* Volume 95, Issue 5, May 2010, pp. 478-483, <https://doi.org/10.1016/j.ress.2009.12.001>
- [4] L.A. Zadeh, "The concept of a linguistic variable and its application to approximate reasoning—I", *Information Sciences* 8, 1975, pp. 199-249.
- [5] L.A. Zadeh, "Outline of a new approach to the analysis of complex systems and decision processes", *IEEE Transactions on Systems, Man, and Cybernetics*, Vol. 3, No. 1, Jan. 1973, pp. 28-44.
- [6] E.H. Mamdani, S. Assilian, An experiment in linguistic synthesis with a fuzzy logic controller, *International Journal of Man-Machine Studies*, Vol. 7, No. 1, 1975, pp. 1-13. [https://doi.org/10.1016/S0020-7373\(75\)80002-2](https://doi.org/10.1016/S0020-7373(75)80002-2)
- [7] I. Subach and I. Parashchuk, “Methodology of formation of fuzzy associative rules with weighted attributes from SIEM database for detection of cyber incidents in special information and communication systems”, Chapter in book: *Advances in Automation II*, March 2021, <https://doi.org/10.20535/2411-1031.2023.11.1.283575>
- [8] I. Subach and I. Parashchuk, “A Fuzzy Model of the Security Event and Incident Management for Technological Processes and Objects”, book: *Advances in Automation II*, March 2021, pp 550–559, https://doi.org/10.1007/978-3-030-71119-1_54
- [9] A. Bouramdane, Cyberattacks in Smart Grids: Challenges and Solving the Multi-Criteria Decision-Making for Cybersecurity Options, Including Ones That Incorporate Artificial Intelligence, Using an Analytical Hierarchy Process, September 2023, *Journal of Cybersecurity and Privacy* 3(4), <https://doi.org/10.3390/jcp3040031>
- [10] A. Borisova, “Contemporary languages for programming artificial intelligence”, *International Scientific Conference "Defense Technologies"* 2019, pp. 512-517, ISSN 2815-4282, https://www.aadcf.nvu.bg/scientific_events/df2019/AngelaRBorisova.pdf [Accessed Jan 10, 2024]
- [11] L. Nikolov, "Wireless Network Vulnerabilities Estimation", *International Scientific Journal "Security and Future"*, Vol. 2 (2018), Issue 2, pp. 80-82, <https://stumejournals.com/journals/confsec/2018/2/80.full.pdf> [Accessed Jan 18, 2024]
- [12] M. Nedelchev and D. Slavov, “Cybersecurity recommendations and best practices for digital education”, *Scientific research and education in the air force*, 2023, pp. 47-52, <https://doi.org/10.19062/2247-3173.2023.24.6>
- [13] Y. Dechev, “Research on the impact of online learning on individual learning styles”, *Mathematics and informatics*, April 2023, Volume 66, issue 2, pp 155-169. <https://doi.org/10.53656/math2023-2-5-res>
- [14] V. Stoyanova, “Problems with information security on mobile devices”, *International Scientific Journal "Industry 4.0"*, WEB ISSN 2534-997X; print ISSN 2534-8582, Year IV, Issue 4, 2019, pp. 200-202, <https://stumejournals.com/journals/i4/2019/4/200>
- [15] Mathworks support documentation, Fuzzy Toolbox, gauss2mf <https://www.mathworks.com/help/fuzzy/gauss2mf.html> [Accessed Jan 18, 2024]
- [16] Mathworks support documentation, Fuzzy Toolbox, gbellmf, <https://www.mathworks.com/help/fuzzy/gbellmf.html> [Accessed Jan 18, 2024]

Fuzzy inference system for investment value assessment based on historical data

Krasimir Slavyanov

Department Computer Systems and Technologies
"Vasil Levski" National Military University

Shumen, Bulgaria

k.o.slavyanov@gmail.com

Abstract. The analysis of financial parameters is of fundamental importance when planning one or another investment in shares of a given company. It is important for such an analysis to consider some basic numerical parameters such as: annual revenue growth for the last few years, gross, operating, and net profit margins, price/earnings ratio, current price, average annual price, and other historical data for analysis. In this research, an investment decision-making approach based on fuzzy logic is proposed, which evaluates various aspects of a given company's activity. Mamdani method and the fuzzy logic toolset in MATLAB were used. A set of fuzzy rules forms the basis of the investment evaluation system and determines the investment type recommendation, depending on the financial data provided. Simulation experiments with different inputs prove the correct approach and the adequate solutions that can be obtained. The precise set of input variables and well-thought-out logical rules can achieve a reduction in risks for specific investment intentions.

Keywords: fuzzy inference system, investment value, membership function.

I. INTRODUCTION

Fuzzy Inference Systems (FIS) are successfully applied in areas such as IT project management [1] and cyber security [2], as well as for total risk calculation for new projects of any type [3]. In this scientific report, a simulation fuzzy inference system (FIS) based on the principles of fuzzy logic ([4][5]) is proposed for investment value estimation. It uses Mamdani's method described in [6] for odd controlled systems to analyse financial parameters. The system aims to help in making investment decisions, evaluating the main or different areas of a given company's activity. The use of artificial intelligence and in particular fuzzy logic systems to support investment decisions [7] [8] and stock market behavior in general have been well studied and researched, such as in [9] [10] [11] [12] [13] [14] because even the smallest changes in the values of given indicators

should be included in the in-depth analysis that every financial operation requires. The expectations are that, after the application of such decision support systems, the risks will be maximally reduced and the profits - increased, which is desired by every single company.

II. MATERIALS AND METHODS

To achieve the set goals, Fuzzy Logic Toolbox in Matlab was chosen, as it offers, in addition to multifunctional programming options, wide-ranging adaptability of the synthesized models, both to input values and when exporting to other programming and implementation environments. Linguistic variables at the input of the FIS in this case are of different dimensions and not all of them have numerical units, therefore Mamdani's method of operation [6] was chosen.

The fuzzy input variables are 6, and the goal of their selection is to achieve maximum informational activity, given the multifactorial influence of statistical data on the formation of economic trends and potential. The only output variable expressing the purpose of the study is "Type of Investment". Input Linguistic Variables:

- Revenue-Gr-4Y (annual revenue growth for the last 4 years).
- Gross-Profit-Margin.
- Operating-Income-Margin.
- Net-Profit-Margin.
- P/E Ratio (Price-to-Earnings Ratio).
- Current Price, compared to 5Y (current price compared to the annual average of the last 5 years).

The structure of the Mamdani type FIS is depicted in Fig. 1.

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8025>

© 2024 Krasimir Slavyanov. Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

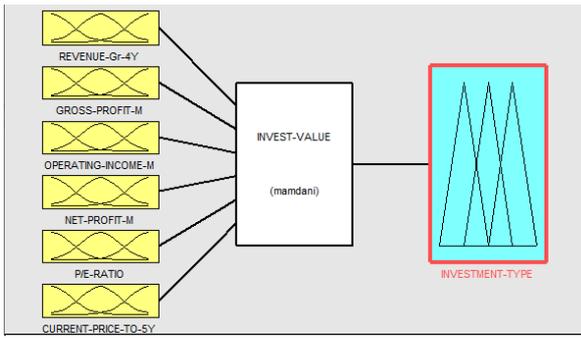


Fig. 1. Fuzzy Inference System "Invest value"

For the membership functions for all the input fuzzy variables, the shape of trapezium is selected, because with its use one of the higher levels of density is achieved during each of the input values determination. The membership functions for simulation purposes are named and positioned as followed for each of the six input variables:

1. Annual Revenue Growth for the last 4 years range (-100;100)

- mf 1.1 "Negative" < 0
- mf 1.2 "Slow" 0 - 15
- mf 1.3 "Fast" 15 - 25
- mf 1.4 "Rapid" > 25

2. Gross Profit Margin range (-100;100)

- mf 2.1 "Negative" < 0
- mf 2.1 "Average" 0 - 20
- mf 2.1 "High" 20 - 40
- mf 2.1 "Exceptional" > 40

3. Operating Income Margin range (-100;100)

- mf 3.1 "Negative" < 0
- mf 3.2 "Low" 0 - 10
- mf 3.3 "Good" 10 - 15
- mf 3.4 "High" > 15

4. Net Profit Margin range (-100;100)

- mf 4.1 "Negative" < 0
- mf 4.2 "Low" 0 - 10
- mf 4.3 "Healthy" 10 - 20
- mf 4.4 "High" > 20

5. P/E Ratio (Price-to-Earnings Ratio) range (-100;100)

- mf 5.1 "Negative" < 0
- mf 5.2 "Undervalued" 0 - 15
- mf 5.3 "Average" 15 - 25
- mf 5.4 "High" 25 - 40
- mf 5.5 "Very high" > 40

6. Current Price, compared to 5-year average range (-100;100)

- mf 6.1 "Cheap" < -30
- mf 6.2 "Bargain" -30 - -15
- mf 6.3 "Low margin of safety" -15 - 0
- mf 6.4 "Expensive" > 0

Membership functions of the input fuzzy variable "Revenue Growth for the last 4 years" is depicted in figure 2. Another input variable "Price-to-Earnings Ratio" is depicted in Fig.3.

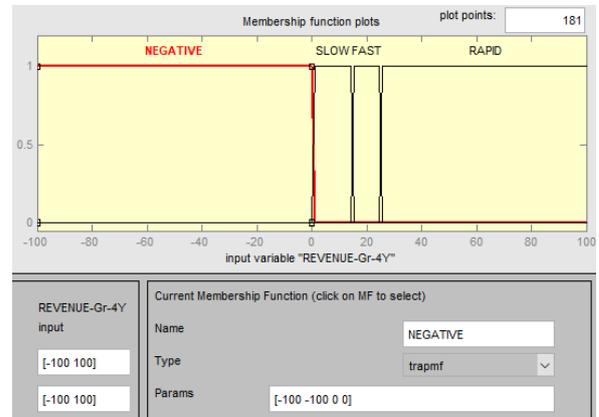


Fig. 2. Membership functions of the input fuzzy variable "Revenue Growth for the last 4 years"

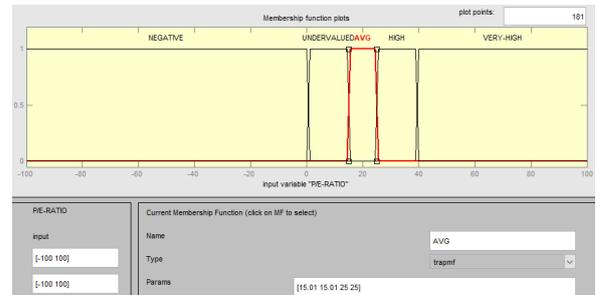


Fig. 3. Membership functions of the input fuzzy variable "Price-to-Earnings Ratio"

The output fuzzy variable Type of Investment with range (0; 4) is designed with the following membership functions (fig. 4): Avoid (0 - 1), Risky (1 - 2), Worthy (2 - 3), Very profitable (3 - 4). These membership functions are depicted in fig. 4.

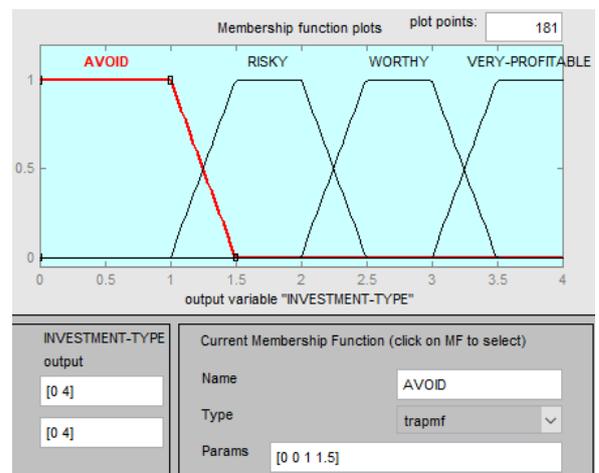


Fig. 4. Membership functions of the input fuzzy variable "Price-to-Earnings Ratio"

The designed structure of input and output linguistic variables is connected to a system of 30 fuzzy rules, where an investment logic is followed at different combinations of values of the input fuzzy variables. Each

rule is designed to represent a combination of values for the input variables and determine the classification of the investment. These rules are formed based on an exemplary investment evaluation system and determine the recommendation for the type of investment, depending on the financial statistics provided. This kind of data can be obtained from specialized databases or web sites such as [15]. The system of rules is depicted in fig. 5.

1. (REVENUE-Gr-4Y==NEGATIVE) => (INVESTMENT-TYPE=AVOID) (1)
2. (REVENUE-Gr-4Y==SLOW) => (INVESTMENT-TYPE=RISKY) (1)
3. (REVENUE-Gr-4Y==FAST) => (INVESTMENT-TYPE=WORTHY) (1)
4. (REVENUE-Gr-4Y==RAPID) => (INVESTMENT-TYPE=VERY-PROFITABLE) (1)
5. (GROSS-PROFIT-M==NEGATIVE) => (INVESTMENT-TYPE=AVOID) (1)
6. (GROSS-PROFIT-M==AVERAGE) => (INVESTMENT-TYPE=RISKY) (1)
7. (GROSS-PROFIT-M==HIGH) => (INVESTMENT-TYPE=WORTHY) (1)
8. (GROSS-PROFIT-M==EXCEPTIONAL) => (INVESTMENT-TYPE=VERY-PROFITABLE) (1)
9. (OPERATING-INCOME-M==NEGATIVE) => (INVESTMENT-TYPE=AVOID) (1)
10. (OPERATING-INCOME-M==LOW) => (INVESTMENT-TYPE=RISKY) (1)
11. (OPERATING-INCOME-M==GOOD) => (INVESTMENT-TYPE=WORTHY) (1)
12. (OPERATING-INCOME-M==HIGH) => (INVESTMENT-TYPE=VERY-PROFITABLE) (1)
13. (NET-PROFIT-M==NEGATIVE) => (INVESTMENT-TYPE=AVOID) (1)
14. (NET-PROFIT-M==LOW) => (INVESTMENT-TYPE=RISKY) (1)
15. (NET-PROFIT-M==HEALTHY) => (INVESTMENT-TYPE=WORTHY) (1)
16. (NET-PROFIT-M==HIGH) => (INVESTMENT-TYPE=VERY-PROFITABLE) (1)
17. (PIE-RATIO==NEGATIVE) => (INVESTMENT-TYPE=AVOID) (1)
18. (PIE-RATIO==VERY-HIGH) => (INVESTMENT-TYPE=AVOID) (1)
19. (PIE-RATIO==HIGH) => (INVESTMENT-TYPE=RISKY) (1)
20. (PIE-RATIO==AVG) => (INVESTMENT-TYPE=WORTHY) (1)
21. (PIE-RATIO==UNDERVALUED) => (INVESTMENT-TYPE=VERY-PROFITABLE) (1)
22. (CURRENT-PRICE-TO-5Y==EXPENSIVE) => (INVESTMENT-TYPE=AVOID) (1)
23. (CURRENT-PRICE-TO-5Y==LOW-M-SAFETY) => (INVESTMENT-TYPE=RISKY) (1)
24. (CURRENT-PRICE-TO-5Y==BARGAIN) => (INVESTMENT-TYPE=WORTHY) (1)
25. (CURRENT-PRICE-TO-5Y==CHEAP) => (INVESTMENT-TYPE=VERY-PROFITABLE) (1)
26. (REVENUE-Gr-4Y==RAPID) & (GROSS-PROFIT-M==EXCEPTIONAL) & (OPERATING-INCOME-M==HIGH) & (NET-PROFIT-M==HIGH) & (PIE-RATIO==UNDERVALUED) & (CURRENT-PRICE-TO-5Y==EXPENSIVE) => (INVESTMENT-TYPE=RISKY) (1)
27. (REVENUE-Gr-4Y==FAST) & (GROSS-PROFIT-M==HIGH) & (OPERATING-INCOME-M==GOOD) & (NET-PROFIT-M==HEALTHY) & (PIE-RATIO==AVG) & (CURRENT-PRICE-TO-5Y==EXPENSIVE) => (INVESTMENT-TYPE=AVOID) (1)
28. (REVENUE-Gr-4Y==SLOW) & (GROSS-PROFIT-M==AVERAGE) & (OPERATING-INCOME-M==LOW) & (NET-PROFIT-M==LOW) & (PIE-RATIO==HIGH) & (CURRENT-PRICE-TO-5Y==EXPENSIVE) => (INVESTMENT-TYPE=AVOID) (1)
29. (REVENUE-Gr-4Y==SLOW) & (GROSS-PROFIT-M==AVERAGE) & (OPERATING-INCOME-M==LOW) & (NET-PROFIT-M==LOW) & (PIE-RATIO==AVG) & (CURRENT-PRICE-TO-5Y==CHEAP) => (INVESTMENT-TYPE=WORTHY) (1)
30. (REVENUE-Gr-4Y==RAPID) & (GROSS-PROFIT-M==EXCEPTIONAL) & (OPERATING-INCOME-M==HIGH) & (NET-PROFIT-M==HIGH) & (PIE-RATIO==HIGH) => (INVESTMENT-TYPE=WORTHY) (1)

Fig. 5. Fuzzy rules of the FIS "Invest Value"

Aggregation Method 'sum' is used to combine the different rules and their input values into a common expression. Summing up the values provides a clear view of the cumulative impact of the different rules in the system.

Defuzzification Method 'centroid' is used to centre the values in the decision around the centre of the result area. In this way an easier interpretation and understanding of the results is provided, which can be used to make specific investment decisions.

III. RESULTS AND DISCUSSION

The correct functioning of the Fuzzy Inference System has been confirmed with numerous simulation experiments, where logically justified results are obtained for determining the type of investment under different input parameters. In table 1, the results obtained for the respective values of the fuzzy input variables in 10 different experiments which were conducted in MATLAB are recorded.

An example of such a simulation experiment is row 9 in Table 1, where the values of the fuzzy variables have determined membership as follows:

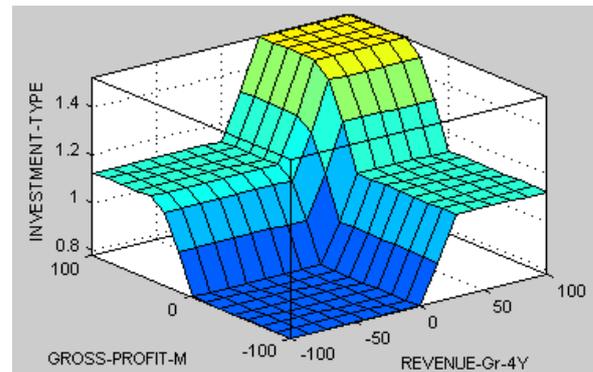
- "Revenue Growth 4 Years AVG" = 33.09 ("Rapid")
- "Gross Profit Margin" = 30.15 ("High")
- "Operating Income Margin" = 12.5 ("Good")
- "Net Profit Margin" = 13.97 ("Healthy")
- "Price-to-Earnings Ratio" = 21.32 ("Average")
- "Current Price, compared to 5-year AVG" = -19.85 ("Bargain")

At these values, FIS obtained "Investment Type" = 2.86 and the investment is classified as "Worthy".

TABLE 1 FIS - SIMULATION EXPERIMENTAL RESULTS

Fuzzy input values						FIS output value
Revenue Growth 4 Years AVG	Gross Profit Margin	Operating Income Margin	Net Profit Margin	Profit / Earnings Ratio	Current-Price, compared to 5 Y AVG	Investment-Type
-15.67	-14.18	4.444	-9.701	-14.18	28.15	0.777
19.85	13.97	19.85	5.147	-6.618	13.97	1.68
21.64	29.1	25.19	14.18	33.58	-7.407	2.52
31.62	46.32	22.79	26.12	47.01	16.3	2.27
34.56	31.62	22.79	25.74	11.03	-36.03	3.44
31.62	13.97	25.74	15.44	-5.147	-36.03	2.45
18.38	16.91	12.5	25.74	19.85	-34.56	2.81
-40.44	-8.088	-6.618	-8.088	-19.85	8.088	0.623
33.09	30.15	12.5	13.97	21.32	-19.85	2.86
19.85	47.79	19.85	5.147	-6.618	13.97	1.92

The shape of the surface in that case is shown on fig. 6. The result is clearly defined.



By introducing more granularity to the input by creating and adding more linguistic variables, the result could be better justified. This can also occur when more fuzzy FIS rules are created.

IV. CONCLUSIONS

The use of this approach to create a FIS for the evaluation of an investment could be continued by generating program code and putting this or a similar system into operation when seeking a reasoned opinion on specific investment intentions when the resource time for making the decision is limited.

A similar system can be created to evaluate the impact of a given training [16], weather conditions on flight [17], in predictions and evaluation with artificial intelligence [18] or means to achieve goals related to risk assessment. The application of FIS in a similar approach can summarize various input parameters such as special features of the probing signal [19], cybersecurity assessment methodology [20] or vulnerability analysis in server systems [21].

A comprehensive platform for investment risk analysis could be created by combining this approach with the output of a deep learning system that would serve to derive values for FIS input parameters.

ACKNOWLEDGMENTS

This work was supported by the NSP DS program, which has received funding from the Ministry of Education and Science of the Republic of Bulgaria under the grant agreement no. Д01-74/19.05.2022

REFERENCES

- [1] N. Vasylykiv, L. Dubchak, A. Sachenko, T. Lendyuk and O. Sachenko, "Fuzzy Logic System for IT Project Management" ICT&ES-2020: Information-Communication Technologies & Embedded Systems, November 12, 2020, Mykolaiv, Ukraine, <https://ceur-ws.org/Vol-2762/paper9.pdf> [Accessed Jan 11, 2024]
- [2] D. K. Jana and Ghosh, R., "Novel interval type-2 fuzzy logic controller for improving risk assessment model of cyber security", Journal of Information Security and Applications, 2018, 40, pp. 173–182. <https://doi.org/10.1016/j.jisa.2018.04.002>
- [3] R. Doskočil "An evaluation of total project risk based on fuzzy logic", Verslas: Teorija ir praktika, 2015, ISSN 1648-0627, 15(2), pp. 23-31, https://www.researchgate.net/publication/290471213_An_Evaluation_of_Total_Project_Risk_Based_on_Fuzzy_Logic [Accessed Jan 12, 2024]
- [4] L.A. Zadeh, "The concept of a linguistic variable and its application to approximate reasoning—I", Information Sciences 8, 1975, pp. 199-249.
- [5] L.A. Zadeh, "Outline of a new approach to the analysis of complex systems and decision processes", IEEE Transactions on Systems, Man, and Cybernetics, Vol. 3, No. 1, Jan. 1973, pp. 28-44.
- [6] E.H. Mamdani, S. Assilian, An experiment in linguistic synthesis with a fuzzy logic controller, International Journal of Man-Machine Studies, Vol. 7, No. 1, 1975, pp. 1-13. [https://doi.org/10.1016/S0020-7373\(75\)80002-2](https://doi.org/10.1016/S0020-7373(75)80002-2)
- [7] Z. Janková, D. K. Jana, P. Dostal, "Investment Decision Support Based on Interval Type-2 Fuzzy Expert System", April 2021, Engineering Economics 32(2), pp. 118-129, <https://doi.org/10.5755/j01.ee.32.2.24884>
- [8] H. Dourra and S. Pepe, "Investment using technical analysis and fuzzy logic", Fuzzy Sets and Systems, Volume 127, Issue 2, 16 April 2002, pp. 221-240, [https://doi.org/10.1016/S0165-0114\(01\)00169-5](https://doi.org/10.1016/S0165-0114(01)00169-5)
R. C. Camara, A. Cuzzocrea, G. M. Grasso, C. K. Leung, S. B. Powell, J. Souza, and B. Tang, "Fuzzy Logic-Based Data Analytics on Predicting the Effect of Hurricanes on the Stock Market", IEEE International Conference on Fuzzy Systems (FUZZ-IEEE), 2018. pp. 1–8. <https://doi.org/10.1109/FUZZ-IEEE.2018.8491523>
- [9] P. C. Chang, C. Y. Fan and J. L. Lin, (2011). "Trend discovery in financial time series data using a case based fuzzy decision tree." Expert Systems with Applications, 38, pp. 6070–6080, <https://doi.org/10.1016/j.eswa.2010.11.020>
- [10] A. Esfahanipour and W. Aghamiri, "Adapted Neuro-Fuzzy Inference System on indirect approach TSK fuzzy rulebase for stock market analysis.", Expert Systems with Applications, 37(7), 2010, pp. 4742–4748. <https://doi.org/10.1016/j.eswa.2009.11.020>
- [11] S. Othman and E. Schneider, "Decision making using fuzzy logic for stock trading", International Symposium on Information Technology. IEEE, 2010, pp. 880–884, <https://doi.org/10.1109/ITSIM.2010.5561564>
T. A. Jilani and S. M. A. Burney, "A refined fuzzy time series model for stock market forecasting". Physica A, 387, 2008, pp. 2857–2862. <https://doi.org/10.1016/j.physa.2008.01.099>
- [12] T. T. Khuat and M. H. Le, "An Application of Artificial Neural Networks and Fuzzy Logic on the Stock Price Prediction Problem". International Journal on Informatics Visualization, 2017, 1, (2), pp. 40-49, <http://hdl.handle.net/10453/161164> [Accessed Jan 12, 2024]
- [13] <https://www.investing.com/equities>, [Accessed Jan 12, 2024]
- [14] Y. Dechev "Research on the impact of online learning on individual learning styles", Mathematics and Informatics, Volume 66, Number 2, 2023, pp. 155-169, <https://doi.org/10.53656/math2023-2-5-res>
- [15] D. Slavov and M. Nedelchev, „Impact of weather conditions on flights and aircraft“, Proceedings of the conference “Scientific research and education in the air force – AFASES 2023”, pp. 152-159, ISSN, ISSN-L: 2247-3173, <https://doi.org/10.19062/2247-3173.2023.24>
- [16] A. Borisova, „Predictions and evaluation with AI in cybersecurity“ Proceedings of International Scientific Conference — Defense Technologies I DefTech 2022, Shumen, Bulgaria, pp. 394-400, ISSN 2367-7902, https://dtf.aadcf.nvu.bg/wp-content/uploads/2022/11/Proceeding_DTF_2022.pdf [Accessed Jan 10, 2024]
- [17] D. I. Dimitrov and V. M. Vasilev, „Special features of the probing signal parameters in nonlinear radar“, International scientific conference "Research and technologies for the needs of the defense and armed forces - Hemus 2008", Military Publishing House", Sofia, 2008, ISSN1312-2916, pp. 36 – 50.
- [18] R. S. Dimov, L. G. Nikolov and D.S. Dimov, „Cybersecurity Assessment Methodology for E-Learning Platforms“, Proceeding of International Scientific Conference “Defense Technologies” 2022, https://dtf.aadcf.nvu.bg/wp-content/uploads/2022/11/Proceeding_DTF_2022.pdf [Accessed Jan 18, 2024]
- [19] R. Dimov, L. Nikolov and D. Dimov, „Vulnerability Analysis in Server Systems“, International Scientific Journal "Security & Future", web ISSN 2535-082X; print ISSN 2535-0668, Year V, Issue 4, 2021, pp. 141-146 <https://stumejournals.com/journals/confsec/2021/4/141>, [Accessed Jan 28, 2024]

One approach for application of geographic information systems and fuzzy logic in business decision-making

Krasimir Slavyanov

Department Computer Systems and Technologies
"Vasil Levski" National Military University
Shumen, Bulgaria
k.o.slavyanov@gmail.com

Abstract. Computer information systems are applied in all areas of human activity and their main purpose is information analysis and forecasting to make effective and optimal management decisions. Geographic Information Systems (GIS) are modern computer information systems for processing, mapping, and analyzing geospatial information. The creation of new projects in a GIS environment to support management decisions could be combined with artificial intelligence technologies such as fuzzy logic, so that different dimensional input geographic and business parameters can automate to some extent some logically based management decisions. This report explores the possibilities of fuzzy logic technologies to process geographic and statistical economic data for making adequate business decisions. Data on localities, distances to a specific site, demographic profile of the population and historical sales reference for a given region were used to generate output variable values for frequency of advertising campaigns, selection of product range and logistics parameters. The environment for developing the Fuzzy inference system is Matlab, and the software for the geographic information system is ArcView.

Keywords: *fuzzy inference system, geographic information system, membership function.*

I. INTRODUCTION

Modern geographic information systems have a toolkit designed to support various spheres of human activity. The relationships between different statistical data and objects on different types of maps can contribute to the analysis and making of important management decisions, then supported by artificial intelligence [1], [2]. Any company that operates with service and resource providers or uses its branch offices and facilities in a system of locations in different places organizes a complex structure for planning and building its logistics. The application of artificial intelligence to minimize errors and comply with various rules and norms is increasingly necessary in our time,

because the final financial indicators of companies are largely determined from the correct planning of the consumption of resources. The application of fuzzy logic to various tasks related to planning in the economy [3] has various fields of application and in this report both the capabilities of GIS to obtain analytical data and their subsequent use as input data for a Fuzzy Inference System (FIS) are discussed. An example objective for a given company is explored - to support decision-making for a given area such as frequency of advertising campaigns, distribution of certain classes of goods, type of means of transport and value of transport costs.

II. MATERIALS AND METHODS

For the purposes of this study, ArcGIS 10.8 software and demo GIS databases included in ArcView software were used. The experimental scenario is taken in which a company needs to expand its branch network with a new site and is looking for GIS-based locations. The research examined whether output data for analysis could be obtained from GIS related to the population of an area of interest, distance from a central warehouse (hub), statistics on the company's product sales, and average annual income per person in the area. Based on the input data, reasonable decisions ought to be made about the frequency of advertising campaigns, the classes and range of products to be offered, the type of delivery vehicles, and the expected company's transport costs in the area.

The aim of this research is to support the search for these solutions by a fuzzy logic decision-making system, where, based on the fuzzy input variables, pre-set rules are followed and reasoned values of the fuzzy output variables are obtained [4] [5], which in this case should be the sought parameters of the investment.

GIS, with its built-in features for searching a population database of cities in a country, can select a target group of

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8027>

© 2024 Krasimir Slavyanov. Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

cities that meet certain criteria. As a query result, a map with cities with a population of more than 100,000 in the United States are shown on fig. 1.

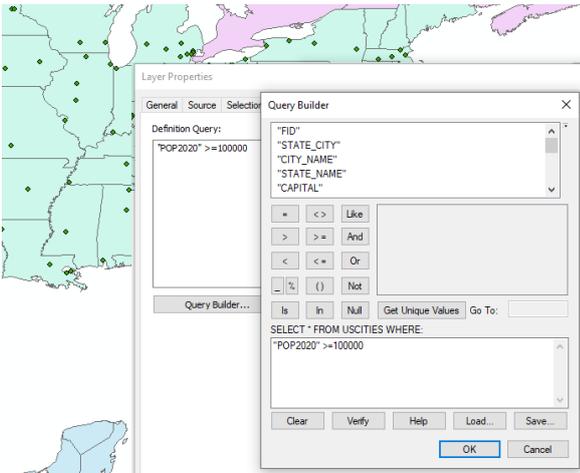


Fig. 1. A query for cities with more than 100 000 citizens.

In a next step, a specific city can be located, as well as neighbouring cities up to 300 miles away (Fig. 2 and Fig. 3).

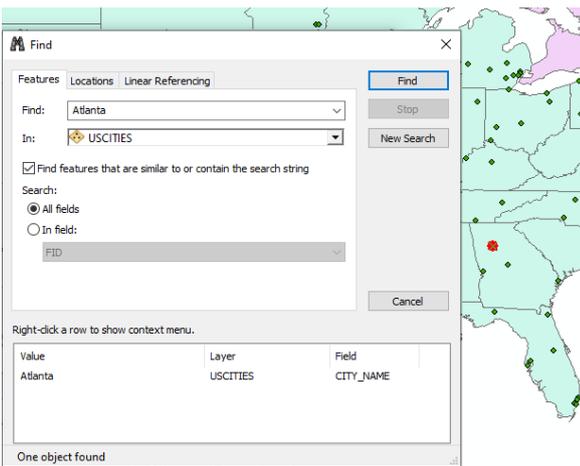


Fig. 2. Query to find a specific location on the map.

Localization of objects of a given type can also be done by querying the database (Fig. 4).

Each of the results for the types of objects of interest can be further ordered depending on specific information that must be available in the database, in this case the stores can be ordered by the amount of their orders from the company (fig. 5 and fig. 6).

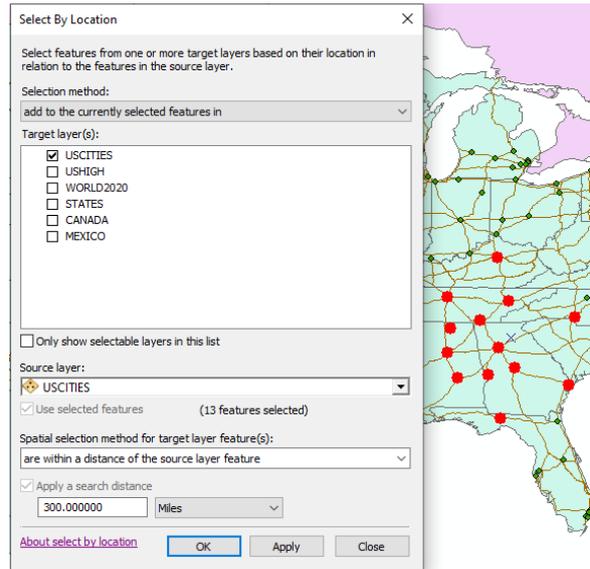


Fig. 3. Query to find neighboring cities up to 300 miles in distance.

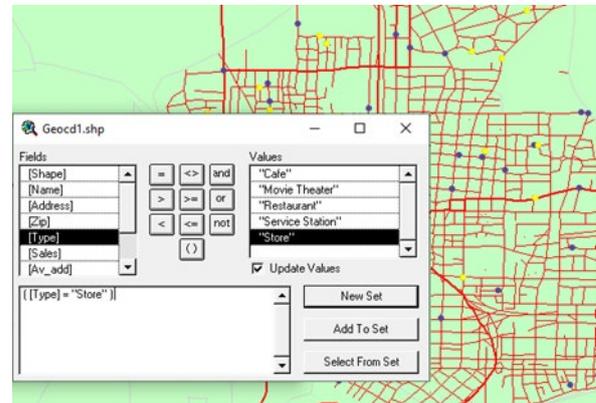


Fig. 4. A selection of stores in a given city where the company has contracts.

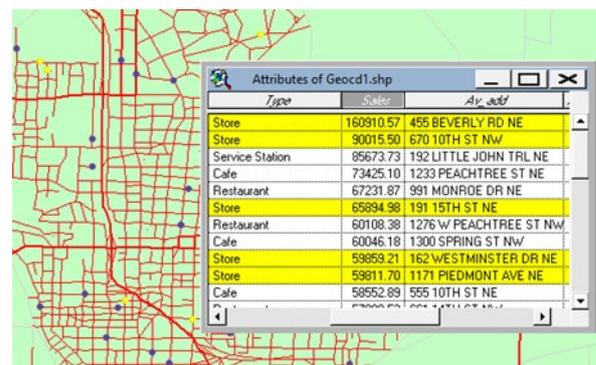


Fig. 5. Objects with orders for over 50,000 USD.

Using the study-specific GIS functionalities, exported values for the Mamdani-type [6] FIS input fuzzy variables can be generated with the structure previously described, depicted in Fig. 7.



Fig. 6. Fuzzy inference system with GIS data designed to be used for fuzzy input variables.

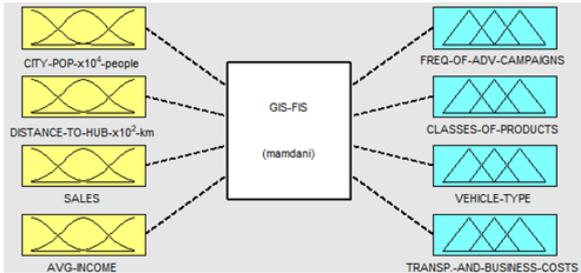


Fig. 7. Fuzzy inference system with GIS data designed to be used for fuzzy input variables.

The fuzzy input variables with their membership functions are designed as follows:

- Population of the city (smallest - up to 10,000; small - up to 25,000; middle - up to 50,000; big - up to 100,000 and biggest - over 100,000).
- Distance to the central warehouse - transport time (up to 2 hours - up to 150 km; up to 3 hours - up to 200 km; up to 4 hours - up to 300 km, over 4 hours - over 300 km).
- Sales history (up to 50,000 USD; up to 100,000 USD; over 100,000 USD).
- Average annual income (up to 50,000 USD; up to 100,000 USD; over 100,000 USD).

Membership functions for the population of the city were created by gaussian combination type, for distance to the warehouse – trapezoidal, for sales history – pi-shaped, for the average annual income – triangular [7]. The input fuzzy variable “Distance to hub”, designed to have four sections from zero to 500 km is shown on fig. 8.

The fuzzy variables for the output linguistic variables are designed, with membership functions as follows:

- Frequency of advertising campaigns (1-3 per year; 4-6 per year; 7-10 per year).
- Classes of products to offer (middle class; high class; premium class).
- Type of vehicle to the site (utility van; box-truck; semi-truck).
- Transport and work costs (small; average; large).

The membership functions for the classes of offered products are generalized bell-shaped, depicted in Table 1. The functions of the remaining fuzzy variables are triangular.

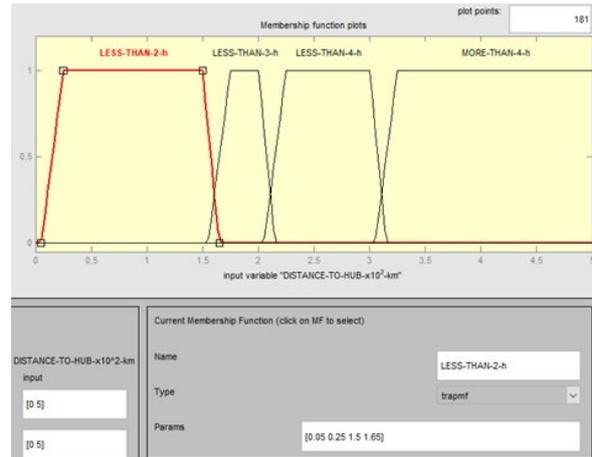


Fig. 8. Membership functions for the input variable “Distance to hub”.

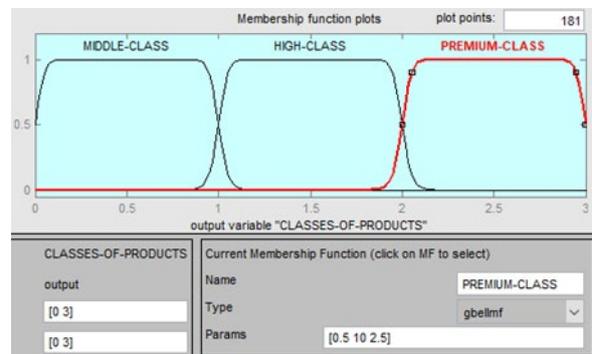


Fig. 9. Membership functions for the product classes to be offered at the new company site.

To study experimental performance of the system, 20 fuzzy rules are synthesized (shown in Table 1).

TABLE 1 FUZZY RULES

Rule №	IF				THEN			
	Popul.	Dist	Sales	Income	Freq. Adv.	Pr. Class	Vehicle	Tr. Cost
	Options pool				Options pool			
	<10k	<2h	<50k	<50k	1-3	MID	VAN	SMALL
	<25k	<3h	<100k	50-100k	4-6	HIGH	Box-T	AVG
	<50k	<4h	>100k	>100k	7-10	PREM	Semi-T	LARGE
	>100k	>4h	>100k	>100k				
1	<10k	<2h	<50k	<50k	4-6	MID	VAN	SMALL
2	<10k	<2h	<50k	50-100k	7-10	HIGH	VAN	SMALL
3	<10k	<3h	<50k	50-100k	4-6	HIGH	Box-T	AVG
4	<10k	<4h	<100k	>100k	1-3	PREM	Box-T	AVG
5	<25k	<2h	<50k	<50k	4-6	MID	VAN	SMALL
6	<25k	<2h	<50k	50-100k	4-6	HIGH	Box-T	AVG
7	<25k	<3h	<50k	50-100k	4-6	HIGH	Box-T	AVG
8	<25k	<4h	<100k	>100k	1-3	PREM	Box-T	AVG
9	<50k	<2h	<50k	<50k	4-6	MID	VAN	SMALL
10	<50k	<3h	<100k	50-100k	7-10	HIGH	Box-T	AVG
11	<50k	<4h	<100k	50-100k	7-10	HIGH	Box-T	AVG
12	<50k	>4h	>100k	>100k	1-3	PREM	Semi-T	LARGE
13	<100k	<2h	<50k	<50k	4-6	MID	Box-T	AVG
14	<100k	<3h	<100k	50-100k	4-6	HIGH	Box-T	AVG
15	<100k	<4h	<100k	50-100k	7-10	HIGH	Box-T	AVG
16	<100k	>4h	>100k	>100k	4-6	PREM	Semi-T	LARGE
17	>100k	<3h	<50k	<50k	4-6	MID	Box-T	AVG
18	>100k	<4h	<100k	50-100k	7-10	HIGH	Box-T	AVG
19	>100k	>4h	<100k	50-100k	4-6	HIGH	Semi-T	LARGE
20	>100k	>4h	>100k	>100k	4-6	PREM	Semi-T	LARGE

III. RESULTS AND DISCUSSION

The parameters of the FIS are: implication method - min, aggregation - max, type of defuzzification - LoM (last of maxima). In the simulation study of the operation of FIS, results are obtained that confirm the correct combination of

the input linguistic variables to obtain the necessary data at the output of the system. One example is on fig.10 – fuzzy input values and fig.11 – fuzzy output values.



Fig. 10. FIS simulation – fuzzy input values.

The results may be more accurate if the number of rules in the set is increased. The different types of input and output variables can be modified depending on the specific task. The explanation of the simulation data is described on Fig. 12.

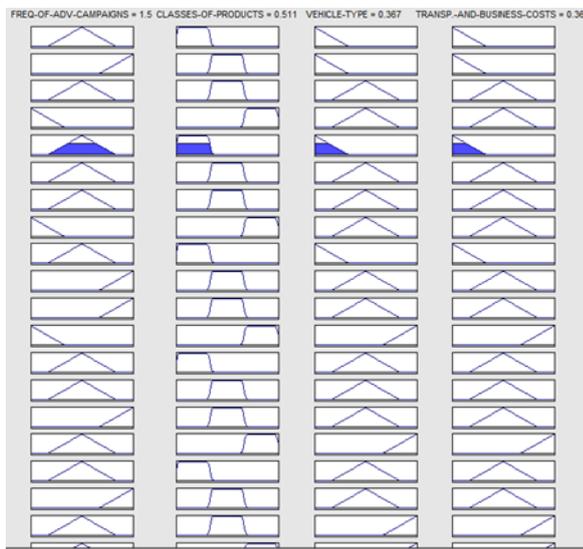


Fig. 11. FIS simulation – fuzzy output values.

CITY-POP-x10⁴-people = 2.127 (21 270 citizens) &
 DISTANCE-TO-HUB-x10²-km = 0.8686 (less than 2 hours) &
 SALES-x10k-USD = 3.397 (33 970 USD) &
 AVG-INCOME = 0.4231 (less than 50k USD)
 ==>
 FREQ-OF-ADV-CAMPAIGNS = 1.5 (4-6 times per year);
 CLASSES-OF-PRODUCTS = 0.511 (middle class);
 VEHICLE-TYPE = 0.367 (utility van);
 TRANSP.-AND-BUSINESS-COSTS = 0.367 (small costs)

Fig. 12. Simulation with input and output fuzzy values (summary).

IV. CONCLUSIONS

This approach is applicable only to dedicated GIS projects for logistic management, enterprise resource planning systems (ERP), and for research of the market situation purpose. For any other implementation of similar geodata usage approaches in other areas of human activity with artificial intellect, a specific database would be needed.

The described working structure of an expert GIS system and a company's management decision system can be adapted or used in various fields of human activity in which action planning on the ground or in space is required, such as for tracking purposes in military sciences [8], application of UAVs for surveillance [9] or defensive approaches against UAVs [10], in analysing the spatial position of users [11], as well as in combination with other applications of artificial intelligence in defence and security [12].

ACKNOWLEDGMENTS

This work was supported by the NSP DS program, which has received funding from the Ministry of Education and Science of the Republic of Bulgaria under the grant agreement no. Д01-74/19.05.2022.

REFERENCES

- [1] H. Aghajani and A. Alizadeh-Zoeram, "Identifying urban neighborhoods with higher potential for social investment using GIS-FIS approach", May 2020, Applied Geomatics 13(7), <https://doi.org/10.1007/s12518-020-00317-4>
- [2] A. I. Loureiro, A. Bressane, V.F. Nascimento and R. G. Negri, "Enhancing Landfill Monitoring and Assessment: A Proposal Combining GIS-Based Analytic Hierarchy Processes and Fuzzy Artificial Intelligence", October 2023, Knowledge 3(4):610-625, <https://doi.org/10.3390/knowledge3040038>
- [3] A. Wismadi, M. Brussel, H. Sutomo and M.F.A.M. Van Maarseveen, "GIS infrastructure interdependency modelling with fuzzy inference systems (FIS) for predicting the distribution of economic opportunities", Conference: Ecocity World Summit 2009 : the 8th International Ecocity Conference : Urban Ecological Foundations for Climate Solutions, December 2009
- [4] L.A. Zadeh, "The concept of a linguistic variable and its application to approximate reasoning—I", Information Sciences 8, 1975, pp. 199-249.
- [5] L.A. Zadeh, "Outline of a new approach to the analysis of complex systems and decision processes", IEEE Transactions on Systems, Man, and Cybernetics, Vol. 3, No. 1, Jan. 1973, pp. 28-44.
- [6] E.H. Mamdani, S. Assilian, "An experiment in linguistic synthesis with a fuzzy logic controller", International Journal of Man-Machine Studies, Vol. 7, No. 1, 1975, pp. 1-13. [https://doi.org/10.1016/S0020-7373\(75\)80002-2](https://doi.org/10.1016/S0020-7373(75)80002-2)
- [7] Mathworks Support - Functions <https://www.mathworks.com/help/fuzzy/referencelist.html> [Accessed Jan 19, 2024]
- [8] D. Dimitrov and D. Atanasov, "Implementation of the hough transform in detection of target trajectory", International Scientific Conference, Shumen, 2017, pp. 400-408,

https://www.aadcf.nvu.bg/scientific_events/papers/NS_2017.pdf
[Accessed Jan 13, 2024]

- [9] M. Iliev and M. Bedzheva, "An Approach for Application of UAVs for Observation of Processes in Agriculture", 7th International Conference on Energy Efficiency and Agricultural Engineering (EE&AE), 2020, <https://doi.org/10.1109/EEAE49144.2020.9279028>
- [10] V. M. Genoff, L. E. Manov, Y. V. Yosifov, „Experimental evaluation of the applicability of low-budget non-professional lasers for blinding drones at ranges over 3 km“, Proceedings of International Scientific Conference —Defense Technologies, 2023, ISSN 2815-4282, pp. 439-443,
- [11] M. Nedelchev, R. Dimov, S. Parvanov, "Algorithm for application of information for management of users spatial disposition in the process of automated software-defined radio communication network implemented by orthogonal frequency division and multiplexing", Proceedings of the conference “Scientific research and education in the air force – AFASES 2023”, pp. 39-46, <https://doi.org/10.19062/2247-3173.2023.24.5>
- [12] A. Borisova, L. Nikolov, "Systems with artificial intelligence for defense and security", Proceedings of the conference “Scientific research and education in the air force – AFASES 2023”, pp. 53-58 <https://doi.org/10.19062/2247-3173.2023.24.7>

Usability and utility of the SnipTouch innovative agility training device prototype in patients with upper extremity impairments after stroke: a multiple case study

Andrejs Snipkis
NRC "Vaivari"
Jurmala, Latvia
andrejs.snipkis@gmail.com

Guna Semjonova
Department of Rehabilitation
Riga Stradins University
Riga, Latvia
Guna.Semjonova@rsu.lv

Daina Smite
Department of Rehabilitation
Riga Stradins University
Riga, Latvia
Daina.Smite@rsu.lv

Abstract. Research focus and aim: To investigate the usability and utility of the *SnipTouch* innovative agility training device prototype in patients with upper extremity impairments after stroke. Research methods used: The study of several case studies was selected by formulating the research phenomenon and proposing two units of analysis- 1) usability and 2) utility of innovative prototype device *SnipTouch*. The multiple case study involved 7 stroke survivors with impaired upper limb functions who participated in eight physiotherapy sessions adding the *SnipTouch* intervention. The device operates on a dexterity training principle, where the main task is to quickly touch a lit button. Participants underwent pre-intervention upper extremity assessments using ROM, MMT, NRS, MAS, FMA-UE, 9HPT, BBT, and RTT. After the eighth session of physical therapy, reassessments were conducted with the same tools, supplemented by semi-structured interviews and usability evaluations using UEQ and SUS. The collected data were compiled and analysed using established data analysis methods. Results: Five participants assessed the usability of the equipment in the SUS questionnaire as outstanding (from 87,5 to 97,5 points), one participant as excellent (82,5 points) and one very good (77,5 points). The UEQ on six scales resulted in the following device evaluation: attractiveness 2.6, perspicuity 2.79, efficiency 2.32, dependability 2.14, stimulation 2.64, novelty 2.43. The UEQ benchmark classifies the innovative prototype device *SnipTouch* into *Excellent* category. The results of the upper limb functional tests show improvements in all participants. The main Conclusions and Recommendations: The results of the study demonstrate that the *SnipTouch* innovative device prototype is usable and the overlap of qualitative and quantitative data confirmed the utility of the device in improving reaction time, range of motion, agility, movement coordination, muscle strength, in addition to conventional rehabilitation therapy methods for stroke patients.

Keywords: agility training in stroke patients, innovative device prototype, usability, utility

I. INTRODUCTION

Stroke, the third leading cause of death and the main contributor to global disability, has seen a decrease in mortality in recent years, resulting in a growing population of survivors [1]–[3]. Despite this, up to 80% of patients experience functional impairments and limitations in the upper extremities during the acute phase after a stroke, and 33-66% of patients cannot achieve full functional recovery of the upper extremities in 6 months [4], [5]. Timely rehabilitation is crucial to minimize long-term functional impairments [5]. Research highlights the effectiveness of high repetition upper extremity movements for stroke recovery, highlighting the importance of intensity and duration of continuous therapy [6], [7]. Innovative technologies, including agility training devices, present opportunities to create engaging rehabilitation environments, improve patient motivation, and provide necessary repetitions with minimal supervision [8]–[10]. Despite the available methods, a significant number of stroke survivors continue to face long-term impairments of the upper limb, which requires the exploration of new approaches, particularly those focused on agility [11], [12]. The "SnipTouch" agility training device was developed as a prototype with the aim of enhancing users' agility and improving various motor skills. Although agility training devices have shown promise in improving physical and cognitive skills, more research is needed on their usability and efficiency, especially in stroke patients with upper extremity impairments [13]. To address this gap, our research aims to investigate the usability and utility of the SnipTouch innovative agility training device prototype in patients with upper extremity impairments after stroke.

Print ISSN 1691-5402
Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8021>

© 2024 Andrejs Snipkis, Guna Semjonova, Daina Smite. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

II. MATERIALS AND METHODS

Study Design

Based on the research objective, a multiple case study analysis was chosen as the study design. Following the methodology of Yin [14], the phenomenon under investigation was initially formulated as “usability and utility of the SnipTouch innovative agility training device prototype in patients with upper extremity impairments after stroke”. Given that the phenomenon could be divided into separate parts, the fourth type of analysis design was utilized [14]. The study analysis units were formulated as: 1) the usability of the "SnipTouch" innovative device prototype; 2) the utility of the "SnipTouch" innovative device prototype.

Prototype Development and Assessment Process

Based on the information obtained on medical device standards, the research author developed the "SnipTouch" prototype from October 4, 2021, to January 31, 2022. The primary objective in developing the prototype was to provide a rehabilitation device that excels in usability and applicability, is easy to understand, learn, and setup. The design focused on creating a practical and versatile tool that can be adapted to various rehabilitation goals in various patients, focusing on ease of use and broad applicability without compromising quality or increasing costs. At this stage, the development included programming the Arduino Nano microcontroller using the Arduino Integrated Development Environment (IDE) 1.8 with C++ as the programming language. Currently, the device was designed using 3D modelling software, followed by the fabrication of its components using 3D printing techniques. Subsequently, all hardware components were assembled to complete the device. In addition, a biomedical engineer was appointed to verify the device's compliance with applicable safety standards.

Participant Selection Criteria in the Multiple Case Study

The selection of study participants for the multiple case study was performed based on the research selection criteria, combining convenience and purposeful sampling to ensure the inclusion of theoretically distinct cases. Within the context of a single case, one patient being treated in the Neurorehabilitation Department of NRC “Vaivari” during the study was included. The study included patients who agreed to participate and met the initial selection criteria: 1) Men and women at least 18 years old after a first ischemic or hemorrhagic stroke on either the right or left side, confirmed by magnetic resonance imaging or computed tomography; 2) The expected treatment duration at NRC “Vaivari” is no less than 10 working days; 3) No pronounced cognitive impairments, capable of adequately cooperating with the rehabilitation team, a Mini-Mental State Examination (MMSE) [15] score of 16-30 points; 4) No pre-stroke conditions affecting upper extremity functions; 5) No dislocations or subluxations in the upper extremity identified in the patient's medical history through radiology; 6) Upper extremity paretic function impairment(s), not achieving the maximum score of 18 points in sections six, seven, and eight of the Motor Assessment Scale (Upper Limb Function, Hand

Movements, Advanced Hand Movements) [16], with at least two points in section six; 7) Able to communicate and read in Latvian; 8) None of the following exclusion criteria apply: a) pain in any joint of the paretic upper limb more than 5 points according to the NRS; b) spasticity in any muscle of the paretic upper limb more than 2 points according to the Ashworth scale; c) motor aphasia; d) diagnosed epilepsy.

Intervention and Implementation of the “SnipTouch” Prototype

Before starting the intervention, the upper extremity functions of the participants were evaluated using evaluation tools: Range of Motion (ROM) assessment (goniometry) [17], Manual Muscle Strength Tests (MMT) [18], pain assessment using the Numerical Analog (rating) Scale (NAS) [19], Modified Ashworth Scale (MAS) [20], Fugl-Meyer Assessment for Upper Extremity (FMA-UE) [21], Nine Hole Peg Test (NHPT) [22], Box and Block Test (BBT) [23], Reaction Time Test (RTT) [24]–[26]. Evaluation conducted by an independent researcher. To start the intervention with “SnipTouch”, all the physiotherapists of the study participants received instructions for using the innovative "SnipTouch" device prototype, in addition to the individual practical training sessions on the application were conducted because the intervention was performed by the physiotherapist. During eight physiotherapy sessions (60 min), the physiotherapists, in addition to conventional physiotherapy methods, conducted training using the innovative “SnipTouch” device prototype for the study participant. The operating principle of this device is classified as an agility training equipment type. To use the device, its components are affixed to surfaces chosen by the user. The placement of the button, the size, and the speed of operation of the device vary according to the user's needs and abilities of the user. The primary task of the user is to touch the lit button as quickly as possible (see Fig. 1. and Fig. 2.). Upon touching the lit button, the next one lights up, and the interval between the lighting of the buttons automatically decreases, facilitating an increase in the user's reaction speed and movement speed for successful task completion. The device provides feedback evaluation or indicates the results obtained. During the use of the device, the user performs movements with a high repetition rate. The device consists of five multicolored buttons in two size variations (small with a diameter of 5 mm and/or large with a diameter of 3.5 cm) and a control unit. In addition, there are connection wires of various lengths and device mounts for different surfaces. Based on established rehabilitation goals and the needs of the participant's physiotherapist, the duration of the intervention, the size and placement of the buttons, and the operating speed were selected. The participant underwent a re-assessment of upper extremity functions using the previously applied evaluation tools, and a semi-structured interview was conducted. Study participants were asked questions about the suitability for their needs and rehabilitation goals, as well as the usability of the device and the usefulness of its use to improve upper extremity function. The usability of the device was evaluated using the User Experience Questionnaire (UEQ) [27] and the System Usability Scale (SUS) questionnaire [28], [29].

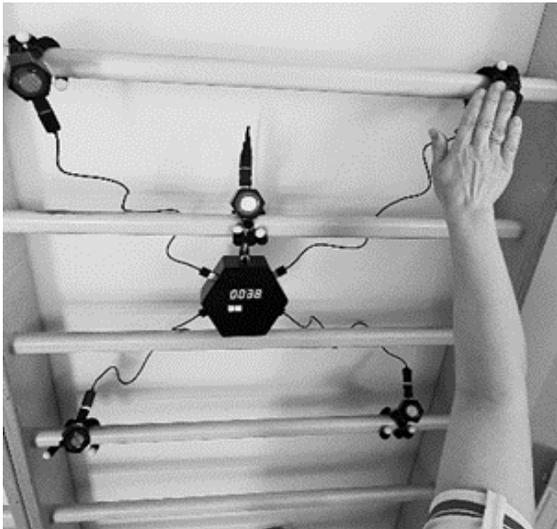


Fig.1. The participant performs a task by pressing the large 3.5 cm buttons on the SnipTouch device prototype mounted on a Swedish wall.

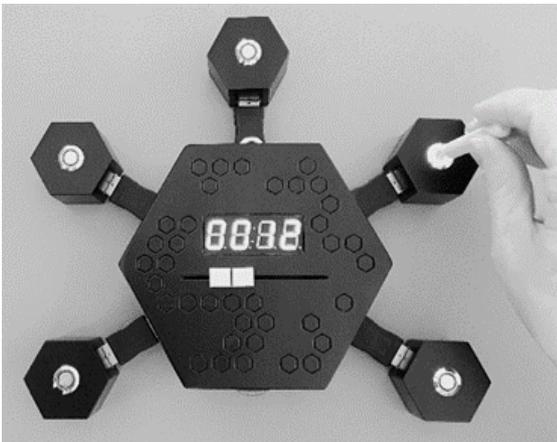


Fig. 2. Participant performs a task by pressing the small 0.5 cm buttons on the SnipTouch device prototype with a dowel.

Data Analysis Methods

In the study used an inductive analysis strategy [14]. Qualitative data were transcribed and coded into categories and subcategories by inductive content analysis with deductive elements. Data were organized by analysis units, identifying patterns, similarities, and differences between and within cases, integrating findings to understand larger correlations. For Range of Motion (ROM), Manual Muscle Strength Tests (MMT), the Numerical Analog (rating) Scale (NAS), Modified Ashworth Scale (MAS), Fugl-Meyer Assessment for Upper Extremity (FMA-UE), Nine Hole Peg Test (NHPT), Box and Block Test (BBT), Reaction Time Test (RTT) scores, and usability scales, descriptive statical methods were used.

F.Ethical Considerations

The study was conducted in accordance with the Declaration of Helsinki [30]. The study adhered to ethical standards according to the Declaration of Helsinki and European data protection regulations, with approval from the ethics committees of Rigas Stradins University (decision no.22-2/559/2021) and NRC "Vaivari" (Nr.40, decision no.4.1).

III. RESULTS AND DISCUSSION

The study consisted of seven participants, creating seven cases for analysis. All participants completed the study with complete data, allowing them to be included in the analysis. The details are in Table I.

The first unit of analysis - Usability

Summarising the results of the SUS questionnaire, it was determined that five participants (P1, P2, P4, P5, P7) rated the device's usability as excellent, corresponding to an A+ level. Expressing the A+ assessment in points, it ranged from 87.5 points for participant P6 to 97.5 points for participant P7. Participant P3 scored 82.5 points on the questionnaire, corresponding to an excellent device usability rating of A. Meanwhile, participant P4 indicated a B+ rating or very good usability of the device. According to the methodology guidelines, the results of the UEQ must be expressed for the entire sample as an average score assessment. Therefore, the following results were obtained on the six UEQ scales. Study participants rated the attractiveness of the device with an average of 2.6 points, perspicuity with 2.79 points, efficiency with 2.32 points, dependability with 2.14 points, stimulation with 2.64 points, and novelty with 2.43 points (see Fig. 3.). The UEQ benchmark classifies the innovative prototype device "SnipTouch" into "Excellent" category. In the proportional distribution of the responses for the 26 items of the UEQ scale, it was found that most of the participants rated the device as friendly, attractive, practical, clear, useful, and meeting expectations, motivating, safe, good, easy to use, valuable, easy to learn, understandable, modern, pleasant, and supportive. Most of the participants evaluated the device as innovative, original, creative, interesting, enticing, and exciting, but one participant P1 rated it as average between innovative and conservative, average between original and widely accepted, rated it as average between creative and monotonous, average between interesting and uninteresting, average between enticing and repelling, average between exciting and boring. Six participants indicated that the device is organised, but participant P2 indicated that the device is partly poorly organised. Most of the participants evaluated the device as average between fast and slow, but three participants, P2, P5, and P6, rated the device as fast. Three participants (P4, P5, P6) rated the device as predictable, participant P1 rated the device as average between predictable and unpredictable, while P2 rated it as partly predictable and participants P3 and P7 rated the device as very unpredictable.

TABLE I

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Subsequent notation in the paper	P1	P2	P3	P4	P5	P6	P7
Age	47	53	48	57	69	61	60
Sex	Female	Male	Female	Female	Male	Male	Male
Stroke type	Ischemic	Hemorrhagic	Ischemic	Hemorrhagic	Ischemic	Hemorrhagic	Ischemic
Location of brain damage	ACM dxt.	ICH sin. frontal lobe	ACM dxt.	ICH sin. frontal lobe	ACM dxt.	At the Pons	ACM sin.
Time after stroke	66 days	159 days	89 days	152 days	120 days	89 days	145 days
Paretic side	Left	Right	Left	Right	Left	Left	Right
Dominant hand	Right	Right	Right	Right	Right	Right	Right
Total score on the Motor Assessment Scale (sections 6-8)	15	12	12	8	15	9	10

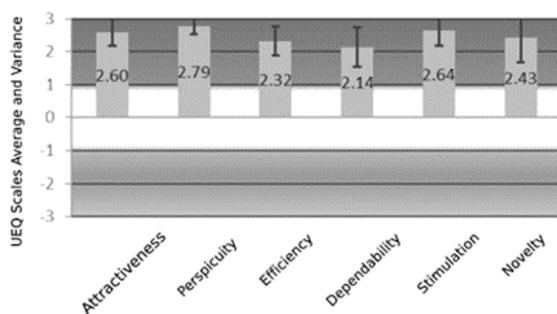


Fig.3. The UEQ scales the main parts scores average and variance.

Data obtained from participants in interviews related to Usability: Evaluation of the Session Process: The participants noted that using the device was interesting and exciting and that they were satisfied with their experience using the "SnipTouch" device prototype. The data from the interview were collected, coded, and separated into 6 categories: 1. *Difficulty Level of Using the Device*: Initially, three participants found the device and the tasks easy to understand, while four adjusted after the first use. Some found it easier with time or with improved physical ability. Challenges included variable button placements, operating speed, performing tasks accurately, using a stylus for small buttons, and visibility issues for a participant with hemianopsia, making task execution more complex for some. 2. *Well-being During Device Use*: Participants reported positive feelings, high motivation, and satisfaction with their achievements. Some experienced emotional relief, despite challenges such as numb fingers or discomfort in the paretic limb, leading to the need for rest breaks. An increase in self-confidence was observed as the familiarity with the device grew. 3. *Well-being After the Device Use Session*: After use, participants experienced positive results, including pleasant fatigue in the paretic limb for some, emotional uplifting for others, and general good sense of well-being, indicating beneficial effects of the session. 4. *Strengths of the Device*: Key strengths identified include ease of use, the ability to monitor results, creative design, engaging and interesting use process, and colourful buttons. Furthermore, its use was noted to distract from pain, enhancing the appeal of the device. 5. *Drawbacks of the Device*: Identified flaws include unstable button

attachments and USB connections, insufficient brightness of large buttons, and too small button sizes, pointing to areas for potential improvement in design and functionality. 6. *Future Perspectives on Using the Device*: Most of the participants are interested in future use and one is ready to buy it. There is a consensus on its potential to speed up rehabilitation goals and the desire for a wider availability. Although some see no need for changes, others suggest improvements such as better button attachments and brighter large buttons to enhance usability and effectiveness.

The second unit of analysis - Utility

Data obtained from Participants' Functional Test Results:

Range of Motion: All participants exhibited improvements in upper limb mobility, excluding shoulder adduction, already at normal levels. However, P4 experienced a slight decrease in shoulder abduction (active: 98 to 85 degrees, passive: 136 to 126 degrees). P2 observed reductions in active pronation (67 to 54 degrees) and active extension (40 to 30 degrees), passive extension also decreased (66 to 53 degrees) and reported notable pain.

Muscle Strength: Assessed at up to three points for P2, P4 and P7 due to increased tone, all participants experienced improvements in muscle strength, with the most significant gains in P2 and P6 in eight muscle groups.

Muscle Tone: Four participants started with normal tone; P2 and P7 experienced reduced spasticity in some muscles, while P4 observed a slight increase in muscle tone in the m. flexor digitorum, increasing from 1 to 1+ on the Ashworth scale.

Pain Intensity: P2 experienced an increase in wrist pain, going from a score of 4 to 5. On the contrary, P4 saw a decrease in pain levels from 5 to 2, and P7 from 5 to 3. P1's pain, initially rated at 5, disappeared entirely, similarly to P6, whose shoulder pain went from 3 to non-existent. The pain level and character of P3 and P5 remained unchanged, consistently with a score of 5, primarily due to positioning.

FMA-UE: During their therapy, six participants showed improvements in the Fugl-Meyer Assessment for

Upper Extremity scores across Domains A to D, with the exception of P2, whose overall score remained unchanged. P3 experienced the most significant improvement, with their score increasing from 45 to 61 points, especially noted in the Coordination/Speed and Upper Extremity domains. P1 reached the maximum possible score of 66 points, with an improvement of three points. All participants improved in at least one domain, except P1 and P5, who began with maximum scores in the Hand domain, and P2, who did not observe any change in Coordination/Speed, remaining at 2 points, and experienced a decrease in the Hand domain score from 13 to 10 points.

NHPT: The test showed that all participants tested improved in the second assessment, with P3 having the most significant improvement of 37.8% and P1 the smallest at 2 seconds, indicating initial results within the normal range.

BBT: The test results showed improvements for six of the study participants (P1, P2, P3, P4, P6, P7) between the initial and second evaluations. The increases ranged from a minimum of 2 blocks (P2) to a maximum of 9 blocks (P7). In contrast, P5 did not show any performance change, maintaining a score of 23 blocks in both assessments.

RTT: The average results of the reaction time test indicated that all study participants had a positive trend in reaction time changes. Participant P4 experienced the largest change, with a 21.3% improvement, which was the most significant change among all participants, while the smallest changes were observed in participant P2, whose result changed by 0.6%.

Data obtained from participants in interviews related to Utility:

In interviews, participants reported that using the "SnipTouch" device prototype was beneficial, noting improvements in 13 physical aspects, two psychoemotional and two cognitive areas from its use. They experienced enhanced movement range, coordination, and speed of movement in their paretic upper extremities. Specifically, improvements in fine motor skills (P1, P2, P7), daily activity use (P4, P5), reduced intensity of pain (P3, P6), better self-care and dexterity (P2), increased muscle strength and decreased tremor (P4) were observed. Enhanced sensation (P6) and better grip (P7) in the paretic upper extremity were also reported. Participants noted better reaction times, attention skills, and increased self-confidence, with three mentioning increased self-esteem after device use. P3 experienced an improvement in mood. Motivation to achieve greater achievement led to faster task completion and, for some, greater self-confidence. The ability to press buttons with a stylus improved self-confidence (P2, P7) and encouraged the use of the paretic limb for writing. The use prompted a more effective use of the paretic upper limb for tasks (P4, P7) and required coordinated movement and precision (P3, P5, P7), with the placement encouraging full use (P7) and improving the range of active motion (P4).

In analyzing user feedback on the "SnipTouch" prototype five participants rated the usability of the device

as excellent in the SUS questionnaire, while two participants rated it as good. These results suggest that these users would likely recommend the "SnipTouch" prototype for use by others. Although one participant rated the device's usability as very good, their completed questionnaire revealed a need for technical assistance from another person to set up and select the device's operating speed, indicating a complexity in use. The participant also mentioned the excessive learning required. The information shared during the interviews clarified these results, highlighting the initial difficulties in understanding how to use the device. According to Liu [31], patients with lower functional and cognitive abilities might require a longer period to process new information. Three participants found it easy to understand how to use the device, its operating principles, and the essence of the tasks right from the start, while the rest grasped how to use the device only after their first experience or trial. Hugues [32] noted that individual's post-stroke individual may need more time and practical trials to learn a new skill. During the interviews, the patients expressed great satisfaction with the use of the device during sessions, which was attributed to the ease of use and the engaging and interesting process. Patients emphasised their high motivation to complete tasks during sessions, consistent with Thomson [33] who found that game-formatted tasks motivate patient participation. Three study participants mentioned that the ability to track the results was a strong aspect of the device, encouraging more active participation. The patients also highlighted those bright lights created emotional uplift. Chen [33] emphasized the importance of participating in the rehabilitation process to increase patient participation, potentially enhancing rehabilitation benefits. Wang [35] suggested that including game elements requires a balance between challenge and avoiding loss in games. This explains the observations in the current study, in which a participant showed low interest and motivation after setting the device at a speed faster than the participant could manage. Reducing the speed in the next session improved the participant's ability to complete tasks and increased their desire to continue using the device. Variability in button placement and device speed during sessions added diversity, which is essential to maintain high patient interest and motivation. This finding is supported by Wang [34]. However, patients who had difficulty holding the peg and pressing small buttons of the device found it challenging. Research confirms that people after stroke experience difficulties with fine motor and grasping, significantly impacting daily activities [36], [37]. Basteris [38] highlighted the need for a high number of repetitions to improve skills. In this study, the patient's ability to press small buttons improved with extensive practice of fine motor skills and grasping during sessions. In interviews, participants identified unstable button attachments to surfaces as a primary drawback of the device, echoing findings from Myers [39] regarding the FitLight device. This suggests the need for improved button attachments for the "SnipTouch" device, considering the deep sensation, movement coordination, and precision difficulties of patients. Future iterations of the "SnipTouch" should consider wireless technology to avoid wire interference in task performance. The agility training devices currently available are primarily designed

for functionally independent individuals, such as athletes. For example, BlazePod and FitLight devices are very advanced, including wireless multicolored LED buttons, which are controlled using an Android or iOS application. In contrast, the initial design concept of SnipTouch device was intended to be maximally easy to use, understandable, and adaptable for any user and their needs, financially inexpensive, and controllable without additional devices (without phone applications) [40], [41], [42]. Using the FitLight system, Al-Selmi and Hosen [40] observed significant improvements in aerobic capacity, speed, and hit quality in badminton players after eight weeks of training. Rogozhnikov [41] reported a 36.2% improvement in task execution time in basketball training with FitLight over four weeks. Chepanov [42] found significant enhancements in reaction speeds and emotional states in karate training with BlazePod devices among teenagers. Such observations indicate that such agility training devices have great potential to improve agility, movement speed, reaction speed, and other physical and functional abilities. Upon analysing information from interviews and data from functional tests, an examination of overlapping data was conducted. This data overlap was interpreted as an indication of the device's utility. Data overlaps confirmed the utility of using the device to improve reaction speed, movement speed, grip, range of motion, fine motor skills, coordination of movements, and muscle strength when applied in addition to conventional rehabilitation therapy methods. This research encountered several limitations that warrant consideration when interpreting the findings. Firstly, the study was characterized by a relatively small sample size, which may impact the generalizability of the results. Additionally, the homogeneity of the study group, which comprised only post-stroke patients with similar functional disorders and their origins, suggests that the utility of the "SnipTouch" prototype might not fully extend to other populations with impaired upper limb function. This underscores the importance of expanding future research to include a more diverse range of participants to validate the prototype's usability and utility more broadly. A significant factor to consider is that all participants were recruited from a single rehabilitation centre. This uniformity in the rehabilitation setting, characterized by a particular treatment environment and methodology, as well as concurrent exposure to various therapeutic interventions, could have influenced the study results. The observed effects observed may, in part, be attributable to the comprehensive rehabilitation approach at the center, rather than the "SnipTouch" intervention alone. Another critical consideration is the varied participants individual factors affecting usability and utility assessments. These variations include attitudes toward new technologies, prior experiences with such technologies, and the influence of personal life philosophies, cultural backgrounds, and social contexts. These factors highlight the complexity of evaluating new rehabilitation interventions and underscore the importance of considering a broad spectrum of individual differences in future research. Additionally, the researcher's dual role as both the inventor of the device and the interviewer in participant interactions could have influenced responses. To ensure credibility, measures such as conducting open-ended interviews, separating personal views, and

verifying codes were implemented. However, there still remains the possibility that the researcher's involvement could have influenced participant responses and data interpretation. The findings of this study provide valuable insights into the usability and utility of the "SnipTouch" prototype, highlighting areas for further research and development in the field of rehabilitation interventions.

IV. CONCLUSIONS

A first multiple case study was conducted to explore the usability and utility of the "SnipTouch" device prototype during inpatient stroke rehabilitation. Integrated findings suggested that the "SnipTouch" technology was a feasible and acceptable tool for use in stroke patients participating in subacute inpatient rehabilitation. The participants reported high satisfaction due to its simplicity, understandability, and engaging nature, although technical properties such as mounting and fastening of the device were noted to need improvement. Furthermore, the results revealed the potential of the "SnipTouch" to enhance motor recovery of the upper extremity in stroke patients during inpatient rehabilitation. A "SnipTouch"-based approach appeared feasible and promising for post-stroke rehabilitation. A randomized controlled trial is recommended to further investigate efficacy.

ACKNOWLEDGMENTS

Special thanks to the National Rehabilitation Centre "Vaivari" for allowing us to conduct this research within their institution. We are particularly grateful to the physiotherapists for their willingness and openness to use the device prototype on their patients, providing a crucial contribution to the successful execution of our study. Additionally, our sincere appreciation goes to the technical engineer at NRC "Vaivari" for her thorough evaluation of the device's safety, ensuring its optimal performance and security for our research.

REFERENCES

- [1] P. Kiper, A. Szczudlik, M. Agostini, J. Opara, R. Nowobilski, L. Ventura, P. Tonin, and A. Turolla, "Virtual Reality for Upper Limb Rehabilitation in Subacute and Chronic Stroke: A Randomized Controlled Trial," *Archives of Physical Medicine and Rehabilitation*, vol. 99, no. 5, pp. 834-842.e4, May 2018. [Abstract]. Available: <https://doi.org/10.1016/j.apmr.2018.0023>. [Accessed Feb. 25, 2024].
- [2] S. Guillén-Climent, A. Garzo, M.N. Muñoz-Alcaraz, "A usability study in patients with stroke using MERLIN, a robotic system based on serious games for upper limb rehabilitation in the home setting," in *J. Neuroeng. Rehabil.*, vol. 18, no. 41, 2021. [Online]. Available: <https://doi.org/10.1186/s12984-021-00837-z>. [Accessed Feb. 25, 2024].
- [3] T. Platz, "Methods for the Development of Healthcare Practice Recommendations Using Systematic Reviews and Meta-Analyses," *Front. Neurol.*, vol. 12, Jul. 2021, Art. no. 699968. [Online]. Available: <https://doi.org/10.3389/fneur.2021.699968>. [Accessed Feb. 25, 2024].
- [4] K. S. Hayward, S. F. Kramer, V. Thijs, J. Ratcliffe, N. S. Ward, L. Churilov, L. Jolliffe, D. Corbett, G. Cloud, T. Kaffenberger, A. Brodtmann, J. Bernhardt, and N. A. Lannin, "A systematic review protocol of timing, efficacy and cost effectiveness of upper limb therapy for motor recovery post-stroke," *Systematic Reviews*, vol. 8, Article no. 187, Jul. 2019. [Online]. Available: <https://doi.org/10.1186/s13643-019-1093-6>. [Accessed Feb. 25, 2024].

- [5] W.T. Chien, Y.Y. Chong, M.K. Tse, C.W. Chien, and H.Y. Cheng, "Robot-assisted therapy for upper-limb rehabilitation in subacute stroke patients: A systematic review and meta-analysis," *Brain Behav.*, vol. 10, no. 8, Art. no. e01742, Aug. 2020. [Online]. Available: <https://doi.org/10.1002/brb3.1742>. [Accessed Feb. 25, 2024].
- [6] R. Bertani, C. Melegari, M. C. De Cola, A. Bramanti, P. Bramanti, and R. S. Calabrò, "Effects of robot-assisted upper limb rehabilitation in stroke patients: a systematic review with meta-analysis," *Neurological Sciences*, vol. 38, pp. 1561-1569, 2017. [Abstract]. Available: <https://doi.org/10.1007/s10072-017-2995-5> [Accessed Feb. 25, 2024].
- [7] S. Ikbali Afsar, I. Mirzayev, O. Umit Yemisci, and S. N. Cosar Saracgil, "Virtual Reality in Upper Extremity Rehabilitation of Stroke Patients: A Randomized Controlled Trial," *Journal of Stroke and Cerebrovascular Diseases*, vol. 27, no. 12, Sep. 2018. [Abstract]. Available: <https://doi.org/10.1016/j.jstrokecerebrovasdis.2018.08.007>. [Accessed Feb. 25, 2024].
- [8] C. A. Aguilar-Lazcano, E. J. Rechy-Ramirez, H. Hu, H. V. Rios-Figueroa, and A. Marin Hernandez, "Interaction Modalities Used on Serious Games for Upper Limb Rehabilitation: A Systematic Review," in *Games for Health Journal*, 2019. [Online]. Available: <https://doi.org/10.1089/g4h.2018.0129>. [Accessed Feb. 25, 2024].
- [9] Y. Wong, L. Ada, R. Wang, G. Månun, un B. Langhammer, "Self-administered, home-based, upper limb practice in stroke patients: A systematic review," *Journal of Rehabilitation Medicine*, vol. 52, no. 10, art. jrm00118, 2020. [Online]. Available: <https://doi.org/10.2340/16501977-2738>. [Accessed Feb. 25, 2024].
- [10] R. Karamians, R. Proffitt, D. Kline, un L. V. Gauthier, "Effectiveness of Virtual Reality- and Gaming-Based Interventions for Upper Extremity Rehabilitation Poststroke: A Meta-analysis," *Archives of Physical Medicine and Rehabilitation*, vol. 101, no. 5, pp. 885–896, 2020. [Abstract]. Available: <https://doi.org/10.1016/j.apmr.2019.10.195>. [Accessed Feb. 25, 2024].
- [11] A. Ezhov, A. Zakharova, un D. Kachalov, "Modern Light Sport Training Systems: Critical Analysis of Their Construction and Performance Features," in *Proceedings of the 9th International Conference on Sport Sciences Research and Technology Support*, vol. 1, pp. 123-129, 2021. [Abstract]. Available: <https://doi.org/10.5220/0010677900003059>. [Accessed Feb. 25, 2024].
- [12] L. A. de-Oliveira, M. V. Matos, I. Fernandes, D. A. Nascimento, un M. E. da Silva Grigoletto, "Test-Retest Reliability of a Visual-Cognitive Technology (BlazePod™) to Measure Response Time," *Journal of Sports Science & Medicine*, vol. 20, no. 1, pp. 179–180, 2021. [Online]. Available: <https://doi.org/10.52082/jssm.2021.179>. [Accessed Feb. 25, 2024].
- [13] A. Voinescu, J. Sui, un D. Stanton Fraser, "Virtual Reality in Neurorehabilitation: An Umbrella Review of Meta-Analyses," *Journal of Clinical Medicine*, vol. 10, no. 7, art. 1478, 2021. [Online]. Available: <https://doi.org/10.3390/jcm10071478>. [Accessed Feb. 25, 2024].
- [14] R.K. Yin, *Case Study Research and Applications: Design and Methods*, 6th ed., Sage, Los Angeles, 2018 (Original work published 1984).
- [15] M. F. Folstein, S. E. Folstein, un P. R. McHugh, "Mini-mental state: A practical method for grading the cognitive state of patients for the clinician," *Journal of Psychiatric Research*, vol. 12, no. 3, pp. 189–198, 1975. [Abstract]. Available: [https://doi.org/10.1016/0022-3956\(75\)90026-6](https://doi.org/10.1016/0022-3956(75)90026-6). [Accessed Feb. 25, 2024].
- [16] J. H. Carr, R. B. Shepherd, L. Nordholm, un D. Lynne, "Investigation of a new motor assessment scale for stroke patients," *Physical Therapy*, vol. 65, no. 2, pp. 175–180, 1985. [Abstract]. Available: <https://doi.org/10.1093/ptj/65.2.175>. [Accessed Feb. 25, 2024].
- [17] R. L. Gajdosik un R. W. Bohannon, "Clinical measurement of range of motion: Review of goniometry emphasizing reliability and validity," *Physical Therapy*, vol. 67, no. 12, pp. 1867–1872, 1987. [Abstract]. Available: <https://doi.org/10.1093/ptj/67.12.1867>. [Accessed Feb. 25, 2024].
- [18] F. P. Kendall un F. P. Kendall, *Muscles: Testing and Function with Posture and Pain*. Baltimore, MD: Lippincott Williams & Wilkins, 2005.
- [19] M. McCaffery un A. Beebe, *Pain: Clinical Manual for Nursing Practice*. St. Louis, MO: Mosby, 1989.
- [20] R. W. Bohannon un M. B. Smith, "Interrater reliability of a modified Ashworth scale of muscle spasticity," *Physical Therapy*, vol. 67, no. 2, pp. 206–207, 1987. [Abstract]. Available: <https://doi.org/10.1093/ptj/67.2.206>. [Accessed Feb. 25, 2024].
- [21] A. R. Fugl-Meyer, L. Jääskö, I. Leyman, S. Olsson, un S. Steglind, "The post-stroke hemiplegic patient. 1. a method for evaluation of physical performance," *Scandinavian Journal of Rehabilitation Medicine*, vol. 7, no. 1, pp. 13–31, 1975. PMID:1135616.
- [22] A. Heller, D. T. Wade, V. A. Wood, A. Sunderland, R. L. Hewer, un E. Ward, "Arm function after stroke: measurement and recovery over the first three months," *Journal of Neurology, Neurosurgery, and Psychiatry*, vol. 50, no. 6, pp. 714–719, 1987. [Online]. Available: <https://doi.org/10.1136/jnnp.50.6.714>. [Accessed Feb. 25, 2024].
- [23] V. Mathiowetz, G. Volland, N. Kashman, and K. Weber, "Adult norms for the Box and Block Test of manual dexterity," *The American Journal of Occupational Therapy: Official Publication of the American Occupational Therapy Association*, vol. 39, no. 6, pp. 386–391, 1985. [Abstract]. Available: <https://doi.org/10.5014/ajot.39.6.386>. [Accessed Feb. 25, 2024].
- [24] A. Jain, R. Bansal, A. Kumar, and K.D. Singh, "A comparative study of visual and auditory reaction times on the basis of gender and physical activity levels of medical first year students," *International Journal of Applied and Basic Medical Research*, vol. 5, no. 2, pp. 124–127, 2015. [Abstract]. Available: <https://doi.org/10.4103/2229-516X.157168>. [Accessed Feb. 25, 2024].
- [25] B.E. Hilbig, "Reaction time effects in lab- versus Web-based research: Experimental evidence," *Behavior Research Methods*, vol. 48, no. 4, pp. 1718–1724, 2016. [Online]. Available: <https://doi.org/10.3758/s13428-015-0678-9>. [Accessed Feb. 25, 2024].
- [26] E. Brenner and J. Smeets, "How can you best measure reaction times?" *Journal of Motor Behavior*, vol. 51, no. 5, pp. 486–495, 2019. [Online]. Available: <https://doi.org/10.1080/00222895.2018.1518311>. [Accessed Feb. 25, 2024].
- [27] "UEQ: User Experience Questionnaire," 2018. Available: [Online]. Available: <https://www.ueq-online.org/>. [Accessed Feb. 25, 2024].
- [28] A. Bangor, P. Kortum, and J. Miller, "Determining What Individual SUS Scores Mean: Adding an Adjective Rating Scale," *Journal of Usability Studies*, vol. 4, no. 3, pp. 114-123, 2009. Available: [Online]. Available: <https://uxpajournal.org/determining-what-individual-sus-scores-mean-adding-an-adjective-rating-scale/>. [Accessed Feb. 25, 2024].
- [29] J. Brooke, "SUS: A Retrospective," *Journal of Usability Studies*, vol. 8, no. 2, pp. 29-40, 2013. Available: [Online]. Available: <https://uxpajournal.org/sus-a-retrospective/>
- [30] WMA, "DECLARATION OF HELSINKI 1964," 1964. Available: [Online]. Available: <https://www.wma.net/what-we-do/medical-ethics/declaration-of-helsinki/doh-jun1964/>. [Accessed Feb. 25, 2024].
- [31] Y. C. Liu, Y. R. Yang, Y. A. Tsai, and R. Y. Wang, "Cognitive and motor dual task gait training improve dual task gait performance after stroke - A randomized controlled pilot trial," *Scientific Reports*, vol. 7, no. 1, art. 4070, 2017. [Online]. Available: <https://doi.org/10.1038/s41598-017-04165-y>. [Accessed Feb. 25, 2024].
- [32] N. Hugues, C. Pellegrino, C. Rivera, E. Berton, C. Pin-Barre, and J. Laurin, "Is High-Intensity Interval Training Suitable to Promote Neuroplasticity and Cognitive Functions after Stroke?" *International Journal of Molecular Sciences*, vol. 22, no. 6, art. 3003, 2021. [Online]. Available: <https://doi.org/10.3390/ijms22063003>. [Accessed Feb. 25, 2024].

- [33] K. Thomson, A. Pollock, C. Bugge, and M. Brady, "Commercial gaming devices for stroke upper limb rehabilitation: a systematic review," *International Journal of Stroke*, vol. 9, no. 4, pp. 479–488, 2014. [Abstract]. Available: <https://doi.org/10.1111/ijss.12263>. [Accessed Feb. 25, 2024].
- [34] M. H. Chen, L. L. Huang, and C. H. Wang, "Developing a Digital Game for Stroke Patients' Upper Extremity Rehabilitation – Design, Usability and Effectiveness Assessment," *Procedia Manufacturing*, vol. 3, pp. 6-12, 2015. [Online]. Available: <https://doi.org/10.1016/j.promfg.2015.07.101>. [Accessed Feb. 25, 2024].
- [35] P. Wang, G. C. H. Koh, C. G. Boucharenc, and C. C. Yen, "Designing Two-player Competitive Games for the Rehabilitation of Upper-Limb Motor Function after Stroke," *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, pp. 2201-2209, 2017. [Abstract]. Available: <https://doi.org/10.1145/3027063.3053069>. [Accessed Feb. 25, 2024].
- [36] S. E. Farmer, V. Durairaj, I. Swain, and A. D. Pandyan, "Assistive technologies: can they contribute to rehabilitation of the upper limb after stroke?" *Archives of Physical Medicine and Rehabilitation*, vol. 95, no. 5, pp. 968–985, 2014. [Abstract]. Available: <https://doi.org/10.1016/j.apmr.2013.12.020>. [Accessed Feb. 25, 2024].
- [37] B. Zhang, D. Li, Y. Liu, J. Wang, and Q. Xiao, "Virtual reality for limb motor function, balance, gait, cognition and daily function of stroke patients: A systematic review and meta-analysis," *Journal of Advanced Nursing*, vol. 77, no. 8, pp. 3255–3273, 2021. [Online]. Available: <https://doi.org/10.1111/jan.14800>. [Accessed Feb. 25, 2024].
- [38] A. Basteris, S. M. Nijenhuis, A. H. Stienen, J. H. Buurke, G. B. Prange, and F. Amirabdollahian, "Training modalities in robot-mediated upper limb rehabilitation in stroke: a framework for classification based on a systematic review," *Journal of Neuroengineering and Rehabilitation*, vol. 11, art. 111, 2014. [Online]. Available: <https://doi.org/10.1186/1743-0003-11-111>. [Accessed Feb. 25, 2024].
- [39] L. Myers, "The Test-Retest Reliability and Minimal Detectable Change of the FitLight Trainer™," *Masters of Education in Human Movement, Sport, and Leisure Studies Graduate Projects*, no. 88, 2021. [Online]. Available: https://scholarworks.bgsu.edu/hmsls_mastersprojects/88/. [Accessed Feb. 25, 2024].
- [40] A. D. H. Al-Selmi and M. S. Hosen, "The Effect of Using Fit Light Exercise in Some Physiological Indicators and Smash Shot for Badminton's Players," *International Journal of Psychosocial Rehabilitation*, vol. 24, no. 3, pp. 4172-4177, Mar. 2020. [Online]. Available: <https://doi.org/10.13140/RG.2.2.33641.31843>. [Accessed Feb. 25, 2024].
- [41] M.A. Rogozhnikov, A.E. Baturin, Yu.V. Yakovlev, A.E. Kuritsyna, "'FITLIGHT' Training System Benefits for Neuromuscular Control Training in Basketball," in *Theory and Practice of Physical Culture*, no. 9, pp. 10-12, 2020. [Online]. Available: <https://cyberleninka.ru/article/n/fitlight-training-system-benefits-for-neuromuscular-control-training-in-basketball>. [Accessed Feb. 25, 2024].
- [42] N.V. Chepanov, "Improvement of reaction speed of karate teens with the use of the simulator «Blazepod»," *Physical Culture. Sport. Tourism. Motor Recreation*, vol. 6, no. 3, pp. 39-45, 2021. [Abstract]. Available: <https://doi.org/10.47475/2500-0365-2021-16306>. [Accessed Feb. 25, 2024].

A method for determining and evaluating webometric indicators of public libraries

Diyora Talipova

Library information system
department Tashkent University of
Information Technologies
Tashkent, Uzbekistan
diyoratalipova7@gmail.com

Barno Ganiyeva

Library information system
department Tashkent University of
Information Technologies
Tashkent, Uzbekistan
barno_1972@mail.ru

Sherbek Normatov

Library information system
department Tashkent University of
Information Technologies
Tashkent, Uzbekistan
shb.normatov@gmail.com

Marat Rakhmatullayev

Library information system
department Tashkent University of
Information Technologies
Tashkent, Uzbekistan
marat56@mail.ru

Abstract. The complexity of modern social communications and the transformation of society's information environment create unique competition among public digital libraries to attract readers. Library websites play an important role in managing the activities of digital libraries and improving their position in the information space. In general, the website is considered the "calling card" of the electronic library. It is not only a means of communication between readers and the library, but also a source of information that allows you to evaluate the activities of the library based on information about the use of library website by readers. The purpose of the study is to develop a data processing method to improve the efficiency of evaluating public library information resources and websites. A method and algorithm for expert assessment of a site using fuzzy logic are proposed. The article presents the possibilities of using web analytics to determine webometric indicators of a library website, study user behavior patterns, as well as analysis that improves the functionality of the site. Libraries are offered a comprehensive method for multi-criteria evaluation of websites. The essence of this method is that with this method we can not only evaluate the website in a traditional way, but also get the following useful results: full evaluation of websites, evaluation of websites according to certain criteria, selective comparison and ranking of websites are presented. An analysis of classification criteria for evaluating public library websites is presented. To minimize subjectivity when evaluating a website, the evaluation process can involve not only experts, but also a wider audience through online and offline surveys. In general, assessment of electronic public library websites is necessary

not only to determine the rating of libraries, but also to make the right management decisions, as well as to determine the needs and interests of readers.

Keywords: *Assessment, electronic public library, webometrics, website.*

I. INTRODUCTION

Today, the development of public libraries is determined by the globalization of activities, increasing the level of technology and intellectualization. During the development of digital technologies, the information-library sector is becoming a center of cognitive resource management in people's intellectual practice, and remote service to the population through websites has become more and more widespread. The website of public libraries is their lifeline and websites are mainly used as an advertising platform to present the virtual image of the library and the information and services provided by the library. According to analysis, library websites in the web space today, analytical tools for effective performance evaluation are becoming more and more popular. Specifically, webometrics is a tool for measuring websites, web pages, phrases on web pages, website visits, hyperlinks, web search results [1].

In the development of new recommendations for improving the efficiency of user services to provide high-quality remote service based on information from public library websites, it is necessary to study data on the number of visits, duration of website use by users,

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8046>

© 2024 Diyora Talipova, Barno Ganiyeva, Sherbek Normatov, Marat Rakhmatullaev.

Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

determine the goals of user visits and determine webometric indicators [2]. Analyzing and testing information access using webometric indicators, and also allows users to independently compare library sites.

II. METHODS OF DETERMINING WEBOMETRIC INDICATORS OF LIBRARY WEBSITES

Webometric research on webometric tools and its current state includes four main directions. These are:

1. Analysis of web page content [3] - [4];
2. Analysis of the structure of web links;
3. Website usage analysis (including users' search and browsing behavior) [5];
4. Analysis of web technologies (search engine performance) [6].

Public libraries are the main knowledge center for users and it is important that information is presented on relevant homepages through websites, but even the highest scoring libraries are observed to meet only half of these requirements. The role of library websites in marketing and quality assurance related to these issues should be taken seriously by library professionals. Islam and Alam studied and analyzed the library websites of private universities in Bangladesh [7]. Their study showed that some private university libraries in Bangladesh proposed different criteria to classify the main indicators in this study for their websites. Although libraries have a higher number of web pages, but their number of link pages is very small, so it turns out that websites with self-linking, external links do not have an international impact factor. Because library websites provide access to many resources, monitoring their performance and understanding user flow is critical to promoting these resources. Evaluating library website performance has become a key factor in determining the relative success or failure of a library service [8].

A. The purpose of the study

The purpose of the study is to increase the information content of libraries and develop their services by evaluating their websites according to various criteria.

To realize the goal, a number of tasks are solved: analysis of criteria and methods of evaluation of libraries, scientific and educational resources, clarification of evaluation criteria and addition of new criteria.

Although there is general agreement on the content of library websites, each library's mission should be reflected. For this reason, public library websites should generally provide a wider range of information appropriate to their broad range of activities than other libraries. When evaluating websites, it is important to consider not only the presence of these indicators, but also the way in which they are presented.

B. Library monitoring

- in the forming of operational tasks and strategic goals;
- in the development of library development concepts;
- when making a decision about the organizational structure of the library;
- monitoring the flow of users and increasing the number of visits to the library;

- used in cases such as library activity research in various fields [9].

The purpose of monitoring of public libraries is often formed on the basis of the problem areas of their activities. These are the following:

- preparation for using the quality assessment system;
- to determine the optimal set of evaluation indicators, taking into account the actual and expected capabilities of the library;
- to study the unsatisfied demand of users for library documents;
- helps to determine the true extent of monitoring indicators such as dealing with refusals and satisfaction of users of library services.

The quality of library services can also be assessed based on the results of an annual user satisfaction survey [10].

Users' need for information is increasing and thematic queries are becoming more complex. In particular, users are increasingly delegating information retrieval and preprocessing tasks to library professionals. Today, in addition to the thematic survey, there is a growing demand for webometric analysis of search results.

C. Criteria of library websites

- Online catalog statistics. Measures the total number of searches performed within the system to find items.
- Searches by category. It allows websites to know how end users use directories.
- Check items. Allows comparison of librarian requests with requests made through book delivery services.
- Electronic services. It helps librarians to determine the level of demand for which types of media (physical and electronic).
- Update items. Libraries determine the possibility to clarify the processes carried out and to update the library information [11].
- Online surveys. This allows librarians to gauge the popularity of books
- Interlibrary subscription requests. It measures the volume and specific items available for interlibrary patron requests.
- Library reports. Statistical information helps librarians to better serve the public and optimize internal management.
- User visits. This indicator determines the level of visits of applicants to librarians and the use of mass media [12].

III. CRITERIA FOR EVALUATING WEBOMETRIC INDICATORS OF LIBRARY WEBSITES

On the basis of the studied methods, the webometric indicators were summarized and the data was pre-processed on the basis of the analysis, and the information classification of the system for determining the webometric indicators of public library websites was developed. This classification of information is reflected in "Fig. 1".

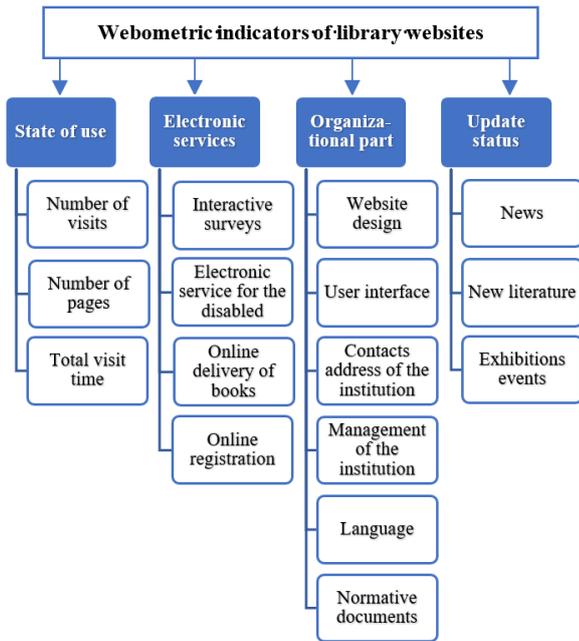


Fig.1. Information classification of the system for determining webometric indicators of public library websites.

Above is an analysis of several quantitative and qualitative criteria for evaluating library websites. It is not difficult to evaluate the performance of the website based on criteria that accept quantitative values, such as the number of visitors to the library's website in a certain period of time, the frequency of updating the website content, the number of interactive services. However, quality indicators such as relevance of website content, completeness and reliability of information, ease of website interface, on the one hand, have ambiguous values, and on the other hand, they are subjective in nature. Therefore, the method of fuzzy variables is proposed to solve this type of problem.

Thus, to evaluate the effectiveness of library websites, the fuzzy variable $\Omega_R = \text{"Assessment of library website effectiveness"}$ is introduced, which receives fuzzy values $M = \{M_1, M_2, M_3, M_4\}$. Here $M_1 = \text{"Low effective"}$, $M_2 = \text{"Medium effective"}$, $M_3 = \text{"Very effective"}$, $M_4 = \text{"Highly effective"}$ are the term values.

A scoring method of expert evaluation is presented to determine the carrier of the set Ω_R consisting of M term-values. The factors that have a strong influence on the effectiveness of the website were selected on Table 1.

Although there are actually several factors for evaluating a website, the 7 most important factors have been selected in this project.

TABLE 1 CRITERIA FOR EVALUATING WEBOMETRIC PERFORMANCE OF PUBLIC LIBRARY WEBSITES

Indicator symbol	Indicator name	Evaluation criteria
A_1	relevance of library website content	0 – not relevant; 1 – less relevant; 2 – moderately relevant; 3 – more relevant; 4 – very expensive

A_2	ease of use of the library website	0 – uncomfortable; 1 – less convenient; 2 – moderately comfortable; 3 – very convenient; 4 – very comfortable
A_3	completeness of library website content	0 – partial information can be obtained; 1 – medium fullness; 2 – almost complete; 3 – complete; 4 – the presence of hyperlinks
A_4	reliability of library website content	0 – resources are not available; 1 – there are some reliable sources; 2 – average reliability; 3 – reliable; 4 – availability of verification
A_5	the number of visits to the library website	0 – up to 10 in 1 month; 1 – up to 100 in 1 month; 2 – up to 1000 in 1 month; 3 – up to 10,000 in 1 month; 4 – more than 10000 in 1 month
A_6	average time of visit to the library website	0 – 1-5 seconds; 1 – 6-10 seconds; 2 – 11-30 seconds; 3 – 31-60; 4 – more than 1 minute
A_7	number of interactive services available on the library website	0 – does not exist; 1 – 1-2; 2 – 3-5; 3 – 6-9; 4 – 10 and above

These factors $A_1, A_2, A_3, A_4, A_5, A_6$ and A_7 characterize the level of efficiency of the library website.

The set carrier Ω_R is determined on the basis of a Table 2 filled by experts and it is in the range $[0;28]$.

TABLE 2 Ω_R IS MATRIX FOR CALCULATING THE SET CARRIER

Factors	Term values			
	M_1	M_2	M_3	M_4
A_1	0	0-1	1-2	2-4
A_2	0-1	1-2	1-3	2-4
A_3	0	1-2	2-3	2-4
A_4	0-1	0-2	1-3	3-4

A_5	0-2	1-2	2-3	2-4
A_6	0-1	0-2	1-3	3-4
A_7	0-1	1-2	2-3	3-4
$\sum M_i$	0-6	4-13	10-20	17-28

For each fuzzy set, the value of the relevance function $\mu_{M_j}(x_i)$ of the trapezoidal form defined by the term-values M_1, M_2, M_3, M_4 is determined.

$$\mu_{M_1}(x) = \begin{cases} 1, & 0 \leq x \leq 2 \\ \frac{6-x}{4}, & 2 < x < 6 \\ 0, & 6 \leq x \end{cases}$$

$$\mu_{M_2}(x) = \begin{cases} 0, & x \leq 4 \\ \frac{x-4}{5}, & 4 < x < 9 \\ 1, & 9 \leq x \leq 11 \\ \frac{13-x}{3}, & 11 < x < 13 \\ 0, & 13 \leq x \end{cases}$$

$$\mu_{M_3}(x) = \begin{cases} 0, & x \leq 10 \\ \frac{x-10}{6}, & 10 < x < 16 \\ 1, & 16 \leq x \leq 18 \\ \frac{20-x}{2}, & 18 < x < 20 \\ 0, & 20 \leq x \end{cases}$$

$$\mu_{M_4}(x) = \begin{cases} 0, & x \leq 17 \\ \frac{x-17}{6}, & 17 < x < 23 \\ 1, & 23 \leq x \leq 28 \end{cases}$$

“Fig. 2” shows the graph of the relevance function. The graph of the function M_1, M_2, M_3, M_4 describes the relevance of term-values with a certain interval.

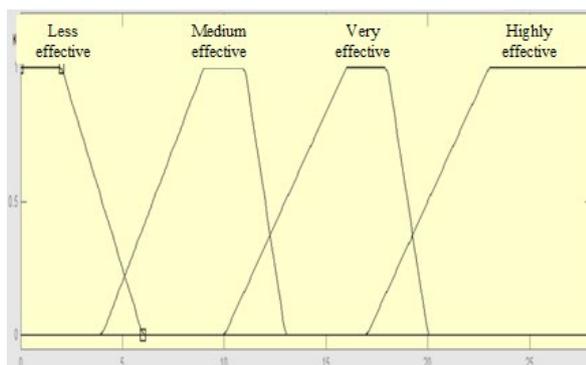


Fig. 2. the relevance function of the fuzzy variable "Assessment of the effectiveness of the library website".

For each factor, the score of the experts is set and filled in as in Table 3.

TABLE 3 LIBRARY WEB SITE PERFORMANCE INDICATOR MATRIX

Web site	A_1	A_2	A_3	A_4	A_5	A_6	A_7	K_{r_i}	μ_{D_1}	μ_{D_2}	μ_{D_3}	μ_{D_4}
r_1	2	3	1	2	2	2	1	13	0	0.5	0	0
r_2	3	2	1	2	1	2	0	11	0	1	0	0
r_3	4	2	3	1	2	3	2	17	0	0	1	0
r_4	3	4	2	2	1	0	1	13	0	0.5	0	0
r_5	1	2	3	1	4	4	3	18	0	0	1	0.17

$K_{r_i} = \sum_{i=1}^7 A_i$, $\max \mu_{M_i}$ – is an assessment of the effectiveness of a library website.

Based on the data presented in Table 3, the following conclusions can be drawn:

For example, r_2 website rating is "medium effective with a weight of 1"; the r_5 website is rated as "fairly effective with a weight of 1, highly effective with a weight of 0.17".

The application of this method allows websites to make decisions in conditions of uncertainty and inaccuracy of their evaluation parameters. Assessment is carried out using the expert assessment method. Highly qualified specialists or scientists working in the library field are involved as experts.

IV. SUMMARY

The proposal of the evaluation criteria of library websites listed above serves as a factor in the development of libraries' services by increasing the information content and evaluating their websites according to various criteria.

A number of tasks aimed at carrying out this research were solved, the criteria and methods of evaluating the scientific and educational resources of libraries were analyzed, the evaluation criteria were clarified and new criteria were added.

Ease of use of web analytics to monitor library website, study user behavior patterns leads to solutions that improve website functionality. These include defining user tasks during development, conducting user tests to better understand the phenomenon, monitoring data to verify the effectiveness of input, and collecting additional data. Studying and evaluating data about the duration of use of websites and the number of visits helps to determine the goals of users' visits and develop new recommendations. Web analytics tools are useful for tracking and evaluating the behavior of public library website users, identifying user content, identifying tracking methods, and subsequently improving performance. Also, the proposed method of fuzzy variables for evaluating the effectiveness of public library websites allows to make decisions in the presence of criteria with quality indicators, as well as in conditions of inaccuracy and uncertainty of information.

REFERENCES

- [1] G.Muruganandham, Webometrics research methods adopted in library and information science: an overview. *Library Philosophy and Practice* (e-journal). 2019.
- [2] A.V. Mikhailova, Culture institutes libraries web pages analysis as an instrument of information and education resources integration external direction implementation. *Culture and arts herald*, 2017, 3, pp. 49-59.
- [3] S. Novljan, and M.Zumer. "Web pages of Slovenian public libraries: evaluation and guidelines", *Journal of Documentation*, vol. 60, №1, pp. 62-76.
- [4] L. B. Shevchenko. Content analysis of websites of libraries of scientific institutions. 02:004. <https://doi.org/10.33186/1027-3689-2022-1-71-90>.
- [5] P. V. Skorodumov and A. Y. Kholodev. Analysis of the website popularity of a scientific institution using various systems to collect statistical data. 2016, pp. 1-10.
- [6] R. Jan and T. Zainab. The impact story of retracted articles Altmetric it! Paper presented at 5th International Symposium on Emerging Trends and Technologies in Libraries and Information Services (ETTLIS). New Dehli, 2018. pp. 402-406. DOI: 10.1109/ETTLIS.2018.8485245.
- [7] M. Islam and S. M. Alam, 2011, "Webometric study of private universities in Bangladesh," *Malaysian Journal of Library & Information Science*, vol. 16, no. 2, pp. 115-126.
- [8] Davydova, O. Marina, A. Solianyuk and Y. Syerov, Social Networks in Developing the Internet Strategy for Libraries in Ukraine. In: CEUR Workshop Proceedings. Vol 2392: Proceedings of the 1st International Workshop on Control, Optimisation and Analytical Processing of Social Networks, COAPSN-2019, pp. 122-133.
- [9] J. Pisanski and M. Zumer. "National library web sites in Europe: an analysis", *Program: electronic library and information systems*, Vol.39, №3, pp. 213-226. <https://doi.org/10.1108/00330330510610564>.
- [10] K. H. Ramanayaka, X. Chen and B. Shi, "Application of Webometrics Techniques for Measuring and Evaluating Visibility of University Library Websites in Sri Lanka". *Journal of the University Librarians Association of Sri Lanka*, Vol.21, Issue 1, January 2018.
- [11] *Learning Analytics from Research to Practice: A Content Analysis to Assess Information Quality on Product Websites*. S. Sarmonpal. Pepperdine University ProQuest Dissertations Publishing, 2018.
- [12] M. K. Verma and K. D. Krishna "Content Analysis of Central Universities Library Websites of North Eastern States of India: A Survey". *Journal of Research in Librarianship* - Vol.2 (5) Sep-Oct, 2015

Integrating Mixed Reality with Neural Networks for Advanced Molecular Visualization in Bioinformatics: A Mathematical Framework for Drug Discovery

Ivan Trenchev

*Faculty of Information Sciences
University of Library Studies and
Information Technologies
South-West University "Neofit Rilski"
Sofia, Bulgaria
i.trenchev@unibit.bg*

Tereza Trencheva

*Faculty of Library Studies and
Cultural Heritage
University of Library Studies and
Information Technologies
Sofia, Bulgaria
t.trencheva@unibit.bg*

Vladimir Angelov

*Faculty of Library Studies and
Cultural Heritage
University of Library Studies and
Information Technologies
Sofia, Bulgaria
ang.vladimir@abv.bg*

Yordan Spirov

*Faculty of Information Sciences
University of Library Studies and
Information Technologies
Sofia, Bulgaria
jspirov@yahoo.com*

Yana Karshiyska

*Faculty of Information Sciences
University of Library Studies and
Information Technologies
Sofia, Bulgaria
4622119-2@unibit.bg*

Kamelia Shumanova

*Faculty of Information Sciences
University of Library Studies and
Information Technologies
Sofia, Bulgaria
shumanova7su@abv.bg*

Abstract. In this study, we develop and present an innovative approach that integrates Mixed Reality (MR) technologies with neural network algorithms, aiming to revolutionize molecular structure visualization in bioinformatics through the application of mathematical methods. The development includes the creation of a mathematical framework aimed at optimizing drug discovery processes, utilizing the potential of MR to facilitate detailed and interactive exploration of molecules in three-dimensional space.

Our approach is based on the use of Unreal Engine for the realization of a simulation environment and the application of Python and PyTorch for the development of complex neural network models. These models are capable of efficiently processing and analyzing molecular data, enabling scientifically grounded manipulation of molecular structures. This approach facilitates the identification of potential active sites for interaction with pharmaceutical agents, improving the efficiency and speed of the drug discovery process.

A key aspect of our work is the development of a comprehensive mathematical framework that effectively simplifies and optimizes molecular design and analysis, while simultaneously increasing the accuracy of predictions for interactions between potential drug molecules and their targets. This approach not only enriches our understanding

of the molecular basis of diseases but also offers a more rational and economical path to pharmacological development.

In conclusion, we propose a new approach that we hope will be considered and applied by the scientific community. This method presents a promising opportunity for advancement in research and development in bioinformatics and pharmacology, providing a solid foundation for further exploration of molecular dynamics and drug discovery through the application of mathematical and computer sciences.

Keywords: *Mixed Reality, Bioinformatics, Neural Networks.*

I. INTRODUCTION

In our previous research, we build upon the innovative integration of Mixed Reality (MR) with bioinformatics from our previous work, by introducing neural network algorithms to enhance molecular visualization. This progression involves a deeper mathematical framework tailored for drug discovery, emphasizing the synergy between MR's interactive 3D exploration capabilities and neural networks' analytical precision. Utilizing Unreal Engine for simulation environments and Python with PyTorch for neural modeling, we aim to revolutionize

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8033>

© 2024 Ivan Trenchev, Tereza Trencheva, Vladimir Angelov, Yordan Spirov, Yana Karshiyska, Kamelia Shumanova.

Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

molecular analysis and design, improving drug discovery's efficiency and accuracy. This comprehensive approach seeks to bridge complex molecular dynamics with pharmacological research, offering a more informed and cost-effective pathway for developing therapeutic solutions [1], [4], [13].

In this research explores the innovative application of mixed reality (MR) in the field of bioinformatics, particularly in enhancing genomic data analysis and visualization. It outlines a methodology incorporating Unreal Engine, MATLAB, and NAMD for dynamic simulation and visualization, addressing computational and data processing challenges. Highlighting MR's potential to improve collaboration, data interpretation, and innovation, the paper positions MR as a transformative tool for genomic research, paving the way for advanced exploration and understanding of complex biological data [6], [7], [9].

By employing a multidisciplinary methodology that synergizes Unreal Engine's immersive simulation capabilities with MATLAB's computational prowess and NAMD's molecular dynamics simulation, the research underscores the transformative potential of MR in genomic studies. This integration facilitates a more intuitive and interactive examination of complex genomic data, potentially leading to groundbreaking advancements in bioinformatics research. The paper argues for the enhanced collaborative and analytical capabilities afforded by MR, promising significant strides in the interpretation of genomic information and the acceleration of bioinformatics methodologies. This exploration serves as a cornerstone for future investigations, aiming to leverage MR and computational innovations to unravel the complexities of genomic data, thus fostering a deeper understanding of biological processes and enhancing drug discovery and development pipelines [12], [14], [15].

In this continuation of our exploration into the integration of Mixed Reality (MR) technologies in bioinformatics, we delve into the sophisticated realm of neural networks. Building on the foundation laid by our previous study on MR for molecular visualization, we now introduce advanced neural network algorithms to further enhance our mathematical framework for drug discovery. This novel approach leverages the dynamic capabilities of MR alongside the computational power of neural networks, aiming to refine and accelerate the identification of potential drug targets. By incorporating Unreal Engine, Python, and PyTorch, we develop intricate models for the meticulous analysis of molecular structures, offering new insights into the molecular dynamics crucial for pharmacological innovation. This step forward not only amplifies our understanding of molecular interactions but also streamlines the pathway towards more effective and economically viable drug development [19].

In this article, we explore the application of search algorithms in the field of artificial intelligence, approaching them with rigorous mathematical analysis. The search algorithms we examine include optimization and graph search methods like A* and genetic algorithms, as well as neural network models for pattern recognition. We pay special attention to the mathematical structures underlying these algorithms, such as the evaluation functions in A* ($f(n) = g(n) + h(n)$), where $g(n)$ represents the actual cost

from the start point to n , and $h(n)$ is a heuristic estimate of the distance from n to the goal. This analysis highlights how mathematical principles and algorithmic strategies can be combined to develop effective solutions in artificial intelligence [5], [6], [21]:

A* Algorithm: Utilizes a function $f(n) = g(n) + h(n)$, where $g(n)$ is the cost from the start point to node n , and $h(n)$ is a heuristic estimate of the distance from n to the goal. This approach minimizes the total score $f(n)$ to find the most efficient path to the goal.

Genetic Algorithms: Model the process of natural selection, where solutions are represented as a set of genes. Selection, crossover, and mutation operators are applied to the solution population to generate new populations with improved characteristics.

Neural Networks: Mathematically described using layers of neurons connected by weights, which are adjusted during training. Training typically uses backpropagation and optimization methods like gradient descent to minimize the difference between the actual and expected output.

II. METHODOLOGY

The methodology employed in the article centers on the development of a simulation environment, utilizing Unreal Engine, a robust platform for creating immersive 3D environments. This approach is designed to visualize molecular interactions in real-time, thereby enhancing the understanding of complex biological processes. The use of Unreal Engine facilitates detailed modeling and interactivity, transforming how scientific research visualizes and analyzes molecules. This approach also integrates the latest advancements in computational biology and neural networks, enriching analytical capabilities and accelerating scientific discoveries [21].

Integrating Python and PyTorch into Unreal Engine 5 (UE5) can greatly enhance the capabilities for developing interactive and intelligent applications. Python offers a wide range of possibilities for automation, data processing, and scripting within UE5, streamlining development workflows. PyTorch, being a leading deep learning library, enables the implementation of advanced machine learning models, including real-time AI simulations and complex data analysis directly within the UE5 environment. This integration can lead to more dynamic and responsive game elements, realistic simulations, and innovative uses of AI in virtual spaces, pushing the boundaries of what's possible in game development and interactive applications [8].

In our research methodology, we employ Convolutional Neural Networks (CNNs) for the analysis and classification of various molecules as potential drugs and for exploring their application in medicine. These networks process and analyze large datasets to identify patterns and characteristics of molecules that could be crucial for developing new therapies. This approach enables a deeper understanding of molecular mechanisms and aids in accelerating the drug discovery process [2], [3].

The application of Convolutional Neural Networks (CNNs) in our methodology extends to the refinement of drug discovery processes by enabling precise prediction and classification of molecular interactions. By leveraging

the computational power of CNNs, we can systematically analyze the efficacy and potential side effects of candidate compounds, thereby streamlining the selection of viable therapeutic agents. This innovative approach not only enhances the efficiency of identifying new drugs but also significantly reduces the time and resources required for traditional drug discovery methods [4], [11].

The methodology for identifying and analyzing the size of cavities within molecules and searching for suitable drug candidates involves computational techniques and molecular simulation. Initially, molecular structures are scanned to detect cavities using algorithms that can accurately map the spatial dimensions of molecules. Subsequently, analysis tools, often based on principles of computational chemistry and physics, evaluate the potential of these cavities to bind with drug-like molecules. This involves calculating interaction energies, fitting scores, and assessing the geometric compatibility of potential drugs with the target site [17].

A mathematical description of the methodology for identifying and analyzing the size of cavities within molecules and searching for suitable drug candidates involves the following steps [11]:

Scanning molecular structures: Let's consider a molecule M with a spatial structure described in a coordinate system. With an algorithm denoted as $A_{scan}(M)$, we can find points in space that form cavities within the molecule.

Let M represent a molecule with a spatial structure described by the coordinates of its atoms (let atoms be indexed as $i = 1, 2, \dots, N$). We can represent this process as follows:

For each point r in space (representing a potential cavity location), we check if it is in proximity to the atoms of molecule M using the following formula:

$$\min_{i=1}^N |r - r_i| > R_{min}$$

where:

r represents the coordinates of the point in space,

r_i represents the coordinates of atom i in molecule M ,
and

R_{min} is the minimum distance that should be maintained between the point r and the atoms of the molecule. If the condition in the formula is met, then the point r is considered part of the cavity within molecule M .

This process continues for each point in space, resulting in a set of points that constitute the cavities within molecule M .

Computational chemistry and physics: Using principles from computational chemistry and physics, we can define a function $E(M)$ that calculates the energy of interaction between the cavities and potential drug candidates.

$$E(M) = \sum_{i=1}^N E_i$$

Calculation of interaction energies: We provide the function $E(M)$ and determine the values of interaction energies E_i for each cavity i .

Assessment of compatibility: Using geometric parameters and mathematical models, we can assess the degree of compatibility between the cavities and potential drug candidates. This can be represented as a function $S(i)$ that evaluates compatibility for each cavity i .

These mathematical algorithms and functions are used in conjunction with specialized software tools and optimization models to automate the process of searching for suitable drug candidates, minimizing the overall interaction energy, and maximizing the compatibility between molecules [10].

III. RESULT AND DISCUSSION

Unreal Engine 5 (UE5) offers robust capabilities for integrating and utilizing artificial intelligence (AI) in the development of games and virtual environments. Here are some of the key features and tools that UE5 provides for working with AI:

1. Advanced Navigation System: UE5 is equipped with an advanced navigation system that enables AI characters (NPCs) to move through complex environments intelligently. This system supports the automatic generation of navigation meshes, facilitating NPCs in avoiding obstacles and pursuing players or other targets within the environment efficiently.

2. Behavior Trees and Blackboard Components: UE5 utilizes Behavior Trees and Blackboard components for crafting intricate AI behaviors. Behavior Trees allow developers to structure AI logic in decision trees, whereas the Blackboard serves as a shared memory for AI agents, enabling the storage of statuses and decision-making based on variables.

3. AI Perception System: The AI Perception System in UE5 enables AI agents to detect players and other objects within the environment through vision, hearing, and other sensors. This allows for the creation of more realistic NPC behaviors that respond to changes in their surroundings.

4. Machine Learning and AI Model Integration: While UE5 does not directly provide support for machine learning within the engine, developers can integrate external machine learning models and AI tools through plugins and APIs. This enables the incorporation of sophisticated AI algorithms and models for behavior prediction, automation, and analysis in games and applications.

5. Support for Agents and Multi-user AI: UE5 supports the creation of complex multi-user environments with multiple AI agents that can interact with each other and with players in real time.

6. Graphical AI Editor: UE5 offers visual tools for creating and debugging AI logic, making the development process accessible and convenient for developers without extensive programming knowledge.

These capabilities make UE5 an exceptionally powerful tool for creating dynamic and intelligent virtual environments where AI plays a central role in character behavior and game dynamics.

Our objective is to employ the methodology of drug discovery as a game, where the disease represents the adversarial player, and the identification of a cure signifies

victory. This paradigm conceptualizes the complex process of drug discovery as a strategic contest, in which the pathogen or disease condition is the antagonist that must be outmaneuvered or defeated. The pursuit of therapeutics becomes a series of strategic moves akin to a game, where understanding the biology of the disease, identifying potential targets, and developing molecules that can effectively interact with these targets are critical steps towards achieving victory. This approach emphasizes the dynamic and competitive nature of the drug discovery process, framing it as an intellectual challenge where success is achieved through strategic thinking, scientific insight, and innovative experimentation.

Our development is grounded in the utilization of Unreal Engine for creating a simulation environment, coupled with the deployment of Python and PyTorch for the construction of complex neural network models. These models are adept at processing and analyzing molecular data, enabling the scientifically grounded manipulation of molecular structures. This methodology facilitates the identification of potential active sites for interaction with pharmaceutical agents, enhancing the drug discovery process's efficiency and speed. We have devised a comprehensive mathematical framework that simplifies and optimizes molecular design and analysis while increasing the accuracy of predictions for interactions between potential drug molecules and their targets. This approach not only deepens our understanding of the molecular foundations of diseases but also provides a more rational and cost-effective route to pharmacological development.

We utilize PyTorch for its dynamic computational graph that allows for flexibility in adjusting and optimizing neural network architectures during runtime. This capability is particularly beneficial for experimenting with complex molecular data, where models may need to evolve as new insights are gained. PyTorch's extensive library of pre-built functions and modules simplifies the process of implementing deep learning models, enabling efficient processing, analysis, and prediction of molecular interactions and structures. Its intuitive syntax and ease of use facilitate rapid development and testing of neural network models within our simulation environment [5], [10].

In this example, we defined a simple neural network using PyTorch for binary classification with one hidden layer.

```
import torch
import torch.nn as nn
import torch.nn.functional as F
from torch_geometric.nn import GCNConv
# Define the GNN model
class GNN(nn.Module):
    def __init__(self, num_node_features,
num_classes):
        super(GNN, self).__init__()
        self.conv1 = GCNConv(num_node_features,
16)
        self.conv2 = GCNConv(16, num_classes)
    def forward(self, data):
        x, edge_index = data.x, data.edge_index
        x = self.conv1(x, edge_index)
        x = F.relu(x)
```

```
x = F.dropout(x, training=self.training)
x = self.conv2(x, edge_index)
return F.log_softmax(x, dim=1)

num_node_features = 9 # For example, if each
atom has 9 features
num_classes = 3 # For example, if we have
3 classes for molecules
model = GNN(num_node_features, num_classes)

data = ... # You need to load your graph data
here
output = model(data)
```

This simple model demonstrates how PyTorch can be utilized to build neural networks for tasks like molecular classification in drug design, where efficient processing and analysis of molecular data are critical for identifying promising compounds – Fig. 1.

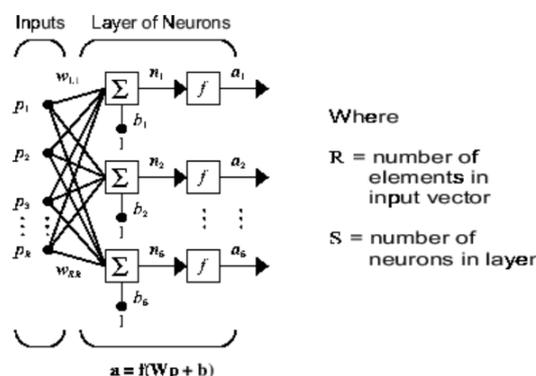


Fig.1 Simple neural network for binary classification /copy from <https://www.mathworks.com/help/deeplearning/ug/neural-network-architectures.html/>

The model defined above, 'ComplexCNN', is a more sophisticated convolutional neural network (CNN) designed for classification tasks in computer vision using PyTorch. This model includes [1], [2]:

- Three convolutional layers ('conv1', 'conv2', 'conv3') with increasing numbers of channels (32, 64, and 128), each followed by a ReLU activation function to introduce non-linearity and a max pooling layer to reduce spatial dimensions and capture important features while discarding irrelevant information.

- A pooling layer ('pool') with a 2x2 kernel and a stride of 2, applied after each convolutional layer to further reduce the size of the feature maps.

- Three fully connected layers ('fc1', 'fc2', 'fc3') to perform classification based on the features extracted by the convolutional layers. The final layer outputs a vector of size 10, assuming there are 10 classes for the classification task.

This architecture is typical for computer vision tasks where the input is an image (in this case, with 3 color channels), and the goal is to classify the image into one of several categories. The use of convolutional layers allows the network to learn spatial hierarchies of features from the input images, making it well-suited for handling the complexities of visual data [4].

The pedagogical process of supervised model training encompasses the optimization of model parameters to diminish the discrepancy between the model's prognosticated output values and the veritable labels of the training data. A pivotal element of this methodology is the computation of the loss function and the employment of backpropagation for the updating of model weights. Predominantly, the cross-entropy function is utilized for classification tasks, whereas the mean squared error serves for regression challenges.

Cross-Entropy Loss (for Classification):

$$L(y, \hat{y}) = - \sum_i y_i \log(\hat{y}_i)$$

Herein, y represents the genuine label (encoded in one-hot encoding format), whilst \hat{y} delineates the probability forecasted by the model for each class.

Mean Squared Error (for Regression):

$$MSE(y, \hat{y}) = \frac{1}{n} \sum_{i=1}^n (y_i - \hat{y}_i)^2$$

In this equation, y is the authentic value, \hat{y} is the value prognosticated by the model, and n signifies the count of instances in the dataset.

Unsupervised Learning

In the realm of unsupervised learning, the model endeavors to unearth latent structures or patterns within the data devoid of preassigned labels. Clustering, exemplified by the K -means method, stands as one of the quintessential techniques in unsupervised learning.

K-means Clustering:

The objective of K-means clustering is to minimize the sum of squared distances between points and their nearest cluster centroid.

$$J = \sum_{i=1}^n \sum_{k=1}^K w_{ik} |x_i - \mu_k|^2$$

Wherein n is the number of examples, K is the cluster count, w_{ik} is a binary indicator denoting whether example i belongs to cluster k , x_i is the example under consideration, and μ_k is the centroid of cluster k [5], [6].

These formulas provide the mathematical foundation for model training in machine learning, with the methodologies for supervised and unsupervised learning being applied in accordance with the specifics of the task and the data available – Fig. 2.

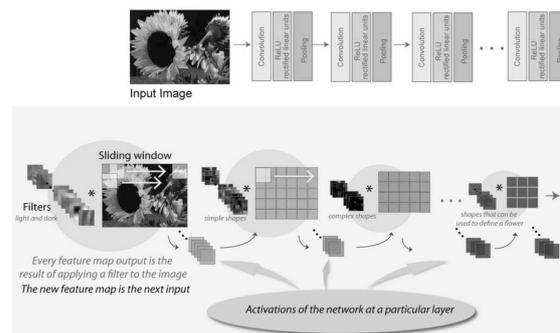


Fig.2. Complex CNN model for classification in computer vision /copy from <https://www.mathworks.com/> /

Within the ambit of the present study, we contemplate the integration of voice commands for the control of simulation processes as a substantial facilitation of both interactivity and efficiency within such systems. Against the backdrop of advancements in automated speech recognition (ASR) and the incursion of deep learning paradigms into this domain, this investigation presents a methodology for the development of a foundational ASR model. The construct is predicated upon the Python programming language, with a pronounced emphasis on the deployment of the 'librosa' library for audio signal processing and 'PyTorch', a leading framework for neural networks [5], [10].

In the context of the investigation, NAMD is indispensable for generating empirical data foundational to the establishment of the mathematical framework proposed for the optimization of drug discovery processes. NAMD's computational capabilities facilitate the simulation of molecular dynamics, providing quantitative insights into atomic interactions and conformational shifts. This simulated output is crucial for constructing an accurate and dynamic representation of molecular systems [18], [20], [22].

When integrated with the proposed framework, the output from NAMD undergoes analytical scrutiny through advanced neural network algorithms, realized through Python and PyTorch. These algorithms conduct a computational analysis of the simulation data, unveiling patterns and interactions not immediately observable. The predictive capacity of neural networks enhances the process of identifying potential active sites and interaction profiles of pharmaceutical relevance.

Moreover, the investigation envisages the use of Unreal Engine's simulation environment to transpose molecular dynamics data into a Mixed Reality (MR) interface. Herein, molecular dynamics simulations from NAMD are transformed into a three-dimensional, interactive space. This MR interface is not merely a visual aid but a scientific apparatus, enabling real-time manipulation of molecular constructs and observation of potential pharmacological interactions within an immersive and intuitive framework [19].

The amalgamation of NAMD's molecular dynamics simulations with data analysis driven by neural networks and the visualization capabilities of MR leads to a comprehensive approach towards molecular design and drug discovery. This confluence aims to surpass traditional

methodologies, promoting a more economical and systematic pathway towards pharmacological innovations [8], [22].

Thus, within the context of the investigation, NAMM emerges not just as a simulation tool but as a cornerstone element that, in conjunction with the proposed mathematical framework, neural networks, and mixed reality technologies, heralds a new era of precision and interactivity in bioinformatics and drug discovery [20].

IV. CONCLUSIONS

The fusion of Unreal Engine, MATLAB, and NAMM into a singular methodology represents a groundbreaking advancement in the realm of bioinformatics research. This synergistic approach enables researchers to harness dynamic simulation, sophisticated visualization, and interactive exploration for the nuanced analysis of genomic data. Through the integration of Unreal Engine and MATLAB, a fluid workflow is established, extending from the initial phases of data processing to the real-time visualization of complex genomic structures. Concurrently, the incorporation of NAMM introduces potent molecular dynamics simulation capabilities, further enriching the research toolkit available for probing the intricacies of genomic phenomena [22].

The integration of Mixed Reality (MR) technologies and neural network algorithms, as discussed in the context of the provided document and elaborated models, signifies a pioneering stride towards the augmentation of molecular structure visualization within the bioinformatics field. This innovative methodology, leveraging the Unreal Engine for simulation environments alongside Python and PyTorch for neural network model development, underscores a multidisciplinary approach to enhancing drug discovery processes. The inception of a mathematical framework dedicated to the optimization of drug discovery processes delineates a novel paradigm that melds the immersive capabilities of MR with the analytical prowess of neural networks. This amalgamation facilitates a more nuanced and interactive exploration of molecular structures in three-dimensional space, thereby enabling a more profound and scientifically informed manipulation of these structures [23]. The proficiency of this approach in identifying potential active sites for interaction with pharmaceutical agents notably augments the efficiency and velocity of the drug discovery process. Furthermore, the establishment of a comprehensive mathematical framework that streamlines and refines molecular design and analysis epitomizes a significant advancement. This framework not only elevates the precision of predictions concerning the interactions between potential drug molecules and their targets but also catalyzes a deeper comprehension of the molecular underpinnings of diseases. Consequently, it paves the way for a more logical and cost-effective trajectory towards pharmacological innovation. In summation, the proposition of this novel approach heralds a promising avenue for progress in bioinformatics and pharmacological research and development. By harnessing the synergy between mathematical, computational sciences, and MR technologies, this methodology offers a robust foundation

for the ongoing exploration of molecular dynamics and drug discovery. It is envisaged that the scientific community will recognize and adopt this approach, thereby leveraging its potential to foster significant advancements in the field [12].

V. ACKNOWLEDGMENTS

This work was supported by the National Science Program "Security and Defense", which has received funding from the Ministry of Education and Science of the Republic of Bulgaria under the grant agreement □ D01-74 /19.05.2022.

REFERENCES

- [1] S. Zinchenko and D. Lishudi, "Star algorithm for neural network ensembling," *Neural Networks*, vol. 170, p. 364–375, February 2024.
- [2] C. Zhao, H. Wang, W. Qi and S. Liu, "Toward drug-miRNA resistance association prediction by positional encoding graph neural network and multi-channel neural network," *Methods*, vol. 207, p. 81–89, November 2022.
- [3] J. Xiao, L. Huang, Y. Song and N. Tang, "A Recursive tree-structured neural network with goal forgetting and information aggregation for solving math word problems," *Information Processing & Management*, vol. 60, p. 103324, May 2023.
- [4] C. Varangot-Reille, G. J. Sanger, P. L. R. Andrews, A. Herranz-Gomez, L. Suso-Martí, J. de la Nava and F. Cuenca-Martínez, "Neural networks involved in nausea in adult humans: A systematic review," *Autonomic Neuroscience*, vol. 245, p. 103059, March 2023.
- [5] H. S. Suh, C. Kweon, B. Lester, S. Kramer and W. Sun, "A publicly available PyTorch-ABAQUS UMAT deep-learning framework for level-set plasticity," *Mechanics of Materials*, vol. 184, p. 104682, September 2023.
- [6] S. Samant, J. J. Bakhos, W. Wu, S. Zhao, G. S. Kassab, B. Khan, A. Panagopoulos, J. Makadia, U. M. Oguz, A. Banga, M. Fayaz, W. Glass, C. Chiastra, F. Burzotta, J. F. LaDisa, P. Iaizzo, Y. Murasato, G. Dubini, F. Migliavacca, T. Mickley, A. Bicek, J. Fontana, N. E. J. West, P. Mortier, P. J. Boyers, J. P. Gold, D. R. Anderson, J. E. Tcheng, J. R. Windle, H. Samady, F. A. Jaffer, N. R. Desai, A. Lansky, C. Mena-Hurtado, D. Abbott, E. S. Brilakis, J. F. Lassen, Y. Louvard, G. Stankovic, P. W. Serruys, E. Velazquez, P. Elias, D. L. Bhatt, G. Dargas and Y. S. Chatzizisis, "Artificial Intelligence, Computational Simulations, and Extended Reality in Cardiovascular Interventions," *JACC: Cardiovascular Interventions*, vol. 16, p. 2479–2497, October 2023.
- [7] M. Sahu, R. Gupta, R. K. Ambasta and P. Kumar, "IoT-driven augmented reality and virtual reality systems in neurological sciences," *Internet of Things*, vol. 25, p. 101098, April 2024.
- [8] J. C. Phillips, D. J. Hardy, J. D. C. Maia, J. E. Stone, J. V. Ribeiro, R. C. Bernardi, R. Buch, G. Fiorin, J. Hénin, W. Jiang, R. McGreevy, M. C. R. Melo, B. K. Radak, R. D. Skeel, A. Singharoy, Y. Wang, B. Roux, A. Aksimentiev, Z. Luthey-Schulten, L. V. Kalé, K. Schulten, C. Chipot and E. Tajkhorshid, "Scalable molecular dynamics on CPU and GPU architectures with NAMM," *The Journal of Chemical Physics*, vol. 153, July 2020.
- [9] A. Patwardhan, A. Ashton, R. Brandt, S. Butcher, R. Carzaniga, W. Chiu, L. Collinson, P. Doux, E. Duke, M. H. Ellisman, E. Franken, K. Grünwald, J.-K. Heriche, A. Koster, W. Kühlbrandt, I. Lagerstedt, C. Larabell, C. L. Lawson, H. R. Saibil, E. Sanz-García, S. Subramaniam, P. Verkade, J. R. Swedlow and G. J. Kleywegt, "A 3D cellular context for the macromolecular world," *Nature Structural & Molecular Biology*, vol. 21, p. 841–845, October 2014.
- [10] F. Malard, L. Danner, E. Rouzies, J. G. Meyer, E. Lescop and S. Olivier-Van Stichelen, "EpyNN: Educational python for Neural Networks," *SoftwareX*, vol. 19, p. 101140, July 2022.

- [11] H. Ma, S. Xiao, D. Dong and I. R. Petersen, "Tomography of quantum detectors using neural networks," *IFAC-PapersOnLine*, vol. 56, p. 5875–5880, 2023.
- [12] Z. Lv, A. Tek, F. Da Silva, C. Empereur-mot, M. Chavent and M. Baaden, "Game On, Science - How Video Game Technology May Help Biologists Tackle Visualization Challenges," *PLoS ONE*, vol. 8, p. e57990, March 2013.
- [13] L. Liang, M. Liu, J. Elefteriades and W. Sun, "Py[Torch-FEA: Autograd-enabled finite element analysis methods with applications for biomechanical analysis of human aorta," *Computer Methods and Programs in Biomedicine*, vol. 238, p. 107616, August 2023.
- [14] O. Legeth, J. Rodhe, S. Lang, P. Dhapola, M. Wallergård and S. Soneji, "CellexalVR: A virtual reality platform to visualize and analyze single-cell omics data," *iScience*, vol. 24, p. 103251, November 2021.
- [15] L. J. Kingsley, V. Brunet, G. Lelais, S. McCloskey, K. Milliken, E. Leija, S. R. Fuhs, K. Wang, E. Zhou and G. Spraggon, "Development of a virtual reality platform for effective communication of structural data in drug discovery," *Journal of Molecular Graphics and Modelling*, vol. 89, p. 234–241, June 2019.
- [16] A. Elsayy, T. Eleiwa, C. Chase, E. Ozcan, M. Tolba, W. Feuer, M. Abdel-Mottaleb and M. Abou Shousha, "Multidisease Deep Learning Neural Network for the Diagnosis of Corneal Diseases," *American Journal of Ophthalmology*, vol. 226, p. 252–261, June 2021.
- [17] R. F. Conchas, A. G. Loukianov, E. N. Sanchez and A. Y. Alanis, "Finite time convergent recurrent neural network for variational inequality problems subject to equality constraints," *Journal of the Franklin Institute*, vol. 361, p. 583–597, January 2024.
- [18] T. D. Azad, A. Warman, J. A. Tracz, L. P. Hughes, B. F. Judy and T. F. Witham, "Augmented reality in spine surgery – past, present, and future," *The Spine Journal*, vol. 24, p. 1–13, January 2024.
- [19] A. Asadzadeh, T. Samad-Soltani and P. Rezaei-Hachesu, "Applications of virtual and augmented reality in infectious disease epidemics with a focus on the COVID-19 outbreak," *Informatics in Medicine Unlocked*, vol. 24, p. 100579, 2021.
- [20] S. Antolinez, P. E. Jones, J. C. Phillips and J. A. Hadden-Perilla, "AMBERff at scale: Multimillion-atom simulations with AMBER force fields in NAMD," *Biophysical Journal*, vol. 123, p. 422a, February 2024.
- [21] W. Anqi, "Economic efficiency of high-performance electric vehicle operation based on neural network algorithm," *Computers and Electrical Engineering*, vol. 112, p. 109026, December 2023.
- [22] B. Acun, D. J. Hardy, L. V. Kale, K. Li, J. C. Phillips and J. E. Stone, "Scalable molecular dynamics with NAMD on the Summit system," *IBM Journal of Research and Development*, vol. 62, p. 4:1–4:9, November 201823.
- [23] Y. Zhao, R. Zhong, L. Cui, "Intelligent recognition of spacecraft components from photorealistic images based on Unreal Engine 4", *Advances in Space Research*, vol.71 pp. 3761-3774, 2022.

Application of a Generalized Net Model in the Communication of Two Independent Traffic in Faculty of Technical Sciences at Konstantin Preslavski University of Shumen

Tsvetoslav Tsankov

Faculty of Technical Sciences
Konstantin Preslavski University of
Shumen
Shumen, Bulgaria
c.cankov@shu.bg

Liliya Staneva

Faculty of Technical Sciences
University "Prof. d-r Asen Zlatarov"
of Burgas
Burgas, Bulgaria
anestieva@mail.bg

Ivelina Vardeva

Faculty of Technical Sciences
University "Prof. d-r Asen Zlatarov"
of Burgas
Burgas, Bulgaria
ivardeva@gmail.com

Dimitar Iliev

Faculty of Technical Sciences
Konstantin Preslavski University of
Shumen
Shumen, Bulgaria
dimitar25_8000@abv.bg

Abstract. In this paper, a generalized net model providing secure communication of two independent network traffic through ISP1 and ISP2 is presented. Also, a generalized net model modelling the communication process in the computer network of the Faculty of Technical Sciences was developed. The aim of the present study is to improve the Faculty network with generalized net model by providing it with greater efficiency and greater flexibility. The main methods in our research are the method of analysis and synthesis and the method of simulation. The application of generalized net in various fields/aspects of science show the possibilities of the mathematical apparatus for modelling various processes. The indexed matrices used provide flexibility for describing and representing the current states of the cores in the positions they fall into.

Keywords: *Communication network, Cores, Generalized net, Independent traffic.*

I. INTRODUCTION

Generalized networks as a theory has entered science widely in the last few years. The well-structured mathematical apparatus describing the individual work processes of the given network facilitates the research and scientific activity of many young scientists. Generalized nets are based on the foundation of Petri nets. Modeling systems and processes using Petri nets is based on the concepts of event and condition. Events are the actions

that change the states of modeling objects. Conditions are predicates or logical descriptions of the state of systems and/or processes. In order to implement the actions, it is necessary to fulfill the relevant conditions. These are called event preconditions. The occurrence of an event can change the preconditions and trigger the fulfillment of other conditions, sub-conditions. The theory of generalized net was proposed by Prof. Krasimir Atanasov, who added a third parameter to Petri net research. In this way, very accurate descriptions of models are made. Numerous network models have been created describing a variety of problems to be solved in both the field of medicine and in the field of technology. Generalized net are also widely used in artificial intelligence systems for describing parallel processes. Generalized nets are more complex in structure than Petri nets. Their components are theoretically divided into static, dynamic, time and memory. Each generalized network has a timescale, and the activation of its transitions takes place at discrete moments in time. One of the factors determining the possibility or impossibility of activating the transitions is associated predicates. At each model point in time, a specific function determines fidelity values for the predicates [9], [11], [13]. Going through the transitions, the kernels acquire new characteristics by means of a characteristic function. The graphical representation of a transition in a generalized net is a vertical line with a

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8030>

© 2024 Tsvetoslav Tsankov, Liliya Staneva, Ivelina Vardev, Dimitar Iliev.

Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

triangle above it, the latter indicating a structure containing seven components. [4], [5], [7], [8]

Of course, the application of this method is particularly suitable for the administration of a communication network. This administration process is extremely complex and completely depends on the system administrator who has to plan and build the necessary network for a given organization. The administrator faces problems related to:

- External threats to the communication network;
- The check of the primary system reducers;
- Checking and scanning for available viruses or malicious codes;
- Check for security breaches;
- To manage users on the network.

The main goal of our research in the present article is to create a generalized network model of the communication of two independent traffics in the Faculty of Technical Sciences at the "Konstantin Preslavski" University of Shumen referring to scientific works [1], [2], [6], [10], [12]. This type of model is particularly useful when parallel transmission of different types of data is required, ensuring independence and efficient use of available resources in the faculty network. The present research would also be useful in the improvement of industrial networking and telecommunication networks by providing greater efficiency, greater flexibility and better security. The generalized structural diagram of the network is presented in Fig. 1.

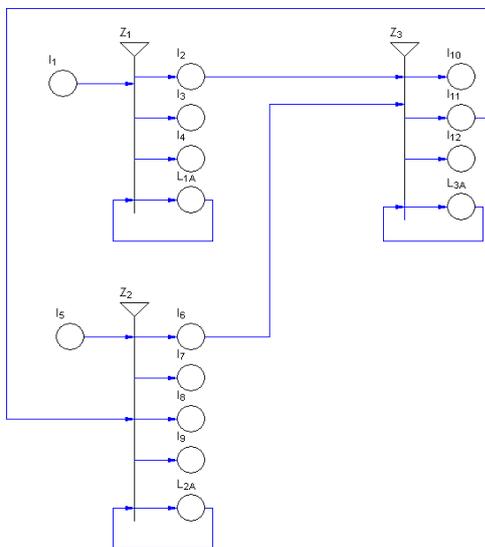


Fig. 1. Generalized net model of the communication network

In addition to the routers, the faculty network also includes logical switches, the settings of which are similar to the switching part of the router. This article does not cover the logical switches, only the routers involved in traffic management for the example network.

The object of research in this paper is the construction and improvement of the faculty network for the following main reasons:

1. Separation of a network that is independent of the university network, specifically all hosts in the building are connected through common switches, which leads to cases of student access to teaching computers. The

separate faculty network allows the scientific work of the professors and doctoral students not to be an obstacle for the other faculty.

2. Jumping over an intermediate (proxy) server that is improperly used to access the Internet and hinders the scientific work of doctoral students. Upon inquiry with other universities, it was found that a proxy server is only used to secure internal services offered from university servers.

II. MATERIALS AND METHODS

The methodology and basic design of the research in this article is the construction of a generalized network. The overall construction refers to sources [2] – [4], [13] and includes:

- Building a static structure of the modeled process; At each event of the modeled process within the generalized net, the model is mapped to one transition. The conditions for an event to occur are represented in the generalized net model by the presence of cores in the corresponding input positions of the transition modeling the event, the presence of predicates in the transition condition that has a fidelity value of TRUE, and the presence of vacancies in the output positions of the transition.

- Covering the dynamics of the modeled process; Each real process actually represents a set of separate sub-processes that run parallel in time, and often in competition with each other. By generalized net modeling of such a population, rich information can be obtained about the values of the various parameters associated with these processes.

- Description of the functionality of the modeled process in a time interval;

For the use of global time components in the model, it is necessary that the modeled process starts and runs at a precise point in time and its duration is determined. If this is fulfilled, then an elementary time step must also be specified, with which the time between the two moments fixing the beginning and end of functioning of the modeled process will increase.

- Determination of the data of interest for the modeled network.

Data acquisition for generalized net models is defined as data related to transitions, positions, cores, and the network as a whole. We can specify variables whose values are calculated during the operation of the generalized net model. In this way, data from various parameters can be obtained for the corresponding modeled process. It is important to set appropriate parameters to the characteristic functions that describe the positions. The created generalized net model can serve to simulate a modeled process and for its optimization and management.

In order to use a generalized net model for process simulation, it is necessary to define it by such random functions that set the true values of the predicates of the conditions and the values of the time parameters of the process. Through simulation, statistics can be obtained about the simulated processes. Based on the created model, more models can be built to further develop the original model. Generalized net can be used in modeling and simulating processes to predict future behavior, to

control and optimize real-time processes that run very slowly.

After the creation of the generalized net model, there is the question of its accuracy and correctness. In this case, it is necessary to have in advance the necessary and appropriate criteria for comparison. In many cases, the best way is to apply the adaptive method of comparison, and if necessary, the correction of the generalized net model is done iteratively based on the differences between the expected and obtained results. Each process is simulated multiple times and the results are compared, possibly averaged, analyzed and evaluated. Indexed arrays provide flexibility for describing and representing the current states of the cores at the positions they fall into. A generalized net model containing the following set of transitions was developed:

$$A = \{Z_1, Z_2, Z_3\} \quad (1)$$

where transitions describe the following processes:

Z_1 = "incoming packets in router 1";

Z_2 = "incoming packets in router 2";

Z_3 = "incoming packets to switch from router 1 and router 2".

The transitions have the following description:

$$Z_1 = \langle \{l_1, L_{1A}\}, \{l_2, l_3, l_4, L_{1A}\}, R_1, \vee(l_1, L_{1A}) \rangle \quad (2)$$

Where

$$R_1 = \begin{matrix} & \begin{matrix} l_2 & l_3 & l_4 & L_{1A} \end{matrix} \\ \begin{matrix} l_1 \\ L_{1A} \end{matrix} & \begin{matrix} false & false & false & true \\ W_{1A,2} & W_{1A,3} & W_{1A,4} & true \end{matrix} \end{matrix} \quad (3)$$

$W_{1A,2}$ – "packets of incoming and outgoing traffic intended for the switch have arrived"

$W_{1A,3}$ – "packages are intended for computer laboratory K3"

$W_{1A,4}$ – "packages are intended for computer lab 401"

Cores coming into position L_{1A} have the characteristic "check packet arrived" after the transition the core can enter positions l_2, l_3, l_4 .

$$Z_2 = \langle \{l_5, l_{11}, L_{2A}\}, \{l_6, l_7, l_8, l_9, L_{2A}\}, R_2, \vee(l_5, l_{11}, L_{2A}) \rangle$$

$$R_2 = \begin{matrix} & \begin{matrix} l_6 & l_7 & l_8 & L_{2A} \end{matrix} \\ \begin{matrix} l_5 \\ l_{11} \\ L_{2A} \end{matrix} & \begin{matrix} false & false & false & true \\ false & false & false & true \\ W_{2A,6} & W_{2A,7} & W_{2A,9} & true \end{matrix} \end{matrix}$$

$W_{2A,6}$ – "packages are intended for Situation Center"

$W_{2A,7}$ – "packages are intended for Siemens computer lab"

$W_{2A,8}$ – "packages are intended for teachers' offices"

$W_{2A,9}$ – "the packages are intended for office teachers"

Cores coming into position L_{2A} have the characteristic "check packet arrived" after the transition the core can enter positions l_6, l_7, l_8, l_9 .

$$Z_3 = \langle \{l_2, l_6, L_{3A}\}, \{l_{10}, l_{11}, l_{12}, L_{3A}\}, R_3, \vee(l_2, l_6, L_{3A}) \rangle, \quad (6)$$

$$R_3 = \begin{matrix} & \begin{matrix} l_{10} & l_{11} & l_{12} & L_{3A} \end{matrix} \\ \begin{matrix} l_2 \\ l_6 \\ L_{3A} \end{matrix} & \begin{matrix} false & false & false & true \\ false & false & false & true \\ W_{3A,10} & W_{3A,11} & W_{3A,12} & true \end{matrix} \end{matrix} \quad (7)$$

$W_{3A,10}$ – "The switch has redirected traffic coming from Router 1 to Router 2 when Router 2 does not have access to the Internet."

$W_{3A,11}$ – "The switch has redirected traffic coming from Router 2 to Router 1 when Router 1 does not have access to the Internet."

$W_{3A,12}$ – "packages are intended for teachers' offices"

Cores coming into position L_{3A} have the characteristic "check packet arrived" after the transition the core can enter positions l_{10}, l_{11}, l_{12} .

In the developed generalized net model, the distribution of traffic in the computer network of the Faculty of Technical Sciences is presented. Through the model, the operation of the network is described, which can be used as a tool for researching the processes taking place in computer networks. This new method provides a means of describing the investigated processes, as the developed generalized net model describes the performance of the computer network.

III. RESULTS AND DISCUSSION

The described generalized net model was implemented, using two identical Cisco routers RV325 for the network of the Faculty of Technical Sciences at the Konstantin Preslavski University of Shumen. The generalized structural diagram of the network is presented in Fig. 2.

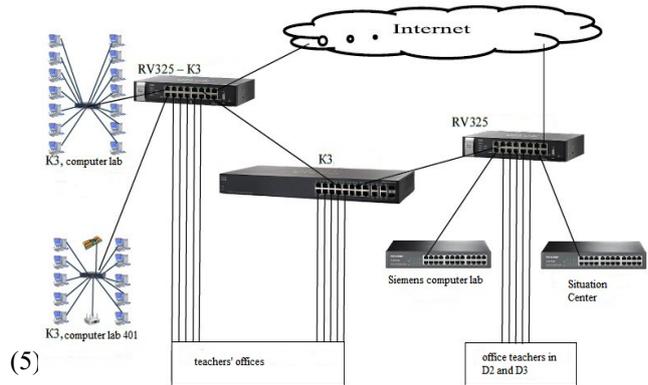


Fig. 2. Structural diagram of the computer network of the Faculty of Technical Sciences

The computer network in Faculty of Technical Sciences was built for two main interrelated reasons:

1. Separation of a network that is independent from the university network, specifically all hosts in the building are connected through common switches, and this leads to cases of student access to faculty computers.

The separate faculty network allows the scientific work of the professors and doctoral students without being an obstacle for the other faculty.

2. Jumping over an intermediate (proxy) server that is improperly used to access the Internet and hinders the scientific work of doctoral students. Inquiring with other universities, it was found that a proxy server is only used to secure internal services offered by University servers. The faculty network is to be extended to the C building in the near future.

IV. CONCLUSIONS

Based on the research, a new approach for describing the traffic distribution in the computer network of the Faculty of Technical Sciences is proposed. The model created by us allows to study the processes [5], [6] taking place in the computer network, the ways of forwarding the packets for the given networks and the distribution of their traffic. It is suitable for future developments and is widely used in all types of networks. The results achieved after the creation of the network in the Faculty of Technical Sciences are extremely satisfactory. The proposed model and its approaches provide an additional opportunity in the training of students in the Computer Networks discipline. The implementation of generalized net model supports the construction of communication networks in all sectors of the industry in the field of computer networks. The use of generalized net model supports the design and visualization of practical and theoretical rationale in the construction of independent network traffic and the distribution of their flows. A further objective is to perform an assessment of the network flows used, to make an allocation of the networks used in order to prevent the load on only one of the networks, i.e. when one network is loaded, part of the flow is transferred to the other and vice versa.

V. ACKNOWLEDGEMENTS

Our scientific paper was co-financed under the project RD-08-110/31.01.2024: Scientific conference with

international participation MATTECH 2024 – Faculty of Technical Sciences.

REFERENCES

- [1] K. Andreev and I. Vardeva, Generalized net model of implementation of port knocking on RouterOS, *Uncertainty and Imprecision in Decision Making and Decision Support: New Advances, Challenges, and Perspectives*, Springer 2022.
- [2] K. Atanasov, Theory of Generalized nets (a topological aspect), *Methods of Operation Research*, 51, 1984, 217-226.
- [3] K. Atanasov, On the concept Generalized net, *AMSE Review*, 1, No 3, 1984, 39-48.
- [4] K. Atanasov, The Generalized nets and the other graphical means for modelling, *AMSE Review*, 2, No. 1, 1985, 59-64.
- [5] P. Atanasova, I. Zheliazkova and A. Levi, Specification of the Knowledge Description Languages; *Proc. Second Int. Conf., "Modern e-learning"*, Varna-Bulgaria, 2007, pp.111-119.
- [6] P. Atanasova, S. Stefanov, I. Zheliazkova and A. Levi, An Adaptive and Intelligent Text Editor for Teachers Support of Practical Exercises; in: *Proc.of the Int. Conf. Comp. Sciences, "08-Kavala"*, Part II, Sofia, 2008, pp. 456-461.
- [7] P. Gocheva and V. Gochev, From Petri nets to Generalized nets, *Collection "Modeling and management of information processes"*, Sofia, Bulgaria, 2010, pp. 21-32.
- [8] D. Denev, Ts. Tsankov, Analysis of the requirements for optical cables for construction of underwater transmission systems, *Journal scientific and applied research*, Vol. 21, 2021, ISSN 1314-6289, pp. 75-79.
- [9] Ts. Tsankov, L. Staneva, I. Vardeva, D. Iliev, Generalized net model of a communication network using the Port Knocking method, *Scientific Conference with international participation MATTEH 2022, Conference proceeding, Vol. 2, Shumen, 2022, ISSN 1314-3921*, pp. 29-34.
- [10] K. Atanasov, On the concept "Generalized net", *AMSE Review*, Vol. 1, No. 3, 1984, pp. 39-48.
- [11] K. Atanasov, The generalized net which represents all Petri nets, *AMSE Review*, Vol. 12, No. 3, 1990, 33-37.
- [12] N. Arabadzhieva-Kalcheva, Ts. Tsankov, Failure Modes and Effects Analysis – FMEA, *Scientific Conference with international participation MATTEH 2022, Conference proceeding, Vol. 2, Shumen, 2022, ISSN 1314-3921*, pp. 58-62.
- [13] D. Denev, Modeled Security in Communication Network Coding, *Annual of Konstantin Preslavski University of Shumen, Vol. XII E, Faculty of technical sciences, 2022, ISSN 1311-834X*, pp. 153-161.

Review of Methods for Classifying and Assessing Information Uncertainty

Oleg Uzhga-Rebrov
Rezekne Academy of Technologies
Institute of Engineering
Rezekne, Latvia
rebrov@tvnet.lv

Peter Grabusts
Rezekne Academy of Technologies
Institute of Engineering
Rezekne, Latvia
peteris.grabusts@rta.lv

Abstract. There is a large number and variety of uncertainties that relate to almost all areas of life and the activity of people. Based on numerous literature sources, this article classifies various uncertainties into the following large groups: (1) stochastic uncertainties and (2) numerical uncertainties, including fuzzy and possibilistic ones. The article presents general approaches to assessing uncertainties in each of these groups. In addition, the article presents the main characteristics of general uncertainty estimates and provides an illustrative example.

Keywords: uncertainty and information, statistical uncertainty, numerical uncertainty, estimation of uncertainty.

I. INTRODUCTION

The materials for research in this article are various publications on the topics presented. The article is a review nature. The presented methods are supplemented with illustrative examples.

The whole world is riddled with various kinds of uncertainties. What are the chances of rain tomorrow? How long will you have to wait for the tram at the stop? How old can a person be who is described as middle-aged? This kind of uncertainty can be continued indefinitely.

To clarify further considerations, we will introduce a generalized concept of a system. In the context of this article, we will consider information systems that consist of variables that represent one or another type of information (data). Let us quote from [1], which defines such systems and the potential uncertainties associated with them.

“In general, systems are viewed as relations among states of given variables. They are constructed for various purposes, such as prediction, retrodiction, extrapolation... control, planning, decision-making, scheduling, and diagnosis. In each system, its relation is utilized in each purposeful way to determine unknown states of some variables based on known states of some other variables.

Systems in which the unknown states are determined uniquely are called *deterministic systems*; all other systems are called *nondeterministic systems*. Each nondeterministic system involves uncertainty of some type. This uncertainty pertains to the purpose for which the system was constructed. It is thus natural to distinguish predictive uncertainty, retrodictive uncertainty... diagnostic uncertainty, and so on. In each nondeterministic system, the relevant uncertainty must be properly incorporated into the description of the system in some formalized language.”

The key point in this quotation is that relevant uncertainties must be identified, displayed, and evaluated using appropriate formal language for expressing those uncertainties.

There is a close relationship between the amount of information and the uncertainty of this information. The absence or insufficiency of existing information usually causes uncertainty. In work [1] this connection is presented schematically (see Figure 1).

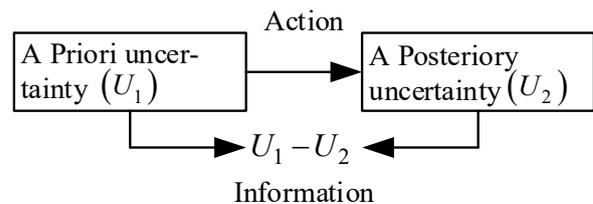


Fig. 1. Schematic representation of the relationship between uncertainty and information [1].

II. STATISTICAL UNCERTAINTIES

The best known are stochastic uncertainties. This is the field of probability theory and mathematical statistics. Uncertainties about the states of relevant variables are expressed by probabilistic estimates.

Let a set of random events $E = \{e_i / i = 1, \dots, n\}$ be given and the probabilities of the occurrence of each of

Print ISSN 1691-5402
Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8024>

© 2024 Olegs Uzhga-Rebrov, Peter Grabusts. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

these random events $\{p_i / i = 1, \dots, n\}$ estimated. Then the probabilistic estimates must satisfy the following axiomatic requirements.

1. $0 \leq p_i \leq 1, \forall i$.
2. If the events are independent of each other, then $p(e_1 \cup \dots \cup e_n) = p(e_1) + \dots + p(e_n)$.
3. If the set E is a complete group of random

events, then $\sum_{i=1}^n p_i = 1$.

The concept of entropy as an estimate of the degree of stochastic uncertainty was introduced in [2]. Let a set of discrete values of a random variable X be given. Entropy as an estimate of the degree of uncertainty in the distribution of values X is calculated using the expression:

$$H(\mathbf{X}) = -\sum_{x_i \in \mathbf{X}} p(x_i) \log_2 p(x_i). \quad (1)$$

where $p(x_i)$ - the probability of occurrence of value x_i variable \mathbf{X} .

Let there be two sets of discrete values of random variables \mathbf{X} and \mathbf{Y} and the probabilities for the values of $x_i \in \mathbf{X}$ to occur depend on the values $y_j \in \mathbf{Y}$. Then conditional entropy for distribution \mathbf{X} / \mathbf{Y} is defined as

$$H(\mathbf{X} / \mathbf{Y}) = -\sum_i \sum_j p(x_i / y_j) \log_2 p(x_i / y_j), \quad (2)$$

where $p(x_i / y_j)$ - the conditional probability of realization of value x_i subject to realization of value y_j .

If the discrete values of random variables \mathbf{X} and \mathbf{Y} are distributed independently, then joint entropy of their joint distribution is defined as

$$H(\mathbf{X}, \mathbf{Y}) = -\sum_i \sum_j p(x_i, y_j) \log_2 p(x_i, y_j), \quad (3)$$

where $p(x_i, y_j)$ is the probability of joint realization of values x_i and y_j .

If the values of random variables \mathbf{X} and \mathbf{Y} are continuous, then the summation operations in expressions (1) – (3) are replaced by integration operations.

When calculating entropy, binary logarithms are usually used. The unit of entropy is then called a bit. In principle, logarithms with other bases can be used to estimate entropy. If logarithms with base e are used, then the unit of measurement is *nat*, if logarithms with base 10 are used, then the unit of measurement is *dit*.

In work [3] the following axiomatic characterization of the concept of entropy is given:

1. Subadditivity: for joint distributed random variables $H(\mathbf{X}, \mathbf{Y}) \leq H(\mathbf{X}) + H(\mathbf{Y})$.
2. Additivity: $H(\mathbf{X}, \mathbf{Y}) = H(\mathbf{X}) + H(\mathbf{Y})$ when the random variables \mathbf{X}, \mathbf{Y} are independent.
3. Extensibility:

$H_{n+1}(p_1, \dots, p_n, 0) = H_n(p_1, \dots, p_n)$ - adding an outcome with probability zero does not change the entropy.

4. Symmetry: $H_n(p_1, \dots, p_n)$ is invariant under permutation of p_1, \dots, p_n .

5. Small for small probabilities:

$$\lim_{q \rightarrow 0^+} H(1-q, q) \rightarrow 0.$$

Entropy estimates are very widely used in various contexts to estimate the degree of uncertainty in statistical information.

III. FUZZY ENTROPY AND FUZZINESS ESTIMATES

Another large class consists of uncertainties associated with numerical estimates. Until the 60s of the 20th century, the only type of such uncertainties were measurement errors. The measured value was presented in the form $x \pm \alpha$, where α is the amplitude of possible measurement errors.

In 1965, L. A. Zadeh published his famous work [4], which laid the foundation for a new class of uncertainties - fuzzy sets and fuzzy numbers. Essentially, fuzzy numbers are fuzzy sets defined on some number axis.

The emergence of fuzzy set theory necessitated the development of new measures. The theory of fuzzy estimates was proposed in [5]. These measures, named after the author, are called fuzzy Sugeno measures. These estimates are determined as follows.

Let ρ be an σ -algebra on universe \mathbf{X} . A Sugeno fuzzy measure is $g : \rho \rightarrow [0, 1]$, verifying:

1. $g(\emptyset) = 0, g(\mathbf{X}) = 1$.
2. If $A, B \in \rho$ and $A \subseteq B$, then $g(A) \leq g(B)$.
3. If $A_n \notin \rho$ and $A_1 \subseteq A_2 \subset \dots$ then $\lim_{n \rightarrow \infty} g(A_n) = g(\lim_{n \rightarrow \infty} A_n)$.

Property 2 is called monotony and property 3 is called Sugeno's convergence.

How can the degree of uncertainty associated with the original fuzzy information be measured? In this article, we will present three types of such measures.

Let a fuzzy random variable \mathbf{X} be given, the values of which are triangular normal fuzzy numbers \tilde{A}_j . For clarity, an example of such a fuzzy number is graphically presented in Figure 2.

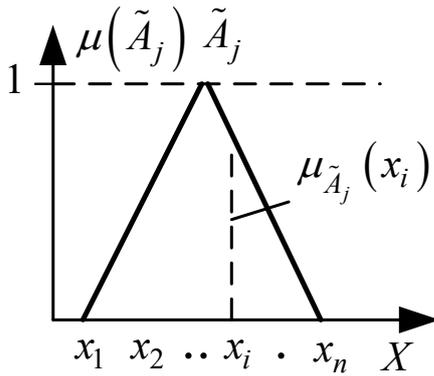


Fig. 2. Graphical representation of a triangular normal fuzzy number \tilde{A}_j .

To estimate the degree of uncertainty of a fuzzy random number, A. L. Zadeh in 1965 proposed the following extension of Shannon entropy

$$H(\tilde{A}_j) = -\sum_{i=1}^n \mu_{\tilde{A}_j}(x_i) p(x_i) \log_2 p(x_i), \quad (4)$$

where $\mu_{\tilde{A}_j}(x_j)$ is the value of the membership function of the element x_i to the fuzzy number \tilde{A}_j ;

$p(x_i)$ - probability of element (value) x_i implementation.

Points x_1, x_2, \dots, x_n in Figure 2 represent the values of the fuzzy variable S in the interval reflecting the basis of the fuzzy number \tilde{A}_j . Unless otherwise assumed, the distribution of x_i values can be considered to be a uniform distribution. Then $p(x_i) = \frac{1}{n}$. The $\mu_{\tilde{A}_j}(x_i)$ values can be read from the graph or calculated if the analytical expression of function $\mu_{\tilde{A}_j}(x_i)$ is given.

If a fuzzy variable S includes m fuzzy numbers \tilde{A}_j , then the total fuzzy entropy for the variable S is defined as the sum of the fuzzy entropies of the fuzzy numbers forming it.

$$H(S) = \sum_{j=1}^m H(\tilde{A}_j). \quad (5)$$

In addition to estimates of fuzzy entropy for fuzzy random numbers, various estimates of the degree of fuzziness for fuzzy numbers have been proposed. It should be kept in mind that estimates of fuzzy entropy and estimates of the degree of fuzziness of fuzzy numbers are different estimates of the uncertainty of these fuzzy numbers. Fuzzy entropy estimates are analogous to Shannon entropy estimates in a fuzzy environment. Estimates of the degree of fuzziness are specific estimates of uncertainty, which is associated only with the forms of membership functions for these fuzzy numbers.

In this paper, we will present two common estimates of the degree of fuzziness for fuzzy numbers.

De Luca and Termini [6] proposed the following estimate of the degree of fuzziness of the fuzzy number \tilde{A} . To visualize further definitions, Figure 3 graphically represents the triangular normal fuzzy number \tilde{A} and its complement $\bar{\tilde{A}}$.

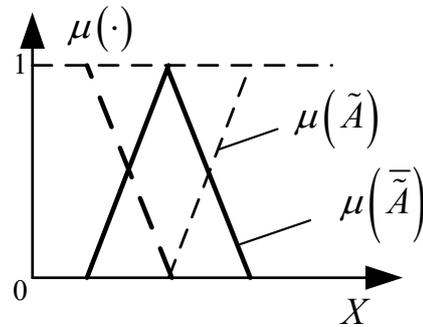


Fig. 3. Graphical representation of a triangular normal fuzzy number \tilde{A} and its complement $\bar{\tilde{A}}$.

$$d(\tilde{A}_j) = H(\tilde{A}_j) + H(\bar{\tilde{A}}). \quad (6)$$

Using Shannon's function

$$S(x) = -x \ln x - (1-x) \ln(1-x), \quad (7)$$

expression (6) can be represented in the following form

$$d(\tilde{A}_j) = k \sum_{i=1}^n S(\mu_{\tilde{A}_j}(x_i)). \quad (8)$$

where k is a positive constant.

Note that the Shannon function (7) uses natural logarithms. This is not of fundamental importance. The choice of logarithm base only affects the units of measurement of the resulting uncertainty. If you want to express the estimated degree of fuzziness in bits, then use $\log_2(x)$ instead of $\ln(x)$.

Estimates of the degree of fuzziness De Luca and Termini must satisfy the following obvious requirements [7]:

1. $d(A) = 0$ if A is a crisp set in \mathbf{X} .
2. $d(\tilde{A})$ assumes a unique maximum if $\mu_{\tilde{A}}(x) = \frac{1}{2}, \forall x \in \mathbf{X}$.
3. $\mu_{\tilde{A}'}(x) \leq \mu_{\tilde{A}}(x)$ if \tilde{A}' is "crisper" than \tilde{A} ,
 i. e., $\mu_{\tilde{A}'}(x) \leq \mu_{\tilde{A}}(x)$ for $\mu_{\tilde{A}}(x) \leq \frac{1}{2}$ and
 $\mu_{\tilde{A}'}(x) \geq \mu_{\tilde{A}}(x)$ for $\mu_{\tilde{A}}(x) \geq \frac{1}{2}$.
4. $d(\tilde{A}) = d(\bar{\tilde{A}})$ where $\bar{\tilde{A}}$ is complement of \tilde{A} .

Another assessment of the degree of fuzziness of a fuzzy number \tilde{A} has the following basis. For a fuzzy

number \tilde{A} and its complement $\bar{\tilde{A}}$, in contrast to crisp sets, the following statements are not mandatory:

$$\begin{aligned} \tilde{A} \cup \bar{\tilde{A}} &= \mathbf{X}; \\ \tilde{A} \cap \bar{\tilde{A}} &= \emptyset. \end{aligned}$$

In work [8] R. Yager argues that the assessment of the degree of fuzziness for a fuzzy number \tilde{A} should reflect the difference between this number and its complement $\bar{\tilde{A}}$. In other words, the estimate of the degree of fuzziness should be a function of the distance between \tilde{A} and $\bar{\tilde{A}}$ or between $\mu_{\tilde{A}}(x)$ and $\mu_{\bar{\tilde{A}}}(x)$. In [8] the author proposed the following metric for estimating the distance between \tilde{A} and $\bar{\tilde{A}}$:

$$D_p(\tilde{A}, \bar{\tilde{A}}) = \left[\sum_{i=1}^n |\mu_{\tilde{A}}(x_i) - \mu_{\bar{\tilde{A}}}(x_i)|^p \right]^{\frac{1}{p}}, p=1,2,\dots \quad (9)$$

This is the Minkowski metric. For $p=1$ we have the Hamming metric:

$$D_1(\tilde{A}, \bar{\tilde{A}}) = \sum_{i=1}^n |\mu_{\tilde{A}}(x_i) - \mu_{\bar{\tilde{A}}}(x_i)|. \quad (10)$$

If $\mu_{\bar{\tilde{A}}}(x) = 1 - \mu_{\tilde{A}}(x)$ then

$$D_1(\tilde{A}, \bar{\tilde{A}}) = \sum_{i=1}^n |2\mu_{\tilde{A}}(x_i) - 1|. \quad (11)$$

For $p=2$ we have the Euclidian metric:

$$D_2(\tilde{A}, \bar{\tilde{A}}) = \left(\sum_{i=1}^n (\mu_{\tilde{A}}(x_i) - \mu_{\bar{\tilde{A}}}(x_i))^2 \right)^{\frac{1}{2}}. \quad (12)$$

If $\mu_{\bar{\tilde{A}}}(x) = 1 - \mu_{\tilde{A}}(x)$ then

$$D_2(\tilde{A}, \bar{\tilde{A}}) = \left(\sum_{i=1}^n (2\mu_{\tilde{A}}(x_k) - 1)^2 \right)^{\frac{1}{2}}. \quad (13)$$

There are other definitions of the complement of a fuzzy set $\bar{\tilde{A}}$. In such cases, the values of $\mu_{\bar{\tilde{A}}}(x_i)$ should appear explicitly in Expressions (8), (10), which are calculated on the basis of the corresponding definition of $\bar{\tilde{A}}$.

Additional information about fuzzy entropy and fuzzy estimates can be found in the works [7], [8], [9].

To model uncertainties greater than those modeled by standard fuzzy numbers the following extensions of fuzzy numbers have been proposed:

1. Interval-valued fuzzy numbers [10].
2. Fuzzy numbers type-2 [11].
3. Interval-valued fuzzy numbers type-2 [12],[13].
4. Intuitionistic fuzzy numbers [14].

In this work, we limit ourselves to considering only standard fuzzy numbers.

Various approaches to combining statistical and fuzzy information have been proposed. In this sense, we can talk about the probabilities of fuzzy events [15] and fuzzy probability estimates.

IV. POSSIBILITY THEORY AND HARTLEY MEASURE

To model very high degrees of uncertainty, a possibility theory has been proposed [16], [17].

Assume that the universe of discourse Ω is a finite set. A *possibility measure* is a function Π from 2^Ω to $[0,1]$, such that:

1. $\Pi(\emptyset) = 0$;
2. $\Pi(\Omega) = 1$;
3. $\Pi(U \cup V) = \max(\Pi(U), \Pi(V))$ for any disjoint subsets U and V .

Let there be a numerical or non-numerical set A , all of whose elements are equally possible. The degree of uncertainty of this set is estimated based on the Hartley function [18]

$$H_0(A) = \log_2 |A|. \quad (14)$$

where $|A|$ denotes the cardinality of the set A .

To better visualize the difference between fuzzy and possibilistic uncertainties, let's look at Figure 4 [19]. Figure 4 (a) shows a graph of the membership function of a triangular normal fuzzy number \tilde{A} .

For any value $x \in \tilde{A}$, the degree of its membership to \tilde{A} , $\mu_{\tilde{A}}(x)$, is uniquely determined (vertical arrows in Figure 4 (a)).

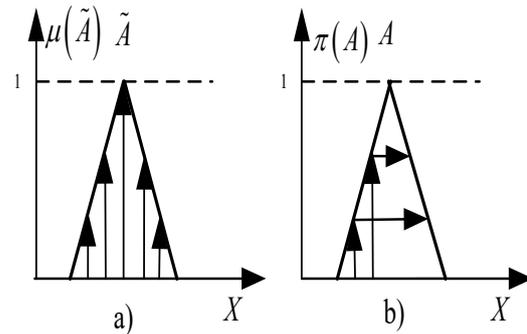


Fig. 4. Graphical representation of the triangular normal fuzzy number \tilde{A} (a) and the possibilistic number A (b). [19]

Figure 4 (b) shows a graph of the distribution of possibilities for the possibilistic number A . For any value of $x \in A$, the degree of its possibility is determined by the horizontal segment of the line connecting the corresponding points on the graph $\pi(A)$ (horizontal lines in Figure 4 (b)).

This is the significant difference between fuzzy and possibilistic numbers, which are expressions of fundamentally different types of numerical uncertainties.

V. ILLUSTRATIVE EXAMPLE

In Figure 5 graphically shows the distribution of three fuzzy probabilities $\tilde{P} = (\tilde{p}_1, \tilde{p}_2, \tilde{p}_3)$.

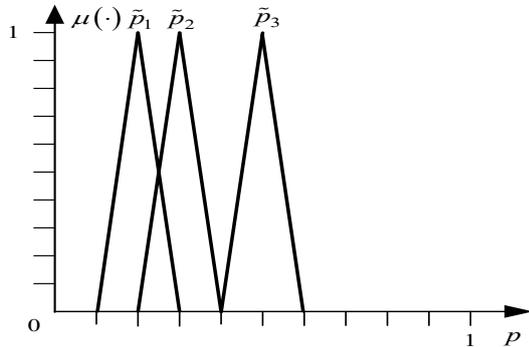


Fig. 5. Graphical representation of the distribution of three fuzzy probabilities.

Required:

1. Calculate the fuzzy entropy value of this distribution.
2. Calculate estimates of the degree of fuzziness of fuzzy numbers $\tilde{p}_1, \tilde{p}_2, \tilde{p}_3$ using the expressions (11), (13).

Using the graph of the membership function of a fuzzy number $\mu(\tilde{p}_1)$, we determine the following reference values of probability p_1 , the corresponding values of the membership function $\mu(p_1)$ and the probability of the implementation $p^*(p_1)$ of these reference values:

p_1	0.10	0.15	0.20	0.25	0.30.
$\mu(p_1)$	0.00	0.50	1.00	0.50	0.00.
$p^*(p_1)$	0.20	0.20	0.20	0.20	0.20.

The values of $p^*(p_1)$ are assigned from the statement that the values of p_1 are uniformly distributed on the base of a fuzzy number \tilde{p}_1 .

According to expression (4):

$$\begin{aligned} H(\tilde{p}_1) &= -(0.00 * 0.20 * (-0.699)) + \\ &+ 0.50 * 0.20 * (-0.699) + \\ &+ 1.00 * 0.20 * (-0.699) + \\ &+ 0.50 * 0.20 * (-0.699) + \\ &+ 0.00 * 0.20 * (-0.699) = \\ &= 0.000 + 0.070 + 0.140 + 0.070 + 0.000 = \\ &= 0.280. \end{aligned}$$

Since the shapes of the graphs of the membership functions of the fuzzy probabilities \tilde{p}_2, \tilde{p}_3 are exactly the same as for the fuzzy probability \tilde{p}_1 , the fuzzy entropy estimates for all three fuzzy numbers are the same. Therefore, the value of fuzzy entropy for distribution \tilde{P}

based on the property of additivity of fuzzy entropy estimates is equal to:

$$H(\tilde{P}) = 3 * 0.280 = 0.840.$$

According to expression (11):

$$\begin{aligned} D(\tilde{p}_1, \tilde{p}) &= |2 * 0.00 - 1| + |2 * 0.50 - 1| + \\ &+ |2 * 1.00 - 1| + |2 * 0.50 - 1| + |2 * 0.00 - 1| = \\ &= 1.00 + 0.00 + 1.00 + 0.00 + 1.00 = 3.00. \end{aligned}$$

According to expression (13):

$$\begin{aligned} D_2(\tilde{p}_1, \tilde{p}) &= ((2 * 0.00 - 1)^2 + (2 * 0.50 - 1)^2 + \\ &+ (2 * 1.00 - 1)^2 + (2 * 0.50 - 1)^2 + \\ &+ (2 * 0.00 - 1)^2)^{\frac{1}{2}} = \\ &= (1.00 + 0.00 + 1.00 + 0.00 + 1.00)^{\frac{1}{2}} = 3^{\frac{1}{2}} = 1.732. \end{aligned}$$

VI. CONCLUSIONS

This article provides a brief overview of the most common types of uncertainty in data. Some uncertainties can manifest themselves as phenomena of the external world (statistical uncertainties). Another type of uncertainty is a consequence of the lack of clear boundaries between sets (numbers).

These types of uncertainties are usually identified as fuzzy uncertainties. Possibilistic uncertainties are an extreme type of uncertainty when all elements of a certain set or numerical values in a given interval are equally possible.

Identifying existing uncertainties in data is very important for processing and analyzing these data. In some circumstances it is necessary to estimate the degree of uncertainty in existing data. This article presents the main approaches to assessing various types of uncertainties. Definitions of fuzzy entropy and degree of fuzziness are presented only for triangular normal fuzzy numbers. It should be noted that expressions for calculating fuzzy entropy and degree of fuzziness are proposed for all fuzzy number extensions mentioned in this paper, as well as for other less common fuzzy number extensions.

Fuzzy entropy's estimates are widely used to solve various kinds of practical problems. Works [20], [21] present examples of using fuzzy entropy estimates in decision making problems. Works [22], [23] present examples of using fuzzy entropy estimates in data analysis problems. In work [24], fuzzy entropy estimates are used to solve the supplier selection problem. Works [25] – [27] present the use of fuzzy entropy in classification and clustering problems.

The general conclusion from this article: in order to correctly use uncertain data (information), it is necessary to clearly establish the nature of the existing uncertainty and use methods suitable for this type of identified uncertainty.

REFERENCES

- [1] G.J. Klir, Uncertainty and Information. Foundation of Generalized Information Theory. A John Willey & Sons, Inc., 2006.

- [2] G. E. Shannon, "A Mathematical Theory of Communication," *Bell System Technical Journal*, 27 (3), 1948, pp. 349 – 423.
- [3] J. Aszél, B. Forte, and C. N. Ng, "Why the Shannon and Hartley Entropies are "Natural," *Adv. Appl. Prob.*, 6, 1974, pp. 131 – 146.
- [4] L. A. Zadeh, "Fuzzy sets," *Information and Control*, 8, pp. 338 – 353, 1965, [https://doi.org/10.1016/S0019-9958\(65\)90241-X](https://doi.org/10.1016/S0019-9958(65)90241-X)
- [5] M. Sugeno, "Fuzzy Measures and Fuzzy Integrals – A Survey," *Readings in Fuzzy for Intelligent Systems*, pp. 251 – 257, 1993, <https://doi.org/10.1016/B978-1-4832-1450-4.50027-4>
- [6] D. Luca and S. Termini, "A definition of non probabilistic entropy in the setting of fuzzy set theory," *Information and Control*, 20, pp. 301 – 312, 1972.
- [7] H.-J. Zimmermann, *Fuzzy Set Theory – and its Applications*. (Fourth Edition). New York, Springer Science + Business Media, 2001.
- [8] R.R. Yager, "On the Measure of Fuzziness and Negation, Part 1: Membership in the Unit Interval," *Int. Journal of General Systems*, 5, pp. 221 – 229, 1979. <https://doi.org/10.1080/03081077908547452>
- [9] S. Al-Sharhan, F. Karray, W. Gueail, and O. Basir, *Fuzzy entropy: a Brief Survey*. 10th IEEE Int. Conference on Fuzzy Systems, December 2 – 5, 2001, Melbourne, Australia, 2001. <https://doi.org/10.1109/FUZZ.2001.1008855>
- [10] A Kaufman, *Introduction to the Theory of Fuzzy Subsets: Fundamental Theoretical Elements*. New York, Academic Press, 1975.
- [11] M–S. Kuo and G–S. Liang, "A soft computing method of performance evaluation with MCDM based on interval-valued fuzzy number," *Applied Soft Computing*, 12, pp. 476 – 485, 2012. <https://doi.org/10.1016/j.asoc.2011.08.020>
- [12] J. M. Mendel and R.I.B. John, "Type-2 Fuzzy Sets Made Simple," *IEEE Transactions on Fuzzy Systems*, 10 (2), pp. 117 – 127, 2005. <https://doi.org/10.1109/91.995115>
- [13] H. Bustince, J. Fernandez, H. Hagrás, F. Herrera, M. Pagola, and E. Barrenechea, "Interval Type-2 Fuzzy Sets are Generalizations of Interval-Valued Fuzzy Sets: Toward a Wider View on their Relationship," *IEEE Transactions on Fuzzy Systems*, 23, pp. 1878 – 1882, 2015.
- [14] P. H. Burillo, H. Bustince, and V. Modehano, "Some definition of intuitionistic fuzzy number," *Fuzzy Based Expert Systems, Fuzzy Bulgarian Enthusiasts*, 1994.
- [15] L. A. Zadeh, "Probability measure of fuzzy events," *J. Math. Anal. Appl.*, 23, pp. 421 – 427, 1965.
- [16] L. A. Zadeh, "Fuzzy Sets as a Basis for a Theory of Possibility," *Fuzzy Sets and Systems* 1, pp. 3 – 28, 1978. [https://doi.org/10.1016/0165-0114\(78\)90029-5](https://doi.org/10.1016/0165-0114(78)90029-5).
- [17] D. Dubois and H. Prade, *Possibility Theory – An Approach to Computerized Processing of Information*. New-York: Plenum, 1988. Technology Organization, Edinburg, Australia, 2007.
- [18] R.V. L. Hartley. "Transmission of Information," *Bell Technical Journal*, VII (3), pp. 553 – 563, 1928. <https://doi.org/10.1002/j.1538-7305.1928.tb01236.x>
- [19] L. Warren, *On Modeling Hybrid Uncertainty in Information*. Command and Control Division, DSTO Defense Science and Technology Organization, Edinburg, Australia, 2007.
- [20] G.Wang, J. Zhang, Y. Song, and Q. Li, "An Entropy-Based Knowledge Measure for Atanasov's Intuitionistic Fuzzy Sets and Its Application to Multiple Attribute Decision Making," *Entropy*, 2018. <https://doi.org/10.3390/e20120981>
- [21] N. Zhao and Z. Xu, "Entropy Measures for Interval-valued Intuitionistic Fuzzy Information from a Comparative Perspective and Their Application to Decision Making," *Informatika*, 27 (1), pp. 203 – 228, 2016. <https://doi.org/10.15388/INFORMATICA.2016.82>
- [22] S. Lee, K. L. Man, E.G. Lim, and M. Leach, "Data Analysis with Fuzzy Measure on Intuitionistic Fuzzy Sets," *Int. 2016, MultiConference of Engineers and Computer Scientists, IMECS- March 16 – 18, 2016*.
- [23] J. Dombi, A. V. Lasković, and J. Lerga, "A New Insight into Entropy Based on the Fuzzy Operators, Applied to Useful Information Extraction from Noisy Time-Frequency Distributions," *Mathematics*, 2023. <https://doi.org/10.3390/math11030505>
- [24] M. Rahimi, P. Kumar, B. Moomlvand, and G. Yari, "An intuitionistic fuzzy entropy approach for supplier selection," *Complex & Intelligent Systems*, 7, pp. 1869 – 1876, 2021. <https://doi.org/10.1007/s40747-020-00224-6>
- [25] A. Usha Rubi, J. George Chellin Chandran, T. J. Jain, B. N. Chaiithania, and R. Patil. "REEE – Random Forest Fuzzy Entropy for the classification of Diabetes Mellitus," *AMS Public Health*, 23, 10(2). <https://doi.org/10.3934/publichealth.2023030>
- [26] B. Cardone, and F. Di Martio. "A Fuzzy Entropy-Based Thematic Classification Method Aimed at Improving the Reliability of Thematic Maps in GIS Environments". *Electronics*, 11 (21), 3509, 2022. <https://doi.org/10.3390/electronics11213509>
- [27] P. D'Urso, L. De Giovanni, L.S. Alaimo, R. Mattered, and V. Vitala. "Fuzzy clustering with entropy regularization for interval-valued data with an application to scientific journal citations". *Annals of Operations Research*, 2023. <https://doi.org/10.1007/s10479-023-05180-1>

Framework for Enhancing Customer Loyalty of Telecommunication Companies in India: A Case of Reliance Jio Infocomm Ltd.

Velga Vevere
Commerce Department
Turība University
Riga, Latvia
velga.vevere@gmail.com

Kamaldeep Singh
Commerce Department
Turība University
Riga, Latvia

Iveta Linina
Commerce Department
Turība University
Riga, Latvia
iveta.linina@turiba.lv

Abstract. Enhancing customer loyalty has become a significant concern for several organisations due to the increased competition in the industries. The Indian Telecommunication Industry has experienced a major shift after the launch of Reliance JIO. Many customers have been attracted to Reliance JIO, but it is important for this company to transform the existing customers into loyal customers. The objective of the research is to identify the factors that may increase the brand loyalty of the customer in this industry. To reach this objective the following tasks were set: (1) to research scientific literature on customer loyalty, in general, and in the sphere of telecommunications, in particular; (2) to work out research methodology; (3) to carry out empirical research and discuss results. The research question: What are the factors that can enhance the customer loyalty in the telecommunication industry? Data is collected via customer survey (n=250) and processed by SPSS. The main result of the research lies in the developed customer loyalty framework for telecommunication companies. Practical significance of results lies in recommendations how to enhance customer loyalty towards Reliance Jio Infocomm, Ltd.

Keywords: Customer loyalty, Indian Telecommunication Industry, Brand image, Customer Satisfaction.

I. INTRODUCTION

The telecommunication industry is one of the leading industries in the recent era. Therefore, the competition in the organisations in this industry is also significantly high in the global market for increasing the production of goods and services as well as obtaining customers [1]. Increased dependency on telecommunication companies due to the Covid-19 pandemic also has increased the competition for the organisations in this industry. Many telecommunicating companies have embraced several new services, applications as well as networks. Adopting services such as 5G, satellite services, artificial intelligence and many more can provide the customers with better services, which increases customer satisfaction. This has created problems

for several companies. For example, companies, which cannot provide advanced technologies reduce the engagement of the customers with the company. Evidence also suggests that poor speed of internet and data connectivity also reduces customer loyalty to the telecommunication organisation [2]. Thus, the company need to invest in innovation so that customer can be engaged with the organisation. Moreover, to increase customer loyalty, the company also need to provide them protection to mitigate the risk of cybersecurity. The hacking of data has become one of the major issues, which reduces the trust of the customers. The telecommunication services also have become expensive, which reduces the satisfaction of the customers. Moreover, the individual perception of the customers about the telecommunication services is also essential because customer satisfaction depends on the perspective of the customer. Therefore, several telecommunication organisations cannot satisfy their customers through their services. The telecommunication industry is an important sector in the India because it has helped other industry to develop communication system, driven India's economic growth and also attracted foreign direct investments [3]. This sector has a huge subscriber base with over 1.17 billion consumers as estimated in August, 2022 [4]. This immense growth in this sector has made it world's second largest telecom sector [5]. The advancement in telecommunications has changed the way people used to communicate with each other. The Indian Telecommunication industry has evolved significantly in the past years. The severe competition in the Indian telecom sector is one of the main factors that makes branding vital. Telecom firms must develop a distinctive identity and value proposition that distinguish them from their competitors given the large number of players seeking a piece of the market. A strong brand help businesses in gaining a reputation, foster consumer loyalty, and create a trust [6]. The continually altering market dynamics are another factor that makes branding crucial in the Indian

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8056>

© 2024 Velga Vevere, Kamaldeep Singh, Iveta Linina. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

telecom sector. Telecom businesses must remain on top of trends and swiftly adjust to shifting consumer preferences as a result of the introduction of new technologies like 5G and the rising demand for digital services. In this changing market, it is critical for businesses to demonstrate their creativity, agility, and dedication to satisfying client needs. Finally, branding is crucial to the Indian telecom sector because it enables businesses to engage with customers on a level that goes beyond the services they provide. A powerful brand may establish an emotional bond with consumers, foster trust, and eventually increase advocacy and customer loyalty [7]. Thus, branding is an essential element of any effective telecom strategy in India. In this changing market, it is critical for businesses to demonstrate their creativity, agility, and dedication to satisfying customer needs [8].

The objective of the current research is to identify the factors that may increase the brand loyalty of the customer in this industry. To reach this objective the following tasks were set: (1) to research scientific literature on customer loyalty, in general, and in the sphere of telecommunications, in particular; (2) to work out research methodology; (3) to carry out empirical research and discuss results.

II. MATERIALS AND METHODS

The drastic transformation in the Indian telecommunication industry over the last two decades has been caused due to changes in government policies, technological advancements, and the emergence of new organisations in the market [9]. The Indian telecommunication industry is one of the largest industries in the world. It has over 340 million mobile phone users and a rapidly growing number of internet subscribers as of 2017, which is expected to become more than 1.5 billion users in 2040 [10]. The telecommunication sector introduced mobile telecom service in the 1990s and since then, the industry has grown immensely. Presently, the Indian telecom industry offers a wide range of services, to the service users such as voice and data services, broadband internet, and digital television, among others.

The industry's growth has been driven by various factors, including the increasing affordability of smartphones, low data tariffs, and the government's initiative for digitalization. The sector has witnessed significant consolidation in recent years, with the emergence of new players and mergers and acquisitions among existing players. The telecom industry of India has evolved largely in the past decades and it has contribution to India's economy [11]. As information technology has developed over the years, the telecom services have also expanded and improved in India. Before Reliance Jio entered the telecommunication market of India, there were several companies competing in this sector such as Vodafone, Airtel, Idea, BSNL, Tata Docomo, MTNL, Aircel, and Reliance Communications [12]. However, due to changing market conditions many companies have discontinued their services and presently few companies are operating in the Indian telecom sector but competition among them is high [13].

Reliance Communications entered the Indian telecom industry with the former name Reliance Infocomm. When Reliance Communications began offering its services in

2002, it was one of the pioneers in the Indian telecom sector to introduce the idea of branding [14]. Reliance Communications produced a number of creative marketing initiatives to promote its services after quickly realising the value of branding and marketing. The "Kar lo Duniya Mutthi Mein" campaign was one of the most important branding initiatives undertaken by Reliance Communications [15]. The company's CDMA mobile services were the focus of the ad, which was a resounding success. The advertising campaign included well-known Bollywood actors and actresses, and the slogan "Kar lo Duniya Mutthi Mein" quickly gained popularity among Indian audiences.

In the early 21st century, Bharti Airtel became a successful company in the Indian telecom sector. Bharti Airtel first began operations in 1995, when it was a small regional company. Nevertheless, it swiftly grew to become a national powerhouse. In order to promote its services, Bharti Airtel quickly recognised the value of branding and marketing and developed a number of creative marketing campaigns. The "Har ek friend zaroori hota hai" campaign was one of Bharti Airtel's most important branding initiatives [16]. The campaign has successfully promoted the business's free international calling services. The company created effective marketing strategies to innovatively promote its services. This campaign demonstrated the value of friendships and relationships so that consumers can be emotionally appealed to. The advertisements included well-known Bollywood actors and actresses. The importance of branding for telecom players has increased in response to the increased competition. In 2016, Reliance Jio got introduced in the Indian Telecom market by Mukesh Ambani. Reliance Jio has the vision of enabling 'digital life' in India and thus; it developed 'Jio Digital Life' for offering people with better mobile services. The hashtag of Jio Digital Life have been started using by consumers and many other companies which makes Jio more popular on digital platforms. This company has notably disrupted the market with its affordable data plans and satisfying network quality. According to Talukdar & Chowdhury [17], the branding strategies of 'Jio Digital Life' has successfully fulfilled its aim of promoting the company's 4G services. Moreover, Mukherjee [18] highlighted that Reliance Jio has invested in cell towers, fibre optics network and spectrum for promoting the apps of Reliance Jio such as JioMoney, JioTV and JioChat. This infrastructural investments have been made by this company also for promoting its e-commerce platform. This company has also focused on traditional marketing strategies for making people aware of the offers through posters and billboards. Apart from traditional campaigns, telecom companies in India are also taking advantages of digital media to promote their services [19]. As smartphone usage and internet consumption has increased in India, digital marketing has become an essential part of the telecom industry's branding strategy. Furthermore, Reliance Jio company also provided Jio smartphones at cheaper prices so that more people in India can become mobile users. Mehta [20] also asserted that telecom companies in India collaborates with Bollywood actors for featuring them in their brand promotions.

The Indian market of mobile applications has grown rapidly recently. This market became the fastest growing in

the first quarter of 2018. In 2018-19, Bharti Airtel was about to introduce its new 6000 sites and optical fibre of 2000 km in Gujarat [21]. Bharat Sanchar Nigam Limited (BSNL) also planned to introduce 5G services in the market by 2020. Vodafone India merged with Idea Cellular to become the largest telecom company in India named 'Vodafone Idea' (VI) [22]. The dynamics of the telecommunication industry have been completely changed after the introduction of Reliance Jio on 5th September 2016 for the people of India. Mukesh Ambani introduced the telecom services of Reliance Jio Infocomm Limited [23]. Reliance Jio created tough competition in the telecommunication industry as it provided many alternative options to customers at low prices. The company also provided customers with 4G Handsets at low prices and it triggered a price war in the Indian Telecommunication industry. In the last few years after Reliance Jio's launch in India, the company has made records in the telecom sector. It is the first company in the Indian Telecommunication Industry to secure pan India Unified Licence

Brand equity is the perception of the customer about the brand image of the organisation, which is created through brand association. It can be derived from tangible as well as intangible attributes, which can help to develop brand equity. As suggested by Syed Alwi et al. [24], brand equity can be measured by marketing performance, which can be expressed through behavioural, attitudinal as well as financial outcomes. Therefore, the brand equity of the organisation can help in the financial development organisation. On the other hand, a study by Lin [25] has suggested that brand equity can help to enhance the satisfaction of the customer with the brand. This also can help to enhance the brand loyalty of the organisation. Therefore, their repetitive purchasing behaviour enhances due to brand loyalty. Therefore, this can help to enhance the revenue of the organisation.

Ahmed and Moosavi [26] asserted that customer loyalty is an important achievement of an organisation. Customer loyalty refers to the commitment of customers to make repurchase products and services of the same brands as they prefer to continue using the same brand's goods. There are some factors which can be directly controlled by the organisations such as product and service quality, and also product prices. On the other hand, there are some other sets of factors which cannot be directly controlled by the organisation but countermeasures can be taken to reduce the negative impact of those factors on the telecommunication industry. These factors include competition in the telecom industry, dynamic market trends, and changing consumer needs and preferences. At the same time, there are loyalty factors that can be controlled by the organization. (1) Service quality. In the past decades, several researchers have extensively focused on studying the impact of service quality on customer loyalty because it is highly associated with an increase in customer satisfaction as well as business performance. Service quality is one of the most important factors which can affect customer loyalty. Nsiah & A Mensah [27] have also found that service quality is highly responsible for increasing the rate of customer retention. Service quality is the factor which influences consumers' brand perception. Based on service quality, customers assess a brand by comparing it with other competitive brands [28] [29]. The

perceived service quality of a brand refers to the consumer's assessment regarding the distinction of the goods which are provided by a brand. However, the service quality model demonstrates that customer perceptions and expectations can be different. On the other hand, Kumar et al. [30] found five dimensions through which service quality can be measured, which are 'responsiveness', 'empathy', 'reliability', 'tangible' and 'assurance'. (2) Customer service. Customers can interact with the customer service team to report complaints regarding network issues or any other problem. At that time, the customer service team need to behave properly with the customers and quickly resolve the problems. It is important to act on the issues promptly in order to satisfy the customers and retain them from switching brands. Romdonny & Rosmadi [31] highlighted that satisfying customers can result in enhancing customer loyalty. Research has also found that the telecommunication industry experiences tough competition which forces organisations to implement effective customer service techniques. (3) Brand image. The experience of a consumer while interacting with a brand largely depends on the brand image. Therefore, whenever consumers would seek to purchase the required products or services, the name of the brand would appear into their mind. In this way, organisations can increase customer loyalty by strengthening their position in the customer mind. Consumer's perception of every interaction with brand has important role in shaping the brand image in consumer's mind [32]. (4) Price. Price is one of the most significant factors that affect customer brand loyalty. Price is the cost of the products/services which have to be paid by the customers for purchasing the products. Price competition has increased in the telecom sector and it determines the willingness of consumers to remain loyal to a particular mobile service provider [33]. (5) Trends. Trends are another notable factors which can affect customer brand loyalty. Trends refer to the changes that occur in society, consumer preferences and behaviour. In recent trends, the influence of the internet and technology is noteworthy. As technology continues to advance, customers may have new preferences for the types of products they want to purchase. Companies that adopt new technologies and incorporate them into their products may be more likely to gain loyal customers [34]. Moreover, it can be added that trends also include group actions which means that a change becomes a trend when it is followed by many people. Consumers also tend to take recommendations from other people such as friends and family members. Reference groups are also a vital contributor to the formation of trends. Therefore, telecommunication organisations are required to observe the social changes and adapt their services and marketing strategy accordingly. Telecommunication companies that make investments in research and development to create innovative and high-quality services, along with providing excellent customer service are likely to gain a reputation. This can help the companies to build a strong brand image and consequently increase the rate of customer retention.

In the marketing literature, various authors have provided various definitions of customer loyalty. However, Kiran and Diljit [35] highlighted that the definitions of customer loyalty are broadly categorized into two approaches: the stochastic approach and the deterministic loyalty approach. The stochastic approach views customer

loyalty from a behavioural perspective, where customer behaviour provides insight into the structure of customer loyalty. This includes measures such as purchase share, frequency of purchase, and other operational measures [36]. In contrast, the deterministic approach views customer loyalty as an attitude demonstrated by customers, with the belief that customer behaviour alone is not sufficient in accurately describing the underlying structure of customer loyalty. In order to do so, it is necessary to understand customer attitudes, which can be evaluated through measures such as intention to purchase, customer preferences, customer's desire to recommend the goods to others, and prioritization of supplier [37]. Budianto [38] combined both approaches to defining customer loyalty and identified six parameters where both approaches are explained in terms of their parameters. Therefore, it can be comprehended that the decision of customers to repurchase products of a particular brand and not switch brands depends on their biased and behavioural approaches. Customer loyalty towards the brand can be determined through both the physical and psychological approaches of customers.

A study by Ikramuddin et al. [39] has identified three determinants that can influence customer loyalty in the telecommunication industry. It is a service-providing industry that has rapidly grown over the past few years due to the use of mobile phones. The competition has enhanced in this industry therefore, companies and focusing on attracting customers and retaining them. The service quality provided by the telecommunication organisation is essential for attracting more customers. Diversity of customer needs can be perceived. Therefore, the company need to maintain high-quality service for every kind of customer. Providing high-quality service to telecommunication service users also can help to enhance user satisfaction. It is one of the main influencers of their repetitive purchasing behaviour. This also can help to enhance their trust towards the organisation. Therefore, they can feel more attached towards the organisation and feel secure using their services. It is essential for maintaining the brand loyalty of telecom organisations. On the other hand, a study by Amin et al. [40] also identified four factors related to customer loyalty towards telecommunication service providers. These are service quality, corporate image, trust as well as switching costs.

To gather empirical data the present study employs the method of customer survey using 7-point Likert scale questionnaire divided in 11 blocks according to different aspects of loyalty in the sphere of telecommunications, such as overall service satisfaction, customer service satisfaction, switching propensity, trust in reliance Jio, customized service, company communication, reward programs, brand image, technological innovation, service availability, customer loyalty. The questionnaire was constructed using *Google forms* and distributed via social media. Internal consistency (Cronbach's alpha) test was performed. The result was 0,7853, that certifies good internal consistency..

The present study has identified various inclusion as well as exclusion criteria based on which the sample will be selected from the identified population. Various inclusion, as well as exclusion criteria, have been set for this present study. The quantitative data have been

collected from the customer of Jio. Therefore, a set of inclusion criteria have been set for the survey. Firstly, in order to be included in the survey, the individual needs to be a resident of India. In addition, the individual also needs to be a user of Jio for at least five years. Therefore, the individual who has not constantly using Jio for five years or has shifted to other networks has been excluded from the study. Moreover, individuals who are currently not a resident of India are also been excluded from the study. Snowball sampling has been used to collect data from the survey until data saturation has been observed. The total number of respondents reached 250.

III. RESULTS AND DISCUSSION

The results obtained by the means of online questionnaire were processed by the means of SPSS program, first, to determine the central tendency measures. After that the factor analysis was performed. Table 1 depicts results of descriptive analysis (central tendency measures). The factors (components) are: (1) overall service satisfaction, (2) customer service satisfaction, (3) switching propensity, (4) trust in Jio Reliance, (5) customized services, (6) company communication, (7) reward programs, (8) brand image, (9) technological innovation, (10) service availability, (11) customer loyalty.

TABLE 1 DESCRIPTIVE STATISTICS

Factors	Central Tendency Measures						
	Mean	Median	Mode	Standard Deviation	Variance	Skewness	Kurtosis
1	6.02	6	7	.841	.707	-.038	-1.589
2	4.92	5	5	.813	.660	.149	-1.469
3	4.16	4	5	1.448	2.095	-.571	-.459
4	4.92	5	5	.813	.660	.149	-1.469
5	4.92	5	5	.813	.660	.149	-1.469
6	4.92	5	5	.813	.660	.149	-1.469
7	4.92	5	5	.813	.660	.149	-1.469
8	4.92	5	5	.813	.660	.149	-1.469
9	4.92	5	5	.813	.660	.149	-1.469
10	4.92	5	5	.813	.660	.149	-1.469
11	5.92	6	4	.813	.660	.149	-1.469

The central tendency of the replies is shown by the average value for each variable, which is displayed in the "Mean" column. For instance, with a mean rating of 6.02 out of 10, clients seem pleased with the service provided. Similar inferences may be drawn from the means of other variables, such as customer service satisfaction, switching tendency, and faith in Reliance Jio. The median represents the midpoint between the two extremes of a data set, and is therefore shown in the "Median" column. The medians provide an alternative way of looking at the central tendency. For instance, if half of respondents rank their satisfaction at or above 6.00, we know that they are generally pleased with the service they received. The "Mode" column shows what the most common value is for each variable. It reveals what people often choose as the best appropriate answer to a given circumstance. For instance, a large proportion of clients provided an overall satisfaction rating of 7 for the service they received. Spread

is shown numerically in the "Std. Deviation" column. If the variation or standard deviation of the replies is considerable, it suggests that the consumers have a broad variety of perspectives or experiences. Columns for skewness and kurtosis are supplied. Positive skewness numbers indicate a more skewed distribution toward the right, whereas negative values indicate a more skewed distribution toward the left. A higher kurtosis value indicates a more skewed distribution, whereas a lower kurtosis value indicates a more normal distribution. These statistics provide light on the nature and features of the variable's distribution.

Table 2, in its turn, presents the percentage of variation of the factors: (1) overall service satisfaction, (2) customer service satisfaction, (3) switching propensity, (4) trust in Jio Reliance, (5) customized services, (6) company communication, (7) reward programs, (8) brand image, (9) technological innovation, (10) service availability, (11) customer loyalty.

TABLE 2 PERCENTAGE OF VARIATION OF FACTORS

Factors	Total Variance					
	Initial Eigenvalues			Extraction sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	9.977	90.697	90.697	9.977	90.697	90.697
2	.865	7.860	98.556	-	-	-
3	.159	1.444	100	-	-	-
4	2.011E-15	1.828E-14	100	-	-	-
5	1.659E-16	1.508E-15	100	-	-	-
6	1.267E-17	1.152E-16	100	-	-	-
7	3.058E-32	2.780E-31	100	-	-	-
8	1.325E-35	1.204E-34	100	-	-	-
9	-	-	100	-	-	-
10	1.172E-23	1.066E-22	100	-	-	-
11	1.230E-18	1.118E-17	100	-	-	-
	9.038E-17	8.217E-16	100	-	-	-

The table shows the percentage of total variation explained by each factor. The amount of variation explained by each component is shown in the "Initial Eigenvalues" column. The variation explained after factor extraction is shown as the sums of squared loadings in the "Extraction Sums of Squared Loadings" column. The first eigenvalue of 9.977 in this study represents 90.697% of the variation explained by the first component. As a result, it may be concluded that the first component accounts for a significant fraction of the overall variation. After the first component, the total percentage of variance reaches 90.697%. With an initial eigenvalue of 0.865, the second component may account for an extra 7.860% of the total variance. The sum of the percentages of variance for the

first and second components, however, stays unchanged at 98.556%. An initial eigenvalue of 0.159 assigns 1.444% of the variance to the third component. After the third component, the total percentage of variance hits 100%, indicating that these three components account for all of the volatility in the data.

The statistical data have enabled this study to propose a framework for enhancing customer loyalty in Reliance Jio Infocomm Limited (see figure 1).

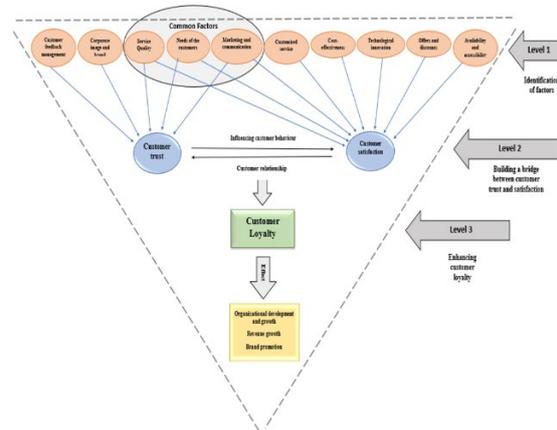


Fig. 1. Conceptual model of customer loyalty in telecommunication industry (Source: Authors')

The framework that has been developed for enhancing the loyalty of the customers in Indian telecommunication is a triangular-shaped model that includes 3 levels. The first stage has focused on identifying the factors that can be associated with customer loyalty and providing an overall view of the theoretical framework. Identification of such factors or variables can help to understand the relationship of several factors with customer brand loyalty. These factors can facilitate customer loyalty. However, the first level of the framework has been divided into three levels. The first level has identified 10 different factors, such as brand image, cost-effectiveness, availability of service, marketing and many more. All of these factors are indirectly related to the customer loyalty of the organisation. The second level of the framework has identified the factors or variables that are directly influenced by the factors that have been identified in the first level. The study has found two variables, which are customer trust and customer satisfaction. These two factors are also directly associated with customer loyalty to the organisation. The primary quantitative data has found a positive correlation of customer satisfaction with customer loyalty. This also has identified a strong positive correlation of customer loyalty with the trust of the customers. In addition, the qualitative data also have suggested that enhancing the trust and satisfaction of the customer through using different strategies can help to develop customer loyalty in the organisation. The third level of the framework also has suggested the necessity of customer loyalty for the telecommunication organisation. This framework has identified the benefits of customer loyalty and has suggested that enhancing customer loyalty can help to enhance their engagement within the organisation. This also can help in increasing the revenue of the organisation. The framework also has suggested that loyalty can help to ensure the development of the organisation.

This framework can also be applied to other companies in the Indian Telecommunication Industry. Customer satisfaction and customer trust both collaboratively play a vital role in enhancing customer loyalty. Based on the research results, the authors have come to the following conclusions.

IV. CONCLUSION

In sum, it can be concluded that customer loyalty is an important aspect of business success because customers are extremely valuable assets of an organisation. Reliance JIO has a huge subscriber base and the company has the concern of retaining the customers.

The statistical data has shown that some customers of Reliance Jio have rated the brand image as average so it is important for the company to monitor what the customers are feeling about the brand and what they perceive. This can enable the management to take proper actions to identify risks to the brand image and maintain a positive brand image. This further attracts new customers and helps to retain existing customers.

Customised services were also found to be a positive connection with customer loyalty. The statistical results have shown that "Customized Services" has a perfect positive connection with customer loyalty (Beta = 1.000). From the qualitative research findings, it can be interpreted that customised services have the scope of satisfying customers because customer needs and preferences are valued by the organisation. Therefore, it can be inferred that Reliance JIO can satisfy its existing customers with customised services and marketing communication.

Customer satisfaction has been found to be impactful on customer loyalty through quantitative and qualitative research. The statistical results have shown a positive correlation between customers' "overall service satisfaction" and "customer loyalty" in Reliance Jio company, shown by the standardized coefficient of 0.890, t-value of 19.288 and p-value of .001. This result inferred that customer satisfaction is an important factor that has an impact on customer loyalty. Customers prefer to repurchase from a brand and recommend the brand to others when they are satisfied with the services.

Customer trust in a telecom company has a vital role in building customer loyalty. The statistical result has found a perfect connection between "Trust in Reliance Jio" and "Customer Loyalty" (R = 1.000) with a standard error of 0.000. Thus, the main concern of a telecom company in India is to gain customer trust in the brands. This finding has aligned with the existing literature that has shown a significant impact of customer trust on customer loyalty. Customer trust is important to influence customer buying behaviour. Customers prefer to purchase from brands which are perceived to be reliable. But the main concern of telecom companies is to make customers repurchase for the long-term and also to make customer brand advocates. The developed framework for customer loyalty in the telecom industry of India depicts the important factors that affect customer loyalty via customer trust and customer satisfaction.

The organization can use this framework for effective relationship management. The frame can help to

understand companies understand the importance of enhancing brand loyalty. This also has shown how relationship management effective marketing communication and many more can help to enhance the loyalty of the customers towards the brand. The company can use this framework for enhancing the trust of the customer who already is satisfied with the services of the organization and also for enhancing the satisfaction of the customers who already trust the brand. Therefore, using this theory for enhancing both satisfaction as well as trust within the customer, can help them to enhance customer loyalty more effectively.

The marketing agencies can use this framework to evaluate the current customer brand loyalty of the companies, which can help to understand the effectiveness of the organization. This also can help them to analyze the strategies that they have implemented for enhancing their customer brand loyalty. This also can help them to evaluate what challenges they are facing regarding their brand loyalty.

The consultancy firms can use this framework to rank the brand loyalty of the companies in the present markets. This will also can help them to develop effective strategies for the companies.

The researchers can use this framework for understanding the factors that influence customer loyalty in an Indian Telecommunication company. In this study, the factors mentioned in the framework have been found to be positively associated with customer loyalty. Thus, researchers can use this information to further develop research objectives.

REFERENCES

- [1] A.-S. Kihara and G.-K. Ngugi, "Factors influencing customer loyalty in telecommunication industry in Kenya," *International Journal of Social Sciences and Entrepreneurship*, vol. 2, no. 4, pp. 14-30, 2014.
- [2] N. Imbug, S.-N.-A. Ambad and I. Bujang, "The influence of customer experience on customer loyalty in telecommunication industry," *International Journal of Academic Research in Business and Social Sciences*, vol. 8, no. 3, pp.103-116, 2018.
- [3] S. Mani, "The Mobile Communications Services Industry in India: Has it led to India becoming a manufacturing hub for telecommunication equipment?" *Pacific Affairs*, vol. 85, no. 3, pp. 511-530, 2012.
- [4] A.-A. Erumban and D.-K. Das, (2016). "Information and communication technology and economic growth in India," *Telecommunications Policy*, vol. 40, no. 5, pp. 412-431, 2016.
- [5] Y.-R. Khan, "Customers preference and satisfaction towards reliance-4 g Jio services in Tiruchirappalli district.," *Jamal Academic Research Journal: An Interdisciplinary*, vol. , no.1, pp. 31-37, 2020.
- [6] R. Sharma and V. Jain, "CSR, trust, brand loyalty and brand equity: empirical evidences from sportswear industry in the NCR region of India," *Metamorphosis*, vol. 18, no. 1, pp. 57-67, 2019.
- [7] A. Coelho, C. Bairrada and F. Peres, "Brand communities, relational outcomes, through brand love," *Journal of Product & Brand Management*, vol. 28, no. 2, pp. 154-165, 2019.
- [8] D. Jamshidi and A. Rousta, "Brand commitment role in the relationship between brand loyalty and brand satisfaction: phone industry in Malaysia," *Journal of Promotion Management*, vol. 27, no. 1, pp. 151-176, 2021.
- [9] D.-K. Sahoo and P.-K. Sahoo, "Efficiency, productivity dynamics and determinants of productivity growth in Indian

- telecommunication industries: An empirical analysis,” *Journal of Public Affairs*, vol. 22, no. 1, pp. 1-8, 2022.
- [10] S. Sun, (2022). “Number of smartphone users in India in 2010 to 2020, with estimates until 2040”, 2022. [Online]. Available at Statista. <https://www.statista.com/statistics/467163/forecast-of-smartphone-users-in-india/> [Accessed 10.02.2024].
- [11] A.-A. Erumban and D.-K. Das, “Information and communication technology and economic growth in India,” *Telecommunications Policy*, vol. 40, no. 5, pp. 412-431, 2016.
- [12] A. Pant, “Determinants of customer loyalty: a study on the factors affecting reliance jio,” *IJFANS International Journal of Food and Nutritional Sciences*, vol. 11, no. 10, pp. 27-33, 2022.
- [13] A.-A. Erumban and D.-K. Das, “Information and communication technology and economic growth in India,” *Telecommunications Policy*, vol. 40, no.5, pp. 412-431, 2016.
- [14] R.-K. Upadhyay, “Disruption in Telecom Sector in India,” *The Deliberation*, November, 2019. [Online]. Available at Available at SSRN: <https://ssrn.com/abstract=4146445> or <http://dx.doi.org/10.2139/ssrn.4146445>
- [15] S. Shenoy, “A study on Marketing strategies adopted by Reliance to push their sales in their Retail Mall Sahakari Bhandar,” *Andean Research Journal*, vol. 6, no. 4, pp. 27-38, 2016-2017.
- [16] C. Barnali, “Code-Switching and Mixing in Communication– A Study on Language Contact in Indian Media,” *The Future of Ethics, Education and Research*, Scientia Moralitas Research Institute, pp. 110-123, 2017.
- [17] A. Talukdar and M.-K. Chowdhury, “The novel marketing strategy of reliance Jio that forever transfigured the telecommunication sector of india: a study,” *International Journal of Management*, vol. 12, no. 9, pp. 11-122, 2021.
- [18] R. Mukherjee, “Jio sparks Disruption 2.0: infrastructural imaginaries and platform ecosystems in ‘Digital India’,” *Media, Culture & Society*, vol. 41, no. 2, pp.175-195, 2019.
- [19] Y. Hole, M.-S. Pawar and E.-B. Khedkar, “Omni channel retailing: An opportunity and challenges in the Indian market,” *Journal of Physics: Conference Series*, vol. 1362, no. 1, November, 2019. [Online]. Available at <https://ui.adsabs.harvard.edu/abs/2019JPhCS1362a2121H> [Accessed 15.02.2024].
- [20] S. Mehta, “Precarity and new media: Through the lens of Indian creators,” *International Journal of Communication*, vol. 13, pp. 5548–5567, 2019.
- [21] A. Verma, S. Dhande & A. Dhande, “Recent Trends in Digital Marketing in Indi,” *Research Journey*, vol. 88, p. 95. 2019.
- [22] R. Pal & S. Shirolkar, Study and analysis of Vodafone-Idea Ltd merger CEO: Ravindra Thakkar,” *Dogo Rangsang Research Journal*, vol. 1, no. 1, pp. 252-257, 2022.
- [23] S. S. Daniel & S. Kanade, “Telecom Industry Bbefore and after Reliance Jio,” *Int. Journal of Social Science and Economic Research*, vol. 6, no. 4, pp. 1223-1231, 2021.
- [24] S.-F. Syed Alwi, B. Nguyen, T.-C. Melewar, Y.-H. Loh and M. Liu, “Explicating industrial brand equity: Integrating brand trust, brand performance and industrial brand image,” *Industrial Management & Data Systems*, vol. 116, no. 5, pp. 858-882, 2016.
- [25] Y.-H. Lin, “Innovative brand experience's influence on brand equity and brand satisfaction,” *Journal of business research*, vol. 68, no. 11, pp. 2254-2259, 2015.
- [26] S. Ahmed and Z. Moosavi, “Factors Influencing the Cell Phone Brand Loyalty of Swedish Generation Y,” 2013. [Online]. Available at <https://www.diva-portal.org/smash/get/diva2:626233/FULLTEXT01.pdf> [Accessed 01.02.2024].
- [27] R. Nsiah & A Mensah, “The Effect of Service Quality on Customer Retention in the Banking Industry in Ghana: A Case Study of Asokore Rural Bank Limited,” 2014 [Online] Available at <https://ssrn.com/abstract=2493709> or <http://dx.doi.org/10.2139/ssrn.2493709> [Accessed 05.02.2024].
- [28] V. Jain, S. Pant & A. Daswani, “Mobile marketing: The emerging Indian perspective,” *International Journal of Mobile Marketing*, vol. 6, no. 2, pp. 17-27, 2011.
- [29] T. M. Khizindar, A. F. Al-Zazzam & I. A. Khanfar, “An empirical study of factors affecting customer loyalty of telecommunication industry in the Kingdom of Saudi Arabia,” *British Journal of Marketing Studies*, vol. 3, no. 5, pp. 98-115, 2015.
- [30] G. Kumar, H. Vani & S. Vandana, “An empirical research on factors affecting mobile subscriber intention for switching between service providers in India,” *International journal of management & business studies*, vol. 1, no. 3, pp. 41-46, 2011.
- [31] J. Romdonny & M. L. N. Rosmadi, „Factors affecting customer loyalty in products,” *Budapest International Research and Critics Institute-Journal*, vol. 2, pp. 337-343, 2019.
- [32] J. Sirapracha & G. Tocquer, “Customer experience, brand image and customer loyalty in telecommunication services,” in *International Conference on Economics, Business and Marketing Management*, vol. 29, no. 3, pp. 112-117., 2012.
- [33] Z. Khundyz, “The Influence Factors of Brand Loyalty: Mobile Phone Industry,” *American Journal of Industrial and Business Management*, vol. 8, pp. 1624-1633, 2018.
- [34] P. Rani, “Factors influencing consumer behaviour,” *International journal of current research and academic review*, vol. 2, no. 9, pp. 52-61, 2014.
- [35] K. Kiran and S. Diljit, (2017). “Antecedents of customer loyalty: Does service quality suffice?” *Malaysian Journal of Library & Information Science*, vol. 16, no. 2, pp. 95-113, 2017.
- [36] I. Shafei and H. Tabaa, (2016). “Factors affecting customer loyalty for mobile telecommunication industry,” *EuroMed Journal of Business*, vol. 11, no. 3, pp. 347-361, 2016.
- [37] A. Gandomi, A., Bazargan and S. Zolfaghari, “Designing competitive loyalty programs: a stochastic gametheoretic model to guide the choice of reward structure,” *Annals of Operations Research*, vol. 280, no. 1, pp. 267-298, 2019.
- [38] A. Budianto, “Customer loyalty: quality of service,” *Journal of management review*, vol. 3, no.1, pp. 299-305, 2019.
- [39] I. Ikramuddin, M. Adam, H. Sofyan and F.Faisal, “Determination of Brand Loyalty in Telecommunications Industry: a Literatur Review,” *International Journal of Engineering & Technology*, vol. 7, no. 3, pp. 59-62, 2018.
- [40] S.-M. Amin, U.-N.-U.Ahmad and L. S. Hui, “Factors contributing to customer loyalty towards telecommunication service provider,” *Procedia-Social and Behavioral Sciences*, vol. 40, pp. 282-286, 2012.

Transforming Higher Education in the Era of Artificial Intelligence Chat Tools: Case Study

Olga Vindaca
Rezekne Academy of Technologies
Rezekne, Latvia
olga.vindaca@rta.lv

Anda Abolina
Rezekne Academy of Technologies
Rezekne, Latvia
anda.abolina@rta.lv

Liga Danilane
Rezekne Academy of Technologies
Rezekne, Latvia
liga.danilane@rta.lv

Abstract. These days it's hard to find someone who hasn't heard of Artificial Intelligence (AI). It is a reality of today's life. Although there are many questions – how to use it effectively, especially in higher education and research. Therefore, the question of AI Literacy becomes relevant, where the key aspects relate to knowledge, skills and psychosocial factors, including a positive attitude towards AI technology and tools. In order to conduct the corresponding transformation of teaching, learning and assessment from the perspective of higher education, the readiness to use AI tools on the example of AI Chat Tools by staff must first be determined. So, within the scope of ERASMUS+ project “DialogEduShift: Transforming Higher Education Teaching and Evaluation Approaches in the Era of AI Chat Tools” the survey was created for cross-country research, including the respondents from the following countries: Poland, Germany, Turkey, Ukraine, Latvia. A comparative analysis of the survey results was then conducted regarding the perspective of three respondent groups: experts in IT field, academician, and university administration. While some questions were specified and intended only for academician.

This article reviews the insights and suggestions gathered during the survey by creating the list of guidelines for effective transformation of teaching and assessment in higher education institutions in the Era of AI Chat Tools. The aim of the article is to determine the AI Literacy of three groups of respondents: IT experts, academician, and university administration who use AI Chat Tools to increase the effectiveness of their work and to summarize the guidelines for updating and renewing teaching and evaluation approaches in higher education institutions by implementing AI Chat Tools. This research is valuable for improving AI Literacy of higher education staff.

Keywords: *artificial intelligence, AI Chat Tools, transformation, teaching, evaluation, higher education.*

I. INTRODUCTION

When did the first thoughts about artificial intelligence (AI) actually arise? As early as 1641, Thomas Hobbes published Leviathan and presented a

mechanical theory of cognition based on combinatorics, emphasizing the role of calculation. At the same time, Blaise Pascal invented a mechanical calculating machine. Subsequently, many other inventions were introduced and used extensively [6].

While the development of AI accelerated significantly in the 1990s, largely due to increases in computing power. One notable event was the victory in 1997 of Deep Blue computer program over world chess champion Garry Kasparov [11]. The history of AI is one of ups and downs, both in terms of interest and funding. Despite a challenging journey, AI is now gaining ever-increasing popularity and is entering a new phase of development.

At the current time, the development of AI represents a turning point that influences various areas of our lives. One area where modern technology plays a key role is education, including higher education (HE). While it raises many questions and discussions regarding its effective use in teaching and evaluation in HE. Despite the increasing prevalence of AI in today's world, many professions still require unique human competence that AI cannot replace. Therefore, the presence of teachers and mentors in educational processes remains, but their traditional roles change to supportive and developing specific skills like critical thinking, interpersonal skills, problem-solving, etc [8].

The effective transformation of teaching and assessment in higher education institutions in the Era of AI Chat Tools is required, focusing on the primary tenets and its implementation. So, the aim of the article is to determine the AI Literacy of three groups of respondents: IT experts, academician, and university administration who use AI Chat Tools to increase the effectiveness of their work and to summarize the guidelines for updating and renewing teaching and evaluation approaches in higher education institutions by implementing AI Chat Tools.

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8014>

© 2024 Olga Vindaca, Anda Abolina, Liga Danilane. Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

II. LITERATURE REVIEW

By conducting the systematic literature review from 2016 to 2022 Helen Crompton and Diane Burke found that interest in research on AI aspect in HE is increasing, and in particular identified five areas of its effective application – from assessment and evaluation to prediction, assistance and student management. While there is a need to empirical research for the appliance of new tools like ChatGPT [5].

According to "The AI Index 2023 Annual Report" presented by Stanford University, AI has entered its age of use. New large-scale AI models were released every month throughout 2022 and early 2023, such as ChatGPT, Bing Chat, etc. with wide range of tasks, from text manipulation and analysis to image generation and unparalleled speech recognition. These systems demonstrate capabilities in answering questions and generating text, images and code that would have been unimaginable a decade ago. AI will continue to improve and as such will become a larger and larger part of our lives. While the effective use and implementation requires additional knowledge and competence [8].

But what exactly is artificial intelligence? The term AI was coined by McCarthy in 1956 during the Dartmouth Conference, where he proposed it as the name for the field of research devoted to the development of machines that can perform tasks that would normally require human intelligence [9]. He is widely regarded as one of the founding fathers of artificial intelligence. The background of early AI was the idea of developing new techniques in data processing. Subsequently, different solutions were sought for various reasons, such as simulating human abilities through machines, applying them in efficient engineering and management applications, providing empirical facts and theoretical hypotheses about the brain or behaviour, and embodying knowledge in computers, in relation to real-life situations, how to relate decision-making, etc. [3].

According to the UNESCO World Commission on the Ethics of Scientific Knowledge and Technology, there is no single or fixed definition of AI, but there is general agreement that AI-based machines are potentially capable of imitating or even exceeding human cognitive abilities, including perception, language interaction, reasoning and analysis, problem solving, creativity, etc. [15].

AI is widely used in our daily lives and also includes education. There are currently many unmet priorities for improving teaching and learning. As a result, educators are looking for technology-driven solutions that are secure, effective, and scalable. They acknowledge the rapid advances in technology in their everyday lives and wonder how these might be applied to teaching and learning. Some are already using AI-powered tools, but there is still a need to understand the full potential of different AI tools, while considering possible risks such as privacy and security risks. Despite the risks, educators are excited to explore how AI can improve the teaching and learning experience for themselves and their students [2].

One of the most popular AI tools is ChatGPT. It is a language model developed by OpenAI that has shown

potential in the education industry. ChatGPT generates human-like responses and conducts conversations with users using natural language processing and machine learning techniques. While ChatGPT and AI-based solutions can provide valuable support and resources in higher education courses, such tools should not be viewed as a replacement for instructors/ educators or traditional teaching instruction. It can be used in various aspects ranging from assessment, teaching/learning to research [13].

According to UNESCO, ChatGPT is a language model that allows people to interact with a computer in a more natural and conversational way. GPT stands for "Generative Pre-trained Transformer" and is the name for a family of natural language models developed by open AI. This is also known as a form of generative AI due to its ability to deliver original results. ChatGPT uses natural language processing to learn from Internet data and provide with artificial intelligence-based written answers to questions or prompts. These models are trained on large text datasets to learn to predict the next word in a sentence and then generate coherent and convincing human-like output in response to a question or statement [14].

It is important to emphasize, that the free version of ChatGPT is based on GPT-3.5, which has limited access to external data or the internet. Additionally, there is a premium option called ChatGPT Plus that uses GPT-4 (Rospigliosi, 2023). Research by Crawford, Cowling, and Allen (2023) demonstrates that ChatGPT outperforms students, suggesting it has the potential to improve higher education courses and potentially revolutionize conventional learning methods [4].

While, Gemini (formerly named Bard) is a generative artificial intelligence chatbot developed by Google (March 21, 2023). Gemini operates on the Language Model for Dialogue Applications (LaMDA) model. It represents Google's family of large conversation models [7].

Additionally, Microsoft Copilot (formerly named Bing Chat), uses large language model technology such as GPT-4 and DALL-E 3 to provide answers [12]. DALL-E 3 is an AI system developed by OpenAI that takes a text prompt as input and generates a new image as output. It builds on its predecessor DALL-E 2, by enhancing caption fidelity and image quality [1].

Summing up, advances in AI such as ChatGPT, Gemini and Microsoft Copilot offer promising potential for transforming various sectors including higher education, conversational interactions and imaging through their representative innovative technologies and capabilities.

After thoroughly reviewing the existing literature on AI, it is essential to outline the methodology employed in this study to address the research questions and objectives identified.

III. MATERIALS AND METHODS

The survey was created within the scope of ERASMUS+ project "DialogEduShift: Transforming Higher Education Teaching and Evaluation Approaches in the Era of AI Chat Tools" for cross-country research,

including the respondents from the following countries: Poland, Germany, Turkey, Ukraine, Latvia.

The theoretical framework of the survey was developed together with the partners, initiated through a comprehensive literature review focused on the integration of AI Chat tools into HE teaching and assessment methods in their respective countries. This included identifying prevailing issues, established practices and existing policies in each partner country. Based on the collective results of all partners, were then evaluated, leading to the formulation of survey questions that covered aspects common to all regions.

The semi-structured survey included ten questions, some of which provided Liker-scale ratings and others of which were open-ended questions, the presented areas are shown in Figure 1.

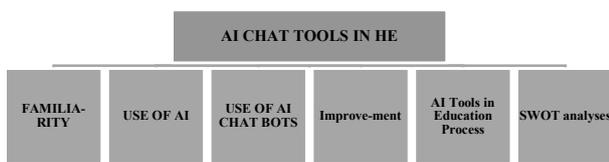


Fig. 1. AI CHAT TOOLS in HE.

Where **Area 1** covered familiarity with concepts such as Artificial Intelligence (AI), Generative AI, data science, machine learning and AI chatbot and required the detailed information on what you know about AI and how you understand it. **Area 2**, on the other hand, dealt with the use or encounter of AI tools in daily life such as AI chatbots, Image generator, Image/ video editor, Video generator, Sound and music generator and Computer vision and required details on the situations and ways of use. In addition, **Area 3** covered the use of AI chatbots such as ChatGPT, Google Bard and Bing Chat. **Area 4** reflected the improvement of the study process in HE thanks to AI technologies, asked how AI technologies can contribute to its improvement, and provided examples/ share experiences when AI tools were helpful or necessary in the study process. It is important to emphasize that this was intended for academicians only. In **Area 5**, six statements on AI in the education process were offered using 5-Likert scale, covering: AI tools in the assessment process; AI tools to create personalized learning approaches; sufficient knowledge and skills for the use of AI technologies in the study process; the need to enhance your knowledge and skills in using AI technologies in the study process; AI creates opportunities for the improvement of the education/study process; AI poses challenges to the education/study process. Area 5 was also only addressed to academicians. Finally, **Area 6** presented SWOT analysis in order to analyse the strengths, weaknesses, opportunities, and threats that the participants believe AI can create in the higher education studying process. A comprehensive survey was conducted across five educational institutions: Rezekne Academy of technologies (Latvia), European House Esthal GmbH (Germany), Sumy State University (Ukraine), Muğla Sıtkı Koçman University (Turkey), Eastern Institute of Business Education (Poland), engaging experts from the IT field, esteemed academicians, and administrative staff.

IV. RESULTS AND DISCUSSION

The primary focus was to gauge familiarity with AI among respondents and understand its integration into daily life in higher education institutions. Total 107 experts participated in the survey. Distribution of participants by country is shown in Figure 2.

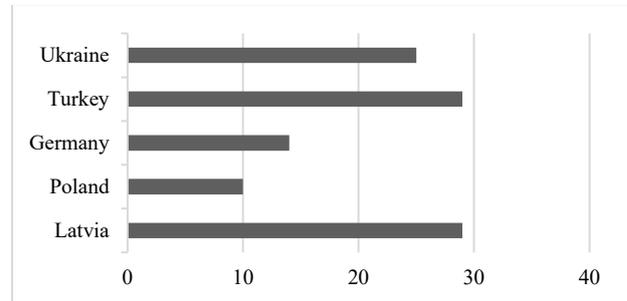


Fig. 2. Distribution by Country.

So, the biggest number of participants were from Latvia and Turkey, while the age of participants varied from 19 to 70.

Aside from the differences between participants, the majority of everyone is familiar with AI and its chatbots (Area 1) and uses it in daily life (Area 2). While the percentage is higher among IT professionals (100%) and academics (80 to 100%) than among administrative staff (around 50%), emphasizing the use of AI chatbots and image generators more than other tools. Notably, the survey highlighted ChatGPT as one of the most popular AI tools (Area 3).

Experts widely concur that AI has the potential to significantly enhance the study process within higher education as well as provide other challenges for improvements (Area 4). Through its advanced algorithms and machine learning capabilities, AI can revolutionize traditional teaching methods by offering personalized learning experiences tailored to individual students' needs and preferences. By analysing vast amounts of data, AI can identify patterns in students' learning behaviours and provide timely feedback, thereby facilitating a deeper understanding of complex concepts. Moreover, AI-powered tools can streamline administrative tasks for educators, allowing them to allocate more time to interactive and engaging teaching activities. As AI continues to evolve, its integration into higher education promises to foster a more efficient, effective, and inclusive learning environment for students across diverse disciplines (Area 4).

Finally, Area 5 was addressed mainly for academicians, the responses shed light on various perspectives. Firstly, participants generally acknowledged the effectiveness of AI tools in the assessment process, with a majority expressing positive opinions. Secondly, there was a notable consensus on the potential of AI tools to create personalized learning approaches, indicating a growing interest in tailored educational experiences. Thirdly, while many respondents felt they possessed sufficient knowledge and skills for using AI technologies in the study process, there were also significant numbers indicating a need for further enhancement in this area, highlighting the

ongoing learning curve associated with AI integration. Fourthly, participants overwhelmingly recognized the opportunities AI creates for improving the education and study process, demonstrating optimism about its transformative potential. Lastly, while a substantial portion recognized the challenges AI poses to the education/study process, particularly in terms of adapting to new technologies and addressing ethical considerations, the overall sentiment remained cautiously optimistic about AI's role in shaping the future of education. Notably, in the academician-specific area, responses indicated a slightly higher level of confidence in utilizing AI technologies, possibly due to their familiarity with research and technological advancements.

In the second part of the questionnaire, SWOT analyses were carried out on the use of AI in higher education to show its advantages and disadvantages. The general responses were analysed without grouping the respondents in accordance to the above-mentioned approach, ensuring a comprehensive assessment of diverse perspectives within the surveyed population.

The data covering the key strengths is presented in Table 1.

TABLE 1 SWOT ANALYSES OF STRENGTHS

Germany	Latvia	Poland	Turkey	Ukraine
STRENGTHS				
<ul style="list-style-type: none"> - individualized learning; - streamlined administration; - enhanced educational processes; - data-driven insights; - facilitated learning; - support for educators; - innovative study approaches 	<ul style="list-style-type: none"> - personalized learning; - individualized student support; - enhanced learning efficacy; - 24/7 virtual assistance; - research assistance; - research skills development; - improved problem-solving; - process automation - Big data; - enhanced information retrieval; 	<ul style="list-style-type: none"> - personalized learning; - automated administration; - process optimization; - data insights; - facilitated learning; - innovative study approaches - enhanced efficiency; 	<ul style="list-style-type: none"> - personalized learning; - instant feedback; - enhanced accessibility; - curriculum optimization; - career development; - lifelong learning; - AI-driven learning; - inclusivity; - Data-Driven Insights; - efficiency - innovation teaching; - support; - improved engagement; 	<ul style="list-style-type: none"> - economic transformation; - personalized learning; - automated feedback/administration; - improved accessibility; - Big data; - process optimization; - innovative education; - enhanced student engagement; - emotional independence;

Thus, the responses from all participants regarding the strengths of using AI in education highlight a collective recognition of its transformative potential in enhancing various aspects of the learning process. Across all countries, there is consensus on AI's ability to personalize learning experiences, streamline administrative tasks, optimize processes, provide valuable data insights, and facilitate easier learning. While specific focuses, tools, and contextual factors may

vary, but the overarching themes underscore the importance of AI in advancing education towards more personalized, efficient, and effective learning environments. As AI continues to evolve and integrate into educational settings, it holds the promise of reshaping the future of education by addressing diverse needs and challenges in a rapidly changing world.

Despite the numerous strengths identified in the use of AI in education, it's important to acknowledge that there are also inherent weaknesses and challenges associated with its implementation. The core weaknesses highlighted within the survey are presented in Table 2.

TABLE 2 SWOT ANALYSES OF WEAKNESSES

Germany	Latvia	Poland	Turkey	Ukraine
WEAKNESSES				
<ul style="list-style-type: none"> - inequality risk; - critical thinking limitations; - privacy concerns; - ethical AI implementation; 	<ul style="list-style-type: none"> - human thought interference; - misinformation - subjectivity in AI systems; - data privacy; - skills/knowledge demand; - ethical concerns; - lack of human involvement; - dependence on technology; - misuse risk; - importance of critical thinking; - less communication 	<ul style="list-style-type: none"> - limitations on critical thinking skills; - privacy concerns; - error potential; - limitations in teaching creativity; 	<ul style="list-style-type: none"> - tech dependence impacting critical thinking/problem-solving; - ethical concerns (data privacy, bias, governance - plagiarism and academic integrity; - emotional intelligence gap; 	<ul style="list-style-type: none"> - limited AI training; - security, ethics, and consequences; - dehumanization risk; - AI in critical infrastructures; - unfair outcomes; - privacy risk; - job displacement; - lack of human factor; - ethical and confidentiality concerns; - data unreliability; - new technology study requirements; - special skills need;

In accordance to Table 2 various weaknesses and concerns associated with the use of AI in education were shed light as well. These include risks of reinforcing existing inequalities, limitations on critical thinking skills, privacy concerns, potential for misinformation and disinformation, subjective AI systems reflecting biased datasets, ethical considerations, dependence on technology leading to diminished human abilities, and the need for new skills and knowledge. Participants also highlighted concerns about the potential for mistakes, limitations in teaching creativity, plagiarism, lack of emotional intelligence, security and ethical aspects, loss of human touch, unfair outcomes, displacement of jobs, and the unreliability of received data. Overall, these responses underscore the importance of addressing these weaknesses and concerns through robust governance frameworks, transparency measures, ethical considerations, and ongoing training to ensure the responsible and effective use of AI in education.

The opportunities presented by the effective use of AI in higher education closely align with its strengths, one could highlight the overlapping benefits and potential advantages that both aspects offer to the learning process. By demonstrating the inherent connection between opportunities and strengths, it becomes evident that leveraging AI in education not only addresses current challenges but also opens up new avenues for improvement and innovation. This perspective underscores the comprehensive and multifaceted benefits of integrating AI into educational settings, ensuring a holistic understanding of its potential impact on learning outcomes and experiences. The analyses of opportunities are presented in Table 3.

TABLE 3 SWOT ANALYSES OF OPPORTUNITIES

Germany	Latvia	Poland	Turkey	Ukraine
OPPORTUNITIES				
<ul style="list-style-type: none"> - positive catalyst for change (accessibility, innovation, global collaboration, new possibilities); - enhance learning enjoyment; - provide extra support; - adapt and personalize learning; 	<ul style="list-style-type: none"> - consultant; - collaborative science engagement; - knowledge creation/expansion; - administrative robots implementation; - in-novative learning approaches - enhanced accessibility; - lifelong learning; - tasks optimization / ideas generation; - student efficiency tool; - self-improvement; 	<ul style="list-style-type: none"> - accessibility; - fostering innovation; - facilitating global collaboration; - enhancing learning enjoyment; - offer additional support; - innovation in teaching methods; - inclusivity promotion; - diverse learning approaches 	<ul style="list-style-type: none"> - higher education improvement; - personalized learning; - accessibility enhance- - lifelong learning; - process automation - data-driven insights; - global collaboration; - in-novative teaching tools; - efficient research; - administrative process optimization; 	<ul style="list-style-type: none"> - enhanced assessment; - improved learning management; - in-novative teaching; - continuous improvements; - operational communication; - information processing; - data and business analytics; - alternative information search; - ideas generation; - task automation - adaptive knowledge delivery;

All participants highlight a collective recognition of the diverse opportunities presented by the use of AI in education. These opportunities span various aspects of the learning process, including accessibility, innovation, global collaboration, personalized learning, and the optimization of administrative tasks. Participants envision AI as a catalyst for positive change, facilitating enjoyable and effective learning experiences while also offering additional support and promoting inclusivity. Moreover, AI is seen as a tool to foster lifelong learning, enhance student engagement and achievement through data-driven insights, and streamline administrative processes for increased institutional effectiveness. Overall, the responses underscore the multifaceted potential of AI to transform and enrich education by addressing a wide range of needs and challenges in the learning environment.

Finally, by identifying the threats associated with the use of AI in education, the same trajectory as in

weaknesses is kept. These threats not only underscore the weaknesses previously mentioned but also represent potential risks and consequences that need to be addressed in the implementation of AI in educational settings (see Table 4).

TABLE 4 SWOT ANALYSES OF WEAKNESSES

Germany	Latvia	Poland	Turkey	Ukraine
THREATS				
<ul style="list-style-type: none"> - job displacement (automation); - ethical dilemmas (privacy); - the risk of widening educational disparities; - potential of AI making incorrect decisions; - proactive, vigilant approach needed; 	<ul style="list-style-type: none"> - knowledge loss; - lack of communication skills; - complexity in controlling AI systems; - unclear future of AI development; - educational inequality; - job loss; - training/preparation required; - no deep understanding; - no critical thinking; - no in-depth analyses; - no individual approaches - no new, unique solutions; - no thinking with fantasy; - the risk of over-reliance on AI - potential negative impacts on communication and critical thinking; 	<ul style="list-style-type: none"> - job displacement; - ethical dilemmas/educational disparities; - risk of wrong choices; - potential for cheating; 	<ul style="list-style-type: none"> - privacy/data security; - focus on quantitative objectives; - ethical concerns; - privacy risks; - job displacement (automation); - digital divide; - misinformation/bias; - regulation required; 	<ul style="list-style-type: none"> - dis-information - impact of AI on the labour market; - Big Data - "robot soldiers"; - ethical concerns; - mindless information copying; - AI dependence - job displacement for educators; - resistance to AI-driven changes in teaching; - automated weapons; - plagiarism prevalence; - dishonesty; - reduction of scientific abilities of students;

So, the core threats include job displacement due to automation, ethical dilemmas related to privacy and accountability, widening educational disparities, potential incorrect decision-making by AI systems, loss of knowledge and critical thinking skills, and the risk of misinformation and bias. Additionally, concerns about the future directions of AI development, privacy and data security risks, and the potential impact on the labour market were also raised. These threats underscore the importance of addressing ethical, regulatory, and educational challenges associated with the implementation of AI in education, ensuring that its integration is done in a responsible and sustainable manner to maximize its benefits while mitigating potential risks. Further discussion is needed to refine the SWOT analysis data of AI tools in HE, ensuring a comprehensive understanding of the strengths, weaknesses, opportunities, and threats they pose.

V. CONCLUSION

Despite the widespread familiarity and daily use of AI among survey respondents, including IT experts, academician, and university administration, especially ChatGPT tool, and a solid understanding of its potential application in higher education, it's essential to recognize that the SWOT analysis reveals a balanced perspective with both advantages and disadvantages.

In summary, the SWOT analysis of the use of AI in higher education reveals a complex landscape with both promising opportunities and significant challenges. The strengths identified include the potential for personalized learning experiences, streamlined administrative tasks, streamlined educational processes, valuable data insights, and facilitated learning. However, these strengths come with weaknesses such as privacy concerns, limitations in critical thinking skills, and ethical dilemmas. Additionally, while there are opportunities to foster innovation, promote inclusion, and improve lifelong learning through AI, there are also threats such as job displacement, increasing educational disparities, ethical concerns, and the risk of misinformation. Although integrating AI into higher education holds promise for transforming learning experiences, it is critical to proactively address these weaknesses and threats through ethical considerations, regulatory frameworks, and ongoing training to ensure responsible and effective implementation.

However, the limitation of the study lies in the different levels of AI use of the three respondent groups, which may have influenced the results obtained and the integration of AI into HE.

Going forward, building on the findings from the SWOT analysis and considering the identified research directions and limitations, further discussion should address the complexities and nuances of AI integration in HE. This discussion could explore the dynamic interplay between technological advancements, educational practices, and sociocultural contexts in shaping the impact of AI on teaching, learning, and institutional structures. Furthermore, there is a need to critically examine the underlying assumptions, values, and power dynamics embedded in AI systems and their impact on educational equity, diversity, and inclusion. Additionally, further discussion should involve stakeholders from diverse backgrounds, including educators, students, policymakers, and industry leaders, to promote interdisciplinary dialogues and collaborative efforts to address the multifaceted challenges and opportunities of AI in HE.

ACKNOWLEDGMENT

The research was carried out with the support of the Erasmus+ project "DialogEduShift: Transforming Higher Education Teaching and Evaluation Approaches in the Era of AI Chat Tools" No. 2023-1-PL01-KA220-HED-000167212.

REFERENCES

- [1] Betker et al. (2023). Improving Image Generation with Better Captions. [Onlain]. Available: <https://cdn.openai.com/papers/dall-e-3.pdf>. [Accessed: February 5, 2024]
- [2] Cardona, M.A., Rodríguez, R.J., Ishmael, K. (2023). *Artificial Intelligence and the Future of Teaching and Learning Insights and Recommendations*. Washington DC: U.S. Department of Education, Office of Educational Technology. [Onlain]. Available: <https://www2.ed.gov/documents/ai-report/ai-report.pdf> [Accessed: January 17, 2024].
- [3] Cordeschi, R. (2007). AI TURNS FIFTY: REVISITING ITS ORIGINS. *Applied Artificial Intelligence*. [Onlain]. Available: https://www.researchgate.net/publication/220355639_AI_turns_fifty_Revisiting_its_origins [Accessed February 8, 2024], doi:DOI: 10.1080/08839510701252304
- [4] Crawford, J., Cowling, M. & Allen, K.A. (2023). Leadership is needed for ethical ChatGPT: Character, assessment, and learning using artificial intelligence (AI). *Journal of University Teaching & Learning Practice*. [Onlain]. Available: https://www.researchgate.net/publication/369112928_Leadership_is_needed_for_ethical_ChatGPT_Character_assessment_and_learning_using_artificial_intelligence_AI [Accessed: February 14, 2024], doi: <https://doi.org/10.53761/1.20.3.02>
- [5] Crompton, H., Burke, D. (2023). Artificial intelligence in higher education: the state of the field. *International Journal of Educational Technology in Higher Education*, 22. [Onlain]. Available: https://www.researchgate.net/publication/370224159_Artificial_intelligence_in_higher_education_the_state_of_the_field [Accessed: January 11, 2024], doi: <https://doi.org/10.1186/s41239-023-00392-8>
- [6] de Sousa et al. (2019). How and where is artificial intelligence in the public sector going? A literature review and research agenda. *Government Information Quarterly*. [Onlain]. Available: https://www.researchgate.net/publication/334685240_How_and_where_is_artificial_intelligence_in_the_public_sector_going_A_literature_review_and_research_agenda [Accessed December 24, 2023], doi: <http://dx.doi.org/10.1016/j.giq.2019.07.004>
- [7] Gan et al. (2024). Performance of Google bard and ChatGPT in mass casualty incidents triage. *The American Journal of Emergency Medicine*, 72-78. [Onlain]. Available: https://www.researchgate.net/publication/375072051_Performance_of_Google_bard_and_ChatGPT_in_mass_casualty_incidents_triage [Accessed February 4, 2024], doi: <https://doi.org/10.1016/j.ajem.2023.10.034>
- [8] Maslej et al. (2023). *The AI Index 2023 Annual Report*. Stanford, CA: AI Index Steering Committee, Institute for Human-Centered AI, Stanford University. [Onlain]. Available: https://aiindex.stanford.edu/wp-content/uploads/2023/04/HAI_AI-Index-Report_2023.pdf [Accessed: February 14, 2024]
- [9] McCarthy et al. (1955). *A PROPOSAL FOR THE DARTMOUTH SUMMER RESEARCH PROJECT ON ARTIFICIAL INTELLIGENCE*. [Onlain]. Available: <http://www-formal.stanford.edu/jmc/history/dartmouth/dartmouth.html> [Accessed: January 18, 2024].
- [10] Rospigliosi, P. (2023). Artificial intelligence in teaching and learning: what questions should we ask of ChatGPT? *Interactive Learning Environments*, 1-3. [Onlain]. Available: https://www.researchgate.net/publication/368730305_Artificial_in_telligence_in_teaching_and_learning_what_questions_should_we_ask_of_ChatGPT [Accessed: February 18, 2024], doi: [10.1080/10494820.2023.2180191](https://doi.org/10.1080/10494820.2023.2180191)
- [11] Seirawan, Y. (1997). Still No Match for the Human Brain. *Communications of the ACM*, 40(8). [Onlain]. Available: <https://dl.acm.org/doi/pdf/10.1145/257874.257878> [Accessed: February, 2024].
- [12] Stephens et al. (2023). Battle of the (Chat)Bots: Comparing Large Language Models to Practice Guidelines for Transfusion-Associated Graft-Versus-Host Disease Prevention. *Transfusion Medicine Reviews*. [Onlain]. Available: https://www.researchgate.net/publication/373254405_Battle_of_the_chatbots_comparing_large_language_models_to_practice_guidelines_for_transfusion-associated_graft-versus-host_disease_prevention [Accessed: February, 2024], doi: <https://doi.org/10.1016/j.tmr.2023.150753>
- [13] Tayan et al. (2023). Considerations for adapting higher education technology courses for AI large language models: A critical review of the impact of ChatGPT. *Machine Learning with Applications* 15. [Onlain]. Available: https://www.researchgate.net/publication/375916566_Considerations_for_Adapting_Higher_Education_Technology_Courses_for_AI_Large_Language_Models_A_Critical_Review_of_the_Impact

- _of ChatGPT [Accessed: January, 2024],
doi:<https://doi.org/10.1016/j.mlwa.2023.100513>
- [14] UNESCO. (2023). *ChatGPT and Artificial Intelligence in Higher Education*. UNESCO. [Online]. Available: [https://www.iesalc.unesco.org/wp-content/uploads/2023/04/ChatGPT-and-Artificial-Intelligence-in-](https://www.iesalc.unesco.org/wp-content/uploads/2023/04/ChatGPT-and-Artificial-Intelligence-in-higher-education-Quick-Start-guide_EN_FINAL.pdf)
- higher-education-Quick-Start-guide_EN_FINAL.pdf [Accessed: February, 2024].
- [15] UNESCO COMEST. (2019). *Preliminary study on the Ethics of Artificial Intelligence*. UNESCO. [Online]. Available: <https://unesdoc.unesco.org/ark:/48223/pf0000367823> [Accessed: January, 2024].
- [16]

Environmental Data and Digital Twins for Road Traffic Safety in Rural Areas

Roberts Volkovičs

Modelling of sociotechnical systems
Vidzeme University of Applied
Sciences
Valmiera, Latvia
roberts.volkovics@va.lv

Viesturs Bambāns

Modelling of sociotechnical systems
Vidzeme University of Applied
Sciences
Valmiera, Latvia
viesturs.bambans@va.lv

Ginta Majore

Modelling of sociotechnical systems
Vidzeme University of Applied
Sciences
Valmiera, Latvia
ginta.majore@va.lv

Abstract. In this article, the critical factors of the road traffic safety in rural areas are reviewed. The critical factors and related information from open data and environmental data are analysed and the meta model is created for processing of road traffic safety data in rural areas. Later on the basis of meta model the Digital Twin is created that could be used for an improvement of the traffic safety on the rural area roads in Latvia. An open data analysis is performed that concludes the opportunities to improve the potential of Latvian traffic accident open data.

Keywords: Road Traffic safety, Digital Twins, Open data, Environmental data.

I. INTRODUCTION

In this article as critical factors (key factors) we will consider such factors that may raise probability of road traffic accidents or probability of higher severity of the accidents if accidents do happen. In the next paragraphs we will list several sources of the information about road traffic accidents in different countries of the world. In case a source of data or report about the traffic safety mentions some factor as an important factor and collects statistics on such factors then we can consider such factor as a critical factor.

In the article [1] critical factors of road traffic accidents are presented in hierarchical structure, see "Fig. 1". This study focuses on finding associations (correlations) from categorical variables which describe road traffic accidents to severity of the accidents and probability of accidents with higher severity.

Correlation rule is the study of correlation between different events. It is a data mining method. In simple terms, correlation rule can produce a type of "A=>B" effect, namely when A happens, B will occur as a result. Association analysis is with the goal of mining the hidden relationship between data, looking for the same event in the correlation of different items [1].

Similar approach with defining critical factors of road traffic accidents is used in many scientific articles, for example in the article [2], where authors formulate critical factors in the following way: "our research data included variables describing the conditions that contributed to the accident and injury severity:

characteristics of the accident (month, time, day type, number of injuries, number of occupants, accident type, number of involved vehicles and cause); weather information (prevailing weather conditions and lighting); driver characteristics (age and gender); and road characteristics (pavement width, lane width, shoulder

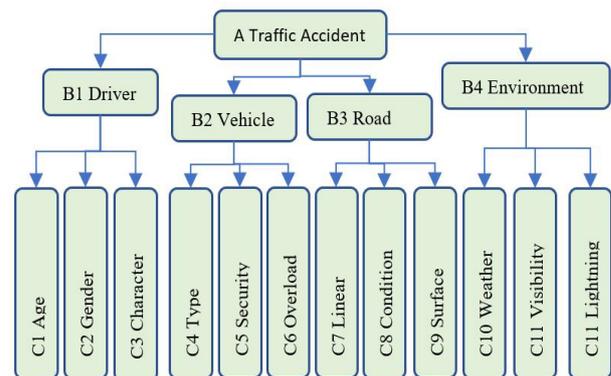


Fig. 1 RTA - critical factors [1].

width, paved shoulder, pavement markings and sight distance)".

We will process the critical factors using our meta model or digital twin with different methods available in the digital twin, for example, statistics and try to distinguish the factors which are more critical than the others based on the open-data we were able to find on the Internet.

II. MATERIALS AND METHODS

In the next table "Tab. 1" we have named the critical factors, that could cause road traffic accidents and raise the severity of road traffic accidents, found from various sources [1], [3], [4], [5], [6], [7], [8]. Most of the critical factors mentioned are traditional ones mentioned already in reports on traffic accidents since the very beginning when analysis of traffic accidents started in the fifties of previous century in the United States.

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8012>

© 2024 Roberts Volkovičs, Viesturs Bambāns, Ginta Majore. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

TAB. 1: CRITICAL FACTORS OF ROAD TRAFFIC ACCIDENTS

VAR. CAT.	CODE	NAME
ACT: Acc. type	ASC	Angle or side coll.
	HOC	Head-on coll.
	PUC	Pile-up coll.
	FOC	Fixed-object coll.
	ROR	Run off road
	CP	Coll. with pedestrian.
AGE: Age	RO	Roll over
	OT	Other
	TEE	≤ 18 or with ≤ 18
	YOU	All [18 – 25]
	ADU	All (25 – 64]
ATF: Atm. fact.	OLD	≥ 64 or with ≥ 64
	YAA	[18 – 25] and (25 – 64]
	GW	Good weather
	LR	Light rain
	HR	Heavy rain
CAU: Cause	OT	Other
	DC	Driver characteristics
	RC	Road characteristics
	VC	Vehicle characteristics
DAY: Day	OT	Other
	BW	Beginning of week (Mon)
	EW	End of week (Friday)
	WD	Weekday
GEN: Gender	WE	Weekend
	M	Male
LAW: Lane width	F	Female
	THI	< 3, 25m
	MED	[3, 25 – 3, 75]m
LIG: Lighting	WID	> 3, 75m
	DAY	Daylight
	DU	Dusk
	IL	Insufficient
MON: Month	SL	Sufficient
	WL	Without lighting
	WIN	Winter
	SPR	Spring
NOI: Num. of inj.	SUM	Summer
	AUT	Autumn
	[1]	1 injury
	[2]	2 injuries
OI: Occup. Inv.	[+2]	> 2 injuries
	[1]	1 occupant
	[2]	2 occupants
PAS: Paved should	[+2]	> 2 occupants
	N	No
	Y	Yes
	NE	Does not exist or impractical
PAW: Pav. width	THI	< 6m
	MED	[6 – 7]m
	WID	> 7m
ROM: Pav. mark.	DME	Does not exist or was deleted
	DMR	Separate margins of roadway
	SLO	Separate lanes only
	SLD	Separate lanes define road
SHT: Should. type	NE	Does not exist or impractical
	THI	< 1, 5m
	MED	[1, 5 – 2, 5]m
SID: Sight distance	WID	> 2, 5m
	ATM	Atmospheric
	BUI	Building
	TOP	Topological
	VEG	Vegetation
TIM: Time	WR	Without restriction
	OT	Other
	[0 – 6]	[0 – 6]
	(6 – 12]	(6 – 12]
	(12–18]	(12–18]
VI: Vehicles inv.	(18–24]	(18–24]
	[1]	1 vehicle
	[2]	2 vehicles
	[3]	3 vehicles

There are many different options of improving human behaviour in drivers position by using modern technologies which are not mentioned in traditional sources of traffic accident data such as usage of mobile phones during the driving, usage of other modern technologies such as infrared automotive night vision of the road which could detect danger from animals or humans on the road during conditions with bad visibility. Nowadays infrared automotive night vision is included as a separate cost option in different models of cars from different car makers with the average price around 2500 EUR [9].

However, according to SAE classification level [10], most of the technologies available today in the cars available to public are released only with Level 1 (driver assistance) or Level 2 (partial automation) driving assistance technologies. This is because each of technology individually usually has several shortcomings, for example, infrared automotive vision does not function very well in heavy rain conditions and conditions with fog.

Lately new developments of self-driving cars are done with the help of LIDAR technology [11]. This technology uses lasers to detect the distance between the car and the nearest object. Or in more complicated case it can construct very accurate real-world 3D model from the laser scans.

However, such solutions are at the moment available only in concept models of the cars. There are predictions on the Internet that first models released with LIDAR technology will have a cost for this option which could exceed 30 000 EUR. LIDAR systems have been used since 1960-ties having initial use cases in space technologies and cartography due to the price of this technology only recently the evolution of technology allowed to start its usage in the industry of self-driving cars [11].

In "Fig. 2" we can see the work principles of LIDAR system [11].

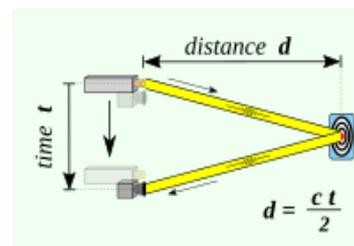


Fig. 2 Work principles of LIDAR system.

In the scope of this work we will focus on our meta model and construction of digital twin for our environment rather than automotive solutions for the cars, but it was worth to mention the options available as automotive solutions as the impact of those solution will only increase on different aspects of traffic safety.

It is important to review data about road traffic accidents on regular basis to find new solutions and options to reduce those events and reduce the severity of those events. We should remember that technology evolves and human behaviour could change during time which means that the topic of road traffic safety will be actual in all times and should be monitored closely.

Knowing such factors of vehicle as geographical location we have technical possibilities to provide feedback to drivers via mobile devices, onboard navigation systems, for example, about dangerous situation on their way. Knowing combination of critical factors which caused the accident we can try to improve the future situation with adjustment of traffic signs and electric lighting in the particular "black spot" or providing the warning to the driver via mobile phone of "black spots" he or she is approaching.

In the "Fig. 3" [4] below we can see the data on road traffic accidents per million inhabitants per country during a period of one year. The most fatalities (approx. 130) per million inhabitants do happen in Kazakhstan and Georgia, the least (approx. 20) do happen in Iceland and Norway. Countries may differ by economic situation, geographic location, culture, traditions and many other aspects.

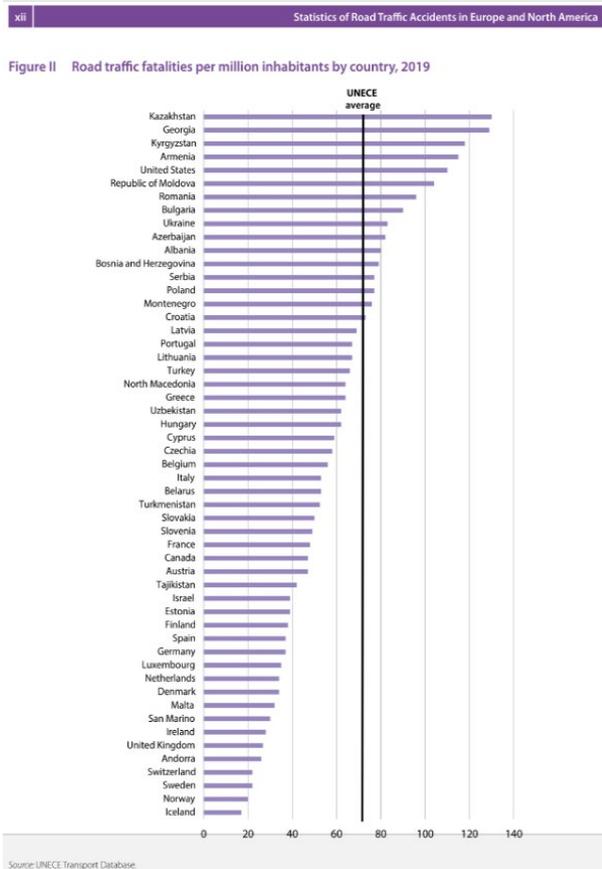


Fig. 3 RTA per million people per country – list.

The graph in "Fig. 3" clearly shows that it is possible to improve the situation with traffic safety on the roads by changing human behaviour with laws and regulations and by changing environment which directly impacts traffic safety.

One can see that neighbouring Baltic countries are in different positions in the graph however we can consider that countries are very similar by the size, the density of people, the rural vs the urban division and many other factors.

We can show the same data as in "Fig. 3" on the map, please, see "Fig. 4" [4] below.

In "Fig. 4" it is visible, that it is possible to achieve different results in different countries and human populations based on different set of laws, rules, regulations, culture, traditions. We should keep looking for solutions and continuously monitor the current situation to be able to react accordingly if situation changes towards negative side.

Open data about the Road Traffic safety

Nowadays government institutions over the world have decided to make some part of the data they collect to be available for everyone and place the data on the Internet so those data are available for everyone who has a connection to the Internet and we call those data an open data. Open data is data that is openly

accessible, exploitable, editable and shared by anyone for any purpose. Open data is licensed under an open license [12].



Fig. 4 RTA per million inhabitants per country – map.

One can find open data about the Latvian road traffic safety, accidents and other aspects related to traffic on the Internet resource [13]. This will be one of open data sets we are going to use in the scope of this article.

Results from data analysis from Latvian data set about road traffic accidents could be compared to other data sets from other countries which could help in proving of null hypothesis and statistic's results. For example, data about road traffic accidents from United States are available on the Internet resource Kaggle [14]. This data set was collected as part of independent research by collecting data from all available open data set sources in the United States.

Other way to get data regarding traffic accidents from the United States is to use their government institution NHTSA official report data. The National Center for Statistics and Analysis (NCSA), an office of the National Highway Traffic Safety Administration, has been responsible for providing a wide range of analytical and statistical support to NHTSA and the highway safety community at large for over 45 years [15], [16], [3].

Information from three of NHTSA's primary data systems has been combined to create a single source for motor vehicle traffic crash statistics. The first data system, the Fatality Analysis Reporting System (FARS), is probably the better known of the three sources. Established in 1975, FARS contains data on the most severe traffic crashes, those in which someone was killed. The second source is the National Automotive Sampling System General Estimates System (NASS GES), which began operation in 1988 and ended in 2015. NASS GES contains data from a nationally representative sample of police-reported crashes of all severities, including those that resulted in death, injury, or property damage. The third source is the Crash Report Sampling System (CRSS), which replaced NASS GES in 2016. CRSS is the redesigned nationally representative sample of police-reported traffic crashes [3].

For several counties in Europe open data on traffic accidents could be found on European Commission's official portal [17].

Analysis of open data

Mostly open data are placed on the Internet in format of CSV. A comma-separated values (CSV) file is a delimited text file that uses a comma to separate values. Each line of the file is a data record. Each record consists of one or more fields, separated by commas. The use of the comma as a field separator is the source of the name for this file format. A CSV file typically stores tabular data (numbers and text) in plain text, in which case each line will have the same number of fields [18].

Nowadays very common method of processing open data in CSV files is Pandas library from Python programming language.

Python programming language allows tabular structures from CSV files to be loaded in the memory of personal computer or the server and to be processed there with many different mathematical methods, statistics methods and algorithms. In many cases Python serves as free and open source alternative to such commercial products as MATLAB, Excel, SPSS.

Pandas is an important Python library for data manipulation, wrangling and analysis. It functions as an intuitive and easy-to-use set of tools for performing operations on any kind of data. Initial works for Pandas was done by Wes McKinney in 2008 while he was developer at AQR Capital management. Since then, the scope of the Pandas project has increased a lot and it has become a popular library of choice for data scientists all over the world [19].

In the "Fig. 5" bellow we can see the meta model used in this work to process open data about traffic accidents.

In the "Fig. 5" as the first step we do see data collection from the Internet from the sources like [13]. The next step is data loading into relational database. From relational database data could be prepared to required format and shape using SQL language and later of-loaded to CSV files for further processing with the Pandas library from Python language which provides even further access to different types of algorithms from mathematics to artificial intelligence.

The meta model in "Fig. 5" is simplified and it does not include all the steps and decision points, but it clearly shows that from each step it is possible to go forward and backward in the processing as processing information from CSV files usually requires data adjustment and error corrections.

This meta model could be further extended connecting it to other models, for example, we could use anomaly detection model to exclude noisy data from the data set or we could use open data collected by weather stations to create analysis of traffic accidents considering weather conditions.

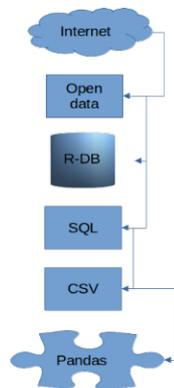


Fig. 5 Steps of the processing of open data.

Digital twins and Road traffic safety

A digital twin is a digital representation of an intended or actual real-world physical product, system, or process (a physical twin) that serves as the effectively indistinguishable digital counterpart of it for practical purposes, such as simulation, integration, testing, monitoring, and maintenance [20].

The first practical definition of a digital twin originated from NASA in an attempt to improve physical-model simulation of spacecraft in 2010 [20]. We can conclude that the digital twins can be utilised in other areas of transportation as well to perform calculations, simulations, integration, testing, monitoring and maintenance.

For the area of road traffic safety, we can consider that the representation of the real world is in the open data collected by the police on traffic accidents, measurements done by sensors of

weather stations on the road, digital cartographic data available for the area and even open data from the space stations like Sentinel-2 or Sentinel-3.

The idea of the model of digital twin impacting the physical model (the real-world traffic system), could be implemented, for example, by performing analysis of situation on one road and measuring the effectiveness of different countermeasures for traffic safety improvements before implementing the most effective countermeasures in wider area. Here digital twins can bring benefits for both traffic safety and economical aspects of countermeasure implementation.

For example, we can find out from the data that many traffic accidents in rural areas do happen due to the collisions with wild animals. And if we see that these types of accidents do happen especially frequently on several roads, we can decide to test different countermeasures for preventing the incidents, like building the bridges for animals to cross the roads, implementing more road signs, implementing sensor systems to scare off wild animals. When we notice by digital twin which is the most effective form of countermeasures we can implement that in wider scope. Thus, decisions are made based on data and solutions are tested on digital twin before further investments.

Several implementations of such ultra sound wild life deterring devices where done in Latvia in 2020. In total 1275 such devices are installed along 34.1 kilometres of state roads in Latvia [21], [22].

Another example would be to make weather condition-based information provisioning to drivers on particular road via electric signs or radio in case we know that weather conditions will get worse after some time and drivers could benefit from this information by driving more carefully.

Since NASA implemented the first digital twin model in 2010, the concept of digital twin model has evolved further in science literature frequently mentioning that the feedback from digital twin to physical twin should be provided almost in real time. However, for the scope of this work we will base our understanding of digital twin assuming that the feedback provided to physical twin could be delayed in time due to the country wide scope and nature of this particular topic.

We can take the idea of time relativity here from physics and astronomy where nowadays scientists try to include the idea of human consciousness in understanding of time relativity, so we can consider that there are several time flows and there are "before and after" time flow for each event, the time spent performing all the steps of each event is out of scope of our interests and could be considered as a moment.

In explaining this relativity (the relativity of time), we shall be able to confirm the idea of the two different flows of time, namely "before to after" and "after to before", and finally explain how the idea of "consciousness" fits perfectly in that presentation of the idea of the relativity of time [23].

III. RESULTS AND DISCUSSION

Usage of Mann Whitney U test for calculation of key factor criticality

In statistics, the Mann-Whitney U test (also called the Mann-Whitney-Wilcoxon (MWW/MWU), Wilcoxon rank-sum test, or Wilcoxon-Mann-Whitney test) is a non-parametric test of the null hypothesis that, for randomly selected values X and Y from two populations, the probability of X being greater than Y is equal to the probability of Y being greater than X [24].

Some key assumptions for Mann-Whitney U Test are detailed below [24]:

- The variable being compared between the two groups must be continuous (able to take any number in a range – for example age, weight, height or heart rate). This is because the test is based on ranking the observations in each group.

- The data are assumed to take a non-Normal, or skewed, distribution. If your data are normally distributed, the unpaired Student's t-test should be used to compare the two groups instead.
- While the data in both groups are not assumed to be Normal, the data are assumed to be similar in shape across the two groups.
- The data should be two randomly selected independent samples, meaning the groups have no relationship to each other. If samples are paired (for example, two measurements from the same group of participants), then a paired samples t-test should be used instead.
- Sufficient sample size is needed for a valid test, usually more than 5 observations in each group.

Further in the paper we will provide the results of calculations for the Mann-Whitney U Test where we will use the variable of traffic accidents death rate and compare it from two groups to calculate if death rate is higher during night or during day.

Data processing case

The majority of road fatalities in Latvia occurred on rural roads (70%). This percentage is much higher than in the European Union as a whole. The share of fatalities on urban roads on the other hand is lower than the EU average. There are no motorways in Latvia. Over the past ten years, fatalities show a downward trend on both road types in Latvia, the decrease on urban roads was considerably larger than in the European Union [25].

In the "Fig. 6" we do see territory of Latvia divided into Urban and Rural areas [25].

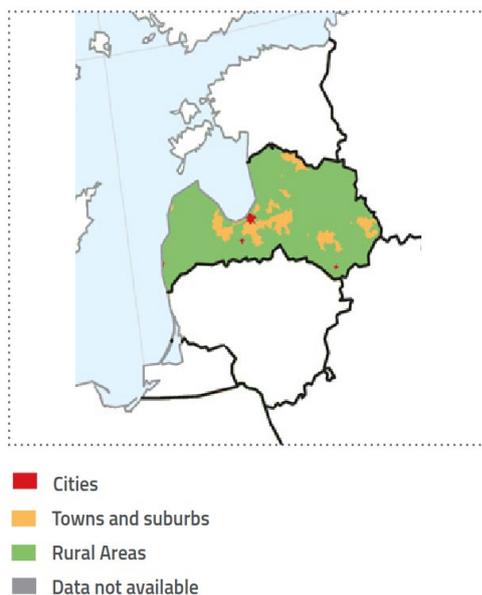


Fig. 6 Degree of urbanization – Latvia.

We can assume that some of the most critical factors causing traffic accidents affect both rural and urban roads in similar way. For example, daylight conditions which affect whole territory of the country at the same time as Latvia has only one time zone and it gets dark almost simultaneously everywhere.

We have collection of open data for traffic accidents in territory of Latvia for almost twenty of years and daylight conditions are one of the factors in the data set "Tab. 2" [13].

ID	ROAD_1	ROAD_KM	ROAD_2	COLUMNn	WEATHER	LIGHT	COLUMNm
0A0001		67	NaN	...	clear	night	NaN
1A0001		87	NaN	...	clear	day	NaN
2A0001		90	NaN	...	cloudy	night	NaN
3A0001		1	NaN	...	cloudy	day	3.0
4A0001		0	NaN	...	cloudy	night	3.0
40983V1484		1	NaN	...	cloudy	day	NaN
40984V1484		6	NaN	...	cloudy	day	NaN
40985V1484		1	NaN	...	cloudy	day	NaN
40986V1488		4	NaN	...	clear	nightfall	NaN
40987V1489		5	NaN	...	sunny	day	NaN

Tab. 2. Traffic accidents – Latvia.

Below descriptive statistics are provided for the data set visible in "Tab. 2". "Tab. 3" shows descriptive statistics for traffic accidents with victims.

Descriptive statistics : Traffic accidents with victims						
Variable	N	Mean	SD	SE	95% Conf. Interval	
victims	40988.0	0.3008	0.4586	0.0023	0.2964	0.3052

Tab. 3 Traffic accidents – victims.

"Tab. 4" shows descriptive statistics for traffic accidents causing death of victims.

Descriptive statistics : Traffic accidents causing - death						
Variable	N	Mean	SD	SE	95% Conf. Interval	
deaths	40988.0	0.0364	0.2111	0.001	0.0344	0.0384

Tab. 4 Traffic accidents – deaths.

"Tab. 5" shows descriptive statistics for traffic accidents in different daylight conditions.

Descriptive statistics : Daylight			
Variable	Outcome	Count	Percent
daylight	1 day	25063	61.15
	2 night	13417	32.73
	3 nightfall	2135	5.21
	3 NaN	373	0.91

Tab. 5 Traffic accidents - daylight

Using the data set described previously we calculated Mann Whitney U test to detect if probability $P(\text{DEATHS}(\text{day})) < P(\text{DEATHS}(\text{night}))$ and we got the following result of Mann Whitney U test:

- (statistic\$ = \$9106797.0, p-value\$ = \$0.002120460965743069)

This proves that accidents which happen during the night time could be more severe in average due to visibility conditions and drivers need to pay attention to this factor as very important one for the safety.

Knowing such data government could decide to change rules for driving, for example, decrease the maximum allowed driving speed on the rural roads with the most accidents and compare the results achieved later. It is worth to mention that this test was performed periodically and the results of Mann Whitney U test returned less p-value with the growth of data set which means that Latvian data set of traffic accidents for such type of calculations does not provide general rules for this type of calculation and the test could be repeated for similar data sets of other countries to gain more evidence to prove the importance of this critical factor.

"Fig. 7" shows graphical representation of frequency of deaths caused by traffic accidents in different day light conditions.

"Fig. 8" a kernel density estimate (KDE) plot. KDE plot is a method for visualising the distribution of observations in a data

set, analogous to a histogram. KDE represents the data using a continuous probability density curve in one or more dimensions [27].

And in "Fig. 8" we see the KDE plot of death distribution in different daylight conditions.

As KDE plot has characteristics as histogram we can conclude that data shape for variable deaths is similar in different daylight conditions which as well full-fills the requirement of having data of similar shape to use Mann-Whitney U test for analysis of the data and calculation of probability of impact on one numeric, continuous and dependent variable from other independent categorical variables.

IV. CONCLUSIONS

In the scope of writing this article we have achieved several results. We have created the meta model on how to create a digital twin to process the data about traffic accidents. We have created a digital twin which allows us to process the data of

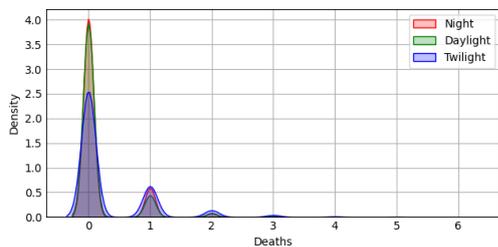


Fig. 8. Deaths KDE distribution in different daylight conditions.

traffic accidents in Latvia and we can use this approach in general as a system which helps to make decisions on how to improve traffic safety in general. The main components of our Digital Twin are:

- CVS files with open data;
- Python scripts and Python Pandas library used for statistical analysis of open data;
- Python scripts used for calculation of moon phase;
- Oracle database in the cloud used for data storage, shared access of data and data processing;
- Oracle SQL Developer used for access of Oracle database in the cloud;
- Oracle SQL loader used for loading large CSV data sets in the database;
- Digital Twin has very good potential for extension with other programming languages and tools.

Using Mann Whitney U test, we have gained statistical evidence that daylight conditions is one of the most critical factors raising probability of traffic accidents and raising severity of traffic accidents on rural area roads in Latvia. Most of the Latvia territory could be considered as rural, as it is visible in "Fig. 6" and most of the accidents with high severity do happen on rural roads so in case we focus on improvement of road traffic safety and especially on reducing accidents with high severity then rural areas could gain the potential benefit out of it.

Using mathematical methods and algorithms we tried to verify if new critical factors could be introduced to classify traffic accidents. We calculated based on exiting algorithms the astronomical phase of the moon for each particular accident and tried to verify if moon phase has some impact on traffic accidents with high severity [28], [29].

In this case we noticed no evidence of moon phase affecting traffic accidents. However, the approach proves that new critical factors could be introduced or not introduced based on the results of calculations gained from our digital twin.

After performing open data analysis of traffic accident data from different countries and available sources. We have noticed opportunities to improve the potential of Latvian traffic accident

open data. In case traffic accidents would be registered with geographical location coordinates we could use spatial data analysis and gain better understanding, for example, on "black spot" data and we could perform further calculations in finding out the reasons of "black spots" forming in each particular case.

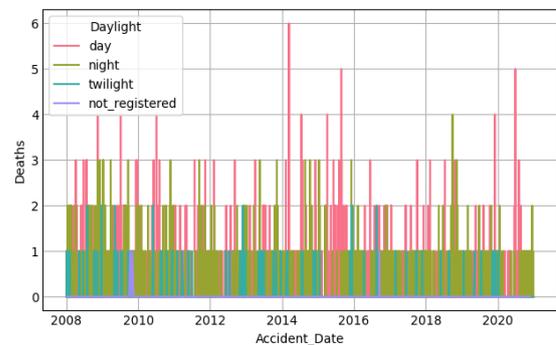


Fig. 7 Deaths different daylight conditions.

V. ACKNOWLEDGMENTS

This research was funded by the European Commission, Research Executive Agency grant number 101079206, "Twinning in Environmental Data and Dynamical Systems Modelling for Latvia" (TED4LAT).

VI. REFERENCES

- [1] J. Xi, Z. Zhao, W. Li, Q. Wang, "A Traffic Accident Causation Analysis Method Based on AHP-Apriori," *Procedia Engineering*, vol. 137, pp. 680-687, 2016. [Online] Available: <https://doi.org/10.1016/j.proeng.2016.01.305>. [Accessed: Dec. 2, 2023].
- [2] J. Oña, G. López, R. Mujalli, F. J. Calvo, "Analysis of traffic accidents on rural highways using Latent Class Clustering and Bayesian Networks, *Accident Analysis & Prevention*," *Procedia Engineering*, vol. 51, pp. 1-10, 2013. [Online] Available: <https://doi.org/10.1016/j.aap.2012.10.016>. [Accessed: Dec. 2, 2023].
- [3] National Highway Traffic Safety Administration, National Center for Statistics and Analysis, *Traffic Safety Facts 2020*. Washington, DC 20590, 2020.
- [4] United Nations, *Statistics of Road Traffic Accidents in Europe and North America: vol. LVI*, 2021.
- [5] Inter-American Development Bank, *Road safety strategy - IDB, Closing the Gap: Reducing road traffic deaths in Latin America and the Caribbean, Action Plan 2010 – 2015*, 2010.
- [6] OECD, International Traffic Safety Data and Analysis Group, *Road Safety Annual Report 2014*, 2014.
- [7] CSDD, *Statistics of Road Traffic Accidents, (Latvian)*, 2021.
- [8] PhD H. Haghpanahan, PhD Prof J. Lewsey, PhD D. F. Mackay, PhD Prof E. McIntosh, PhD Prof J. Pell, PhD Prof A. Jones, PhD N. Fitzgerald, PhD M. Robinson, "An evaluation of the effects of lowering blood alcohol concentration limits for drivers on the rates of road traffic accidents and alcohol consumption: a natural experiment," 2018. [Online] Available: [http://dx.doi.org/10.1016/S0140-6736\(18\)32850-2](http://dx.doi.org/10.1016/S0140-6736(18)32850-2) [Accessed: Dec. 2, 2023].
- [9] "Automotive night vision," in *A Dictionary of the Internet*. Wikipedia, [online document], 2023. [Online]. Available: https://en.wikipedia.org/wiki/Automotive_night_vision. [Accessed Dec. 2, 2023].
- [10] "Self-driving car," in *A Dictionary of the Internet*. Wikipedia, [online document], 2023. [Online]. Available: https://en.wikipedia.org/wiki/Self-driving_car. [Accessed Dec. 2, 2023].
- [11] "Lidar," in *A Dictionary of the Internet*. Wikipedia, [online document], 2023. [Online]. Available: <https://en.wikipedia.org/wiki/Lidar>. [Accessed Dec. 2, 2023].

- [12] "Open data," in A Dictionary of the Internet. Wikipedia, [online document], 2023. [Online]. Available: https://en.wikipedia.org/wiki/Open_data. [Accessed Dec. 2, 2023].
- [13] CSDD, "Historical data of Road traffic accidents, Latvia," CSDD, 2023. [Online]. Available: <https://www.csdd.lv/celu-satiksmes-negadijumi/celu-satiksmes-negadijumu-skaitis>. [Accessed: Dec. 2, 2023].
- [14] S. Moosavi, "US Accidents (2016 - 2021) [Data set]," 2021. [Online]. Available: <https://doi.org/10.34740/KAGGLE/DSV/3286750> [Accessed: Dec. 2, 2023].
- [15] National Center for Statistics and Analysis, 2023. [Online]. Available: <https://www.nhtsa.gov/data> [Accessed: Dec. 2, 2023].
- [16] NCSA Tools, Publications, and Data, 2023. [Online]. Available: <https://crashstats.nhtsa.dot.gov/#!/DocumentTypeList/12> [Accessed: Dec. 2, 2023].
- [17] The official portal for European data, 2023. [Online]. Available: <https://data.europa.eu/en> [Accessed: Dec. 2, 2023].
- [18] "CSV (comma-separated values)," in A Dictionary of the Internet. Wikipedia, [online document], 2023. [Online]. Available: https://en.wikipedia.org/wiki/Comma-separated_values [Accessed Dec. 2, 2023].
- [19] D. Sarkar, R. Bali and T. Sharma, Practical Machine Learning with Python. AI, Apress Berkeley, CA, 2017.
- [20] "Digital twin," in A Dictionary of the Internet. Wikipedia, [online document], 2023. [Online]. Available: https://en.wikipedia.org/wiki/Digital_twin [Accessed Dec. 2, 2023].
- [21] "News article (TV 3)," November 22, 2019. [Online], Available: <https://zinas.tv3.lv/auto/arvien-biezak-uz-latvijas-celiem-tiek-notriekti-savvalas-zveri-sogad-to-skaitis-pieaudzis-lidz-1500/> [Accessed Dec. 2, 2023].
- [22] LVC. State road network statistics (2020), (Latvian, English), 2020.
- [23] S. Jarvis, "The Relativity of Time," 2019. [Online] Available: https://www.researchgate.net/publication/328738389_The_Relativity_of_Time [Accessed: Dec. 2, 2023].
- [24] "Mann-Whitney U Test: Assumptions and Example," in A Dictionary of the Internet. Wikipedia, [online document], 2023. [Online]. Available: <https://www.technologynetworks.com/informatics/articles/mann-whitney-u-test-assumptions-and-example-363425> [Accessed Dec. 2, 2023].
- [25] European Road Safety Observatory, National Road Safety Profile – Latvia, 2021. [Online]. Available: https://road-safety.transport.ec.europa.eu/system/files/2021-09/erso-country-overview-2021-latvia_en.pdf [Accessed Dec. 2, 2023].
- [26] B. Finn, "Latvia - insight paper," 2019. [Online]. Available: <https://ruralsharedmobility.eu/wp-content/uploads/2019/08/SMARTA-IP-Latvia.pdf> [Accessed Dec. 3, 2023].
- [27] Seaborn, "Python package seaborn kdeplot," 2023. [Online]. Available: <https://seaborn.pydata.org/generated/seaborn.kdeplot.html> [Accessed: Dec. 3, 2023].
- [28] J. Meeus, Astronomical Algorithms. Willmann-Bell, 1991.
- [29] "Moon / Lunar Phase Algorithm," 2023. [Online]. Available: <https://stackoverflow.com/questions/2526815/moon-lunar-phase-algorithm> [Accessed: Dec. 3, 2023].



**EDUCATION IN
ENGINEERING SCIENCES**

Information and library education in the context of digitalization of society: promising trends and requirements

S.R. ARAKELOV

*Department "Information and Library Systems",
TUIT named after Muhammad Al-Khwarizmi,
Tashkent, Uzbekistan,
araks2003@rambler.ru*

B.I. GANIEVA

*Department "Information and Library Systems",
TUIT named after Muhammad Al-Khwarizmi,
Tashkent, Uzbekistan,
barno_1972@mail.ru*

Abstract. This article analyzes world trends and foreign experience in creating a new paradigm in the development of information and library education in the digital era. The necessity of using innovative technologies in bachelor's degree in teaching information and library disciplines, the purpose, teaching methods and results of research are discussed. What, in turn, needs to be done and what will help to train highly qualified specialists for information and library specialists of the republic.

Keywords: Digitalization of LIS education, competencies of librarian, information and library education.

I. INTRODUCTION

The rapidly changing world of digital technologies today places high demands on the information and library community. Will the librarian be able to match and be competitive in today's service delivery market? What knowledge, skills and abilities should he have and what can he offer after receiving higher education? On these and many other questions in the field of improving information and library education in the context of digitalization of society, the following reflections are given.

For educational processes in the era of digital technologies, it is necessary to use not only the previously accumulated, but also breakthrough innovative domestic and international experience. The ongoing reforms in the field of education in our country put forward issues for the information and library community that require non-standard approaches in their solution. When assessing the quality of education, Western European higher education is focused on the overall competence of the graduate? In addition to the general body of knowledge, the concept of competence also includes knowledge of the possible consequences of a particular method of influence, the level of skill and experience in the practical use of knowledge. In the most general approximation, competence can be considered as the ability of a subject to act adequately, in accordance with the conditions of the

situation, in the direction of obtaining significant results that have a certain value. This position marks a shift from academic norms of university assessment (knowledge, skills, skills, in fact, internal and closed to the university) to external assessments - the professional and social preparedness of graduates for market conditions. [2]-[3].

In 2009, Tashkent University Information Technologies named after Muhammad Al-Khwarizmi (TUIT), became a member of the international TEMPUS project "New Master's Program in Library and Information Sciences". During the implementation of this project, a number of teachers of the institute and the university had the opportunity to undergo training and professional development in the master's program at Robert Gordon University (Aberdeen, Scotland), one of the teachers received a master's degree in library and information sciences from this university, and a group of teachers took part in the summer schools (Georgia, Armenia, Spain, Italy); new curricula and programs for the master's degree were developed; the methods of teaching information and library disciplines have changed qualitatively; received equipment for educational laboratories [4,5,6]. The program created an opportunity to change, first of all, the idea of the teachers themselves about the educational and methodological process, approaches and methods in their work.

The purpose of research is to improve the training of qualified information and library future specialists based on innovations in digital education (competency-based approach).

The processes of digitalization of classical education - blended learning - should help to master the requirements of this course. Needed to solve the following objectives: increase professional self-esteem; develop skills in working with software (Information and Library Systems (ILS): closed source and open source); develop skills in working with hardware devices (RFID technologies in libraries, computers, printers, robotic scanners, server cabinets, book-readers, SMART book-boxes, digital

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8079>

© 2024 Sergey Arakelov, Barno Ganieva. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

librarians (DL)); meet the requirements for a future library specialist with information and analytical competencies.

In this study were conducted monitoring of academic groups in the undergraduate direction "Library and Information Activities" of TUIT (60 students of the 3rd year and 50 students of the 4th year) showed the effectiveness (about 33% of average scores, about 18% of high scores) of the competency-based approach in the credit-module system education and training of future library specialists in comparison with the traditional (academic) form of education. The data collection tool for this study included the following methods: survey (online questionnaire), observation, analytical and synthetic processing of information [5]. University students were asked to answer questions related to assessing digital competence of the future library specialist, using survey tools Google Form. Online survey data were processed using Microsoft Excel and AI Based Tools. Online survey data were processed using statistical methods to analyze the data, describing percentage frequencies and central tendencies as maximum and minimum.

II. MATERIALS AND METHODS

Having carried out an appropriate study to analyze the current state of information and library education, it is possible to generalize the challenges and problems facing information and library education.

The rapid development of technologies (the Internet, cloud, digital and mobile technologies, social networks), as well as changes taking place in education, affect user expectations and force libraries to develop new resources, services and introduce innovative service services.

In 2011, B. T. Sullivan made a statement that due to the evolution of search engines and the emergence of innovative information carriers, "the academic library is dead" [7]. The author focused on college libraries, citing the following causes of "death":

1. "Physical book collections are outdated." In the author's opinion, the digitized collections of editions made physical collections of books unnecessary. Individual students now pay a subscription fee by contacting any of the major digital book providers for unlimited access to information. Books can be viewed online at any time or downloaded to a portable device. It is noted that some colleges have opted for institutional subscriptions to digital collections, which are now managed by information technology departments, rather than libraries.

2. "Library instructions are no longer needed." To compete with the next generation of search engines, database vendors are forced to create tools that are more user-friendly. As databases have become more intuitive and easier to find information, library instructions for their use are no longer needed.

3. "Information literacy has been fully integrated into the curriculum." Information literacy programs have become part of the general college curriculum.

4. "Libraries and librarians have been replaced by information technology departments." The library buildings have been converted to computer labs, classrooms, and information departments. The evolution

of the collection has become a simple matter of maintaining the instructor-recommended database subscriptions. Cataloging has become the exclusive purview of electronic resource providers (who often employ former librarians for this job).

5. "Help desks have disappeared." They have been replaced by ever-improving search engines and social media tools.

6. "The economy has surpassed quality." Some administrators acknowledge that the old model of libraries and the functionality of librarians is producing results that theoretically exceed the results of the new model: personal service, professional research assistance, access to high-quality sources of information. But so, few students take full advantage of this that the services are no longer economically viable. The widespread adoption of Wikipedia and Google Scholar has led to the realization that traditional academic libraries and librarians have become a luxury.

B. T. Sullivan [7] argues that the "death" of the academic library is hailed by many as progress and the logical next step in the evolution of information. However, he notes that the life of an academic library could be saved if a new generation of librarians spent more time creating a realistic path to the future and less time following outdated trends. In contrast to this statement, there are positions of other authors who are more optimistic about the future of libraries. Thus, T.J. Wiebe (2016) [8], when assessing the role of academic libraries in the higher education system, considers that library resources (for example, journals, monographs, books, disciplinary research tools / databases) and services (for example, interlibrary loan, training information literacy) are still critical to maintaining highly effective research environments. At the same time, many researchers insist on the transformation of libraries, the need to set new tasks, the introduction of innovative forms and methods of work (consulting researchers, data processing and dissemination of open data, organization of open access and repositories, etc.), since they believe that traditional indicators and forms of work no longer sufficiently demonstrate the value of the academic library in the digital environment [9], [10], [11]. The results of a study by C. Smith (2015) [12] indicate that public libraries are also under pressure from the external environment - many have closed, the future of others is uncertain. The author cites data showing that the number of public libraries is decreasing, and their visitors are decreasing. Often the reason for this decline is also the digitization of funds. However, the author rightly notes that, firstly, not all physical information is available in digital format, and secondly, libraries play a much more complex role than simply providing storage for books. L. Pedersen (2016) [13] talks about the need to change the direction of libraries and offer library services related to the development of their users' careers and learning.

In the second decade of the XXI century. a wave of projects with the conditional name "The Future of Libraries" was initiated, which were announced by international and national library associations and other interested organizations. First of all, this is a Project of the

International Federation of Library Associations and Institutions (IFLA), in the report on which for 2013 (<http://trends.ifla.org>) five key trends affecting the information environment are highlighted [14]. In 2017, a report was released [15], which notes that technologies not only greatly facilitated access to information, they also contributed to the creation, publication and dissemination of disinformation, the emergence of "anti-libraries" - huge, apparently authoritative virtual banks of information that can disappear or be changed even faster than they appear. This demonstrates that libraries, as valuable social institutions and infrastructure containing physical collections, are more important than ever. Other trends are also considered, in particular those related to the role of libraries in lifelong learning for adults, 3D printing, etc.

Today it is difficult to predict which technologies emerging in the consumer landscape will be directly related to the training of qualified information and library specialists competitive in the modern labor market. Based on this, it is possible to identify trends in the development of information technologies and try to establish their effectiveness in the strategy of libraries. N. Upadhyay (2015) called for a close monitoring of trends in higher education, information and communication technologies (ICT), information revealing user behavior and social networks [16].

Big data. Research data (Big Data, RD). In an academic setting, researchers store massive collections of data outside the library. These include projects, grant proposals, research notes, research profiles, datasets, experimental results, draft articles, and copies of published articles. Published work, traditionally managed by libraries, is just one direction in the life cycle of all research information. The role of libraries in the formation of institutional data is increasing, as well as in the provision of services for their management (RDM, Research Data Management, research data management) [17, 18, 19]. When asked why librarians should be concerned about big data, N. Upadhyay [16] says that it is because of its prevalence and impact on academic research. Librarians accompanying the research process need to know how big data is used and where it can be found, as well as participate in generating collections of big data that are visible and accessible by creating taxonomies, developing metadata schemas and organizing search methods, and ensure that they are saved for repeated and shared use. This term is associated with the expression "Volume, Velocity, Variety" - the principles on which work with big data is based. This is the amount of information, the speed of its processing and the variety of information stored in the array. Recently, one more principle has been added to the three basic principles - Value, which means the value of information in theoretical or practical terms, which would justify the costs of its storage and processing.

Connected data technologies (Linked Data, LD) are increasingly attracting the attention of the library, despite the fact that the range of communication goes far beyond the capabilities of the individual data available in the library [20]. This technology allows machines to interpret text, place it in context and associate it with appropriate resources, making it possible to work with data from different sources (including the ability to build queries). A

number of works and reviews [21, 22] have been published on the advantages and problems of their use in libraries, the possibilities of LD for the identification of authors in catalogs [1], the connection of data for documents stored in digital collections [23], information contained in catalogs with external data sources [22], etc.

Social media and libraries. Interest in social networking technologies continues to grow among librarians as new tools emerge and the number of online users increases. According to a study published by the PEW in 2016, 74% of Americans who use libraries or their mobile applications are social media users [20]. Libraries, especially public ones, are active on Facebook, Twitter and other resources; academic libraries are also increasingly using social media tools to promote services and resources [21], [22], [23].

The Internet of Things (IoT) is a breakthrough technology that brings connectivity to everyday devices. For example, with inexpensive motion sensors, you can find out which library spaces are available or which sections of bookshelves are most in demand [20]. These statistics can be useful in the long term for space planning or budget allocation for stock picking. It is difficult to find any scientific comprehensive research on this topic. The potential of using the technology for libraries is discussed in the article by M. Wojcik [22].

Virtual reality is a powerful tool that allows the user to feel the digital space in three-dimensional, three-dimensional form, navigate the virtual space using helmets, glasses, displays, gloves and other means. Libraries are implementing this trend through the creation of virtual tours of the library using virtual cameras to explore physical space or use for educational purposes. Investing in virtual reality tools and technologies is a way to stay connected with the library's user community [21], [22].

Another direction of computer reality is augmented reality, that is, the provision of additional information for the perception of the real world (for example, textual information indexed by geographic location). The San Francisco Personal Library uses crowdsourcing to find digital images, inviting local history buffs to add virtual information to elements of the real world (city) [19]. Another approach to using augmented reality technology is presented in the article by C. Smith [12]. The author describes a technology in which the location of books in the library is indicated when searching in the catalog, and then the user is directed to this place (providing information about augmented reality for the building or the interior of the library).

Among the generalizing works on the above technologies (virtual and augmented reality, the Internet of Things), we highlight the publication of K. J. Varnum. In his opinion, they may turn out to be fundamental for libraries and users of library services [23].

Technical innovations in libraries. Both to solve internal technological problems and to create service-oriented maintenance technologies, generate their own information products and services, provide access to purchased licensed resources, the library uses various technical and software tools. Developing new directions

in their activities, libraries acquire robots, virtual reality glasses, equipment for organizing innovative creative spaces and rentals (three-dimensional printers and scanners, large-format plotters for interior printing, universal milling machines, oscilloscopes, etc.). The activities of libraries related to digitization involve the use of modern high-speed scanners of various modifications. The article by R. Fuchs [24] describes which scanner is better to buy for solving problems related to the digitization of photographs, books and other documents.

"Electronic librarian", which allows you to read books in the library while outside it - in the office or at home. The robot uses a laser system to move between bookshelves and avoid obstacles. The machine is able to select a book and turn pages, transferring the content to the user's display [14]. The library is the most suitable place for the implementation of robotics, since here the service robots are under the control of librarians. The robot can be asked to bring a book from the shelf. The speech recognition program matches its name with the classification code stored in the database. The robot detects the location of the book using a built-in navigation system with infrared and laser sensors. He can read the titles of books using image and print character recognition [19].

Machine Learning - a class of artificial intelligence methods, a characteristic feature of which is not a direct solution to a problem, but learning in the process of applying solutions to many similar problems. Simply put, machine learning is the process by which computers can be configured to learn for themselves.

Library 4.0 Concept (Library 4.0)

The evolution of Library 4.0 is associated with the development of web technologies (Web 2.0, 3.0, 4.0) [19], changing user preferences and the needs of readers, since a library that can tune itself to the local needs of its community is a library that is most likely, will be considered successful and relevant [9].

Library 4.0 development process. The process of Library 4.0 development:

- intellectual library;
- Makerspace ("do it yourself", that is, bringing an idea to life with the help of modern technology: 3D printers, robotics, equipment for creating video games, e-books, etc. Libraries not only provide expensive equipment and necessary educational literature, but also invite teachers that teach new technologies to be brought to life, such as soft toys with glowing eyes, illuminated clothing, plastic jewelry and 3D-printed toys, and much more;
- context-sensitive technology (Context-Aware Technology). The technology analyzes the user's behavior and interests, makes it possible to adapt the work to changing conditions, that is, the library can recognize the user and provide individual (personalized) services to both new and existing users;
- big data (Big Data);

- open source code, open source software;
- cloud services (Cloud Service);
- augmented reality and modern display;
- librarian 4.0.

The role of librarians will be very important to the implementation of the above; librarian training 4.0 should be a top priority in the future (competency-based approach).

Thus, from the analysis of discussions of this concept in the literature, we can conclude that Library 4.0 in the future will become an intelligent library in which the system itself will analyze information and provide conclusions to users. Now there is only her general vision and individual developments.

Competence can be defined as the ability or set of knowledge, skills and attitudes required for effective behavior and productivity in various cognitive areas; where knowledge refers to having information about something, knowing or understanding something, skill refers to the ability to apply what is known, and attitude refers to a person's mental or emotional approach to something (Khoo, 2005). In the aggregate of competencies, it is individually important to distinguish between professional competences and personal or general ones.

Professional skills are directly related to the operations performed by the professional, such as cataloging, classification, reference, archiving, and so on. Whereas personal or transferable skills are mostly "secret and personal way": how analytical and critical thinking, effective communication, initiative and a responsible soul is one used to carry out these operations. In other words, these are auxiliary skills that interact with professional skills to perform a specific professional job. Related literature shows that different terms such as transferable skills, general skills and alumni abilities, core competencies (Nonthacumjane, 2011; Fisher, Hallam, & Partridge, 2005, p. 43) are used in connection with personal or general competencies.

According to Khoo (2005), the competencies required by librarians and information professionals can be divided into six domains, including:

- IT skills including Internet, Internet and XML technologies, RFID, federated search engines, programming and scripting, productivity tools,
- traditional librarianship skills, which include acquisition, cataloging, classification, indexing, linking, distribution, sources of information, preservation and archiving, copyright and intellectual property laws, user behavior, user needs,
- skills to create value, including research and decision-making skills, knowledge management, user orientation, service orientation, love of learning, intellectual curiosity, interaction with members of the profession, the ability to articulate the roles of libraries and librarians,

- transferable and soft skills, communication, management, leadership, learning and coaching, and teamwork skills, as well as the ability to empathize with users and understand their information needs,
- appropriate attitude, values and personal qualities, flexibility and willingness to solve a wide range of issues, tasks, adaptability and ability to cope with changes, continuous learning, solidarity,
- knowledge in the subject area, subject knowledge in various fields depending on the organization and the position in which he / she works.

Another study (Partridge, Lee and Munroe, 2010) describing librarian skills 2.0. Needed by a new librarian, these skills are grouped into 7 topics: Technology; Training and education; Research or evidence-based practice; Communication (Communication); Collaboration and teamwork; User orientation; Business savvy and personal qualities.

Shared or transferable skills, such as technology skills, information literacy and continuing education, will be aptitude studies, analytical and critical thinking, effective communication, an innovative and proactive soul, teamwork and collaboration, social sensitivity, self-confidence, solidarity, business and negotiation are some of the skills that have not only gained importance in the profession, but they have “changed the direction” of work around the world and have “taken” a place in the professional literature of recent years.

We can easily and obviously say that there are shifts and big changes in the direction of information professionalization in the necessary skills of the librarian. From traditional professional competencies now to skills of a more essential interdisciplinary nature.

Living in an ever-changing world requires adapting professional skills to digital and interdisciplinary skills in order to be part of a “living world” and not a disappearing one. The only constant in LIP characteristics is change itself and the need to constantly update in the developing world. Since the multidisciplinary nature of the LIS field, just like the double helix structure of DNA (Partridge and Hallam, 2004), both professional and transferable skills are the backbone of 21st century LIPs. Obtaining such abilities and competencies would be the main function of LIS schools and it is the responsibility of the LIP he / she also to keep abreast of the latest developments and those willing to learn and strengthen their own competencies; be a “complete” (Audunson, Nordlie & Spangen, 2003) librarian and information professional.

III. RESULTS AND DISCUSSION

Research suggests that the librarianship market would prefer personal or soft skills such as technology skills, research ability, analytical and critical thinking, and effective communication over professional technical ones. New digital, cultural and economically fast-changing and complex environmental requirements that librarians and information professionals need to be "multi-talented jack of all trades, with high IQ and EQ." (Khuo, 2005), with

multiple skills and multitasking (Hashim & Mokhtar, 2012, p. 155). It is not possible to have all of these competencies in order to be an effective LIP, but depending on the type of organization and the location where he / she works, the LIP must be equipped with at least some of them.

The basic professional and personal skills that a new millennium LIP should possess can determine the following: information process; organization, storage, preservation and dissemination of information; sources of information and services; information policy, law and legislation; information (infra) structure, design and architecture; user groups, information needs and their behavior (search) information; development and management of information centers; information literacy and lifelong learning; user training; specialized subject knowledge; promotion and marketing of library services; IT skills for web design; research and professional projects in at least one foreign language.

Along with professional competencies, the LIP should be equipped with such general competencies as:

- see the big picture,
- analytical and critical thinking,
- effective communication skills, soulful teamwork, interaction and collaboration,
- assertiveness, enthusiasm, flexibility,
- recognition of the value of professional interaction and solidarity,
- initiative, self-confidence and responsiveness,
- open to information literacy and continuing education,
- business and negotiation skills,
- ICT skills.

All the necessary materials of TUIT named after Muhammad Al-Khwarizmi: texts of lectures, laboratory and practical tasks, surveys, tests, presentations in the discipline reflected in the educational-methodical complex and Management of the Information System of Higher Education (HEMIS – E-learning_ xn.tuit.uz; lms.tuit.uz).

The result of this scientific research can serve as a systematic work on the development of a draft program for the creation of a competence model of an information and library specialist during the period of digital transformation of society. It is planned to master the teachers and introduce into the educational process, modern innovative educational, information and communication technologies, methods of distance and multimedia information learning, as well as a general change in the scientific and educational environment and the definition of professional competencies in the training of qualified specialists in the information and library sphere [5]:

- the acquisition of special equipment and the creation of educational multimedia laboratories that allow simulating the processes of library

- technologies (modeling the entire cycle of creating an electronic library);
- development of new training courses, programs, textbooks and teaching aids for the development of an innovative educational environment that meets the requirements of international educational standards in the areas of bachelor's and master's degrees in the field of library and information science;
 - conducting refresher courses for teachers of library and information disciplines and library specialists in Uzbekistan in high-ranking higher educational institutions of foreign countries (on the basis of a magistracy);
 - organization of internships for teachers and library specialists in the use of innovative technologies in their activities by the largest foreign libraries (national, academic, university, public);
 - conducting training - seminars; summer and winter schools in foreign partner universities;
 - organization on a systematic basis of distance learning (e-learning) courses for teachers of library and information disciplines;
 - the possibility of training teachers of Uzbekistan to obtain a PhD degree in high-ranking foreign universities for the further development and qualitative growth of scientific and educational potential, both in library and information education, and in other related industries [5,6];
 - development and creation of a new direction of bachelor's degree, corresponding to new challenges and requirements of digitalization of society.

This formula is used to analyze the quality assurance of teaching (Q) in universities, which can serve as a guide for the application of this methodology for teaching information and library disciplines in domestic universities [5].

$$Q = K^3 \quad (1)$$

1. Know your students
2. Know your subject
3. Know yourself

The model of professional competence of a teacher can be divided into two main sections: competences and criteria. Competencies can be:- general pedagogical and professional; subject; communicative; managerial; information and communication; reflective; competence in the field of innovation.

And the criteria, in turn, help to specify the requirements for the teacher for each competence.

Analyzing modern trends in the development of information and library services in the developed countries of the world and in Uzbekistan, the following conclusions can be drawn on the requirements for the information and library profession and what actions are necessary for this:

– to preserve the fundamental disciplines that are the basis of the profession and will not change significantly from scientific and technical progress.

These are the disciplines information classification and coding systems, basic knowledge on the formation and acquisition of digital collections libraries, technical studies, bibliography, information and biblio-customer service, etc.;

– to develop disciplines that provide knowledge about modern marketing research methods, image enhancement information and library institutions (ILI) in order to keep their appeal in the age of digital technology;

– to instill the skills of analytical research of information resources, i.e. the modern librarian is actually acquiring the competencies of an information analyst (works with a large number of sources of information, Big Data) and rendered no assistance to researchers in the search for scientific information [6].

Nowadays, in our country, libraries are becoming not only the place of distribution of literature and reading, but also socio-cultural centers, open educational spaces, centers for the development of creative youth, start-ups, coworking centers, etc., based on this, new knowledge is needed on the organization of the work of modern information and library institutions to apply in the educational process of higher educational institutions to maintain their attractiveness in the face of new challenges.

The competence-based approach focuses on the formation of key educational competencies, interpreted as a set of skills, knowledge, normative-value attitudes, necessary for the effective solution of personal and socially significant problems in certain areas of activity and culture.

The study opens up possibilities for modeling the modern image of an information and library specialist, using modern scientific and pedagogical methods and tools.

IV. CONCLUSIONS

All this leads to a decrease in the level of teaching efficiency in higher educational institutions, the development of internationalization processes, a decrease in the perception of new knowledge by students and the use of innovative educational and digital technologies.

With the development of digital technologies, librarianship is becoming universal. There is an important shift in the skills and competencies required to effectively manage library collections and services. Traditional professional skills and competencies may have changed in form, but not yet in function and value. A "Complete Librarian" is a professional person who understands library materials and cares about them as content and their physical aspects; organizing and searching for this material; possessing the managerial, institutional and social aspects of the profession and an understanding of the role it can play in society. Librarian of the new era "will become the custodian of digital technologies, information and will be a means of preserving democratic access to information", who constantly improve information services in response to changing needs. In the

21st century, the LIP has a store of competence full of traditional professional skills as well as basic personal or general skills that interact with each other like DNA spirals.

Much in solving difficult issues of improving information and library education depends on the willingness of the teachers themselves to change, i.e. gain new knowledge, skills and abilities and be ready to transmit them to future library specialists. And this process should be systematic, progressive and continuing throughout life (long life learning). Also, the specific formulation of general and specific competencies should lead to the creation of courses by them that provide these competencies at the exit. These changes in the formation of a new teaching paradigm, in our opinion, will help bring the educational process closer to solving real production problems and increase the competitiveness of graduates of library higher educational institutions in the modern market of intellectual services.

REFERENCES

- [1]. I. Abdullahi, et al., 'Internationalization of LIS Education in Europe and North America'. *New Library World*, vol. 108, no. 1/2, Emerald, Jan. 2007, pp. 7-24, <https://doi.org/10.1108/03074800710722144>. Retrieved September 21, 2011 from http://mg.csufresno.edu/papers/forum_2/abdullahi_Virkys.pdf
- [2]. S.R. Arakelov, Information and library science: innovative methods of teaching courses in the bachelor", Proceedings of the 8th International Conference" Central Asia - 2014". - Karshi, 23-25 April.
- [3]. S.R. Arakelov, "Information and Library science: the processes of informatization learning in undergraduate", The Third International Conference on Eurasian scientific development. Proceedings of the Conference. Vienna. ISBN – 13 978-3-902986-31-3, 2014, pp. 78-80.
- [4]. B.I. Ganieva and S.R. Arakelov, Innovative approaches in reshaping activities of the Department 'Information and Library Systems', 2019 International Conference on Information Science and Communications Technologies (ICISCT), IEEE, 2019, <https://doi.org/10.1109/icisct47635.2019.9011922>.
- [5]. M. Rahmatullaev, B. Ganieva, and A. Khabibullaev, Library and Information Science Education in Uzbekistan, Slavic & East European Information Resources, <https://doi.org/10.1080/15228886.2017.1322381>.
- [6]. B. T. Sullivan, Academic Library Autopsy Report, 2050. The chronicle of higher education. 2011. <https://www.chronicle.com/article/Academic-Library-Autopsy/125767> (accessed 19.08.2018).
- [7]. M. A. Rakhmatullaev and A. Khabibullaev, Libraries in Uzbekistan: Past, Present, and Future. Libraries in the early 21 st Century: An International Perspective, edited by R. N. Sharma, (Vol. 1, pp. 375-386), 2011, Berlin, Germany: De Gruyter Saur.
- [8]. T. J. Wiebe, "The library and undergraduate research in the liberal arts: present contributions and future opportunities." *College and Undergraduate Libraries*, 2016, 23 (3), 223-251
- [9]. L. Li, The future of academic libraries in the digital age. Trends, discovery, and people in the digital age. Amsterdam [etc.], 2013, 253-268.
- [10]. F. Salisbury and J. Peasley, "Measuring the academic library: translating today's inputs and outputs into future impact and value." *Information and Learning Science*, 2018, 119 (1/2), 109-120.
- [11]. C. Varela-Prado and T. Baiget, "The future of academic libraries: uncertainties, opportunities and challenges." *Investigacion Bibliotecologica*, 2012, 26 (56), 115-135.
- [12]. C. Smith, "Presence, Permeability and Playfulness: future library architecture in the digital era." *Digital information strategies: from applications and content to libraries and people*, Elsevier, 2016, pp. 229-244, <https://doi.org/10.1016/b978-0-08-100251-3.00016-0>.
- [13]. L. Pedersen, "The future of public libraries: a technology perspective." *Public Library Quarterly*, 2016, 35 (4), 362-365.
- [14]. Glide on the waves or get into the whirlpool? Navigation in an evolving information environment: a review of the IFLA development trends report. // Rossiiskaya bibliotekhnaya assotsiatsiya. http://www.rba.ru/cms_rba/news/upload-files/news/2014/10_04/ifla.pdf (accessed 19.08.2022). (In Russ.).
- [15]. IFLA trend report update. Hague, 2017. 15 p. https://trends.ifla.org/files/trends/assets/documents/ifla_trend_report_2017.pdf (accessed 19.08.2022).
- [16]. N. Upadhyay, "Trends that will affect technology and resource decision in academic libraries in near future." 4th International symposium on emerging trends and technologies in libraries and information services: ETT LIS proc. Noida, 2015, art. 7048175, 75-79.
- [17]. K. Rosa and T. Storey, "American libraries in 2016: creating their future by connecting, collaborating and building community." *IFLA Journal*, 2016, 42 (2), 85-101.
- [18]. M. Tripathi, A. Shukla, and S.K.Sonker, Research data management practices in university libraries: a study. *DESIDOC: Journal of Library and Information Technology*, 2017, 37 (6), 417-424. <https://doi.org/10.14429/djlit.37.6.11336>.
- [19]. L. McKenna, C. Debruyne, and D. O'Sullivan, Understanding the position of information professionals with regards to linked data: a survey of libraries, archives and museums. Proceedings of the ACM/IEEE Joint Conference on Digital Libraries. New York, 2018, 7-16. <https://doi.org/10.1145/3197026.3197041>.
- [20]. M. Wojcik, Internet of things - potential for libraries. *Library Hi Tech*, 2016, 34 (2), 404-420. <https://doi.org/10.1108/lht-10-2015-0100>.
- [21]. Varnum K. J. (ed.). The top technologies every librarian needs to know: a LITA guide Chicago, ALA TechSource, 2014. 131 p.
- [22]. Fuchs R. Choosing the right scanners for you. *Public Library Quarterly*, 2015, 34 (3), 256-269. <https://doi.org/10.1080/01616846.2015.1069682>.

Transversal Skills that Matter to Computer Engineering and Information Technology Undergraduates and Strategies for their Development in English Classroom

Nataliia Aristova

Department of International
Relations and Research Cooperation
Institute of Pedagogy of NAES of
Ukraine
Kyiv, Ukraine
n.aristova.na@gmail.com

Oleksandr Malykhin

Department of Didactics
Institute of Pedagogy of NAES of
Ukraine
Kyiv, Ukraine
malykhinalex1972@gmail.com

Liudmyla Dybkova

Department of Informatics and
Systemology
Kyiv National Economic University
named after Vadym Hetman
Kyiv, Ukraine
dybkova.kneu@ukr.net

Abstract. *The importance of transversal skills for employees who work in the field of computer science is undeniable as transversal skills complement technical computer science skills and play a key role in their professional development and success. It means that while studying at higher educational institutions Computer Engineering and Information Technology undergraduates should have all the opportunities to develop these skills. And the English language classroom is not an exception since English teachers can use a wide range of strategies for developing transversal skills among Computer Engineering and Information Technology undergraduates. The research is aimed at finding out Computer Engineering and Information Technology undergraduates' points of view on the importance of transversal skills for their future work and identifying effective strategies for their development in the English language classroom. 217 Computer Engineering and Information Technology undergraduates were participants in the research conducted by the team of researchers. To find out Computer Engineering and Information Technology undergraduates' points of view of the importance of transversal skills for their future work and to identify effective strategies for their developing in the English language classroom, the researchers developed a questionnaire which consisted of close-ended and open-ended questions and items on a 5-Likert scale. The study may contribute to the improvement of Computer Engineering and Information Technology undergraduates' training by identifying effective strategies for the development of transversal skills in the English language classroom.*

Keywords: *Computer Engineering and Information Technology undergraduates; English classroom; strategies for developing transversal skills; transversal skills.*

I. INTRODUCTION

The importance of transversal skills for employees who work in the field of computer science is undeniable as transversal skills complement technical computer science skills and play a key role in their professional development and success. It means that while studying at higher educational institutions Computer Engineering and Information Technology undergraduates should have all the opportunities to develop these skills. And the English language classroom is not an exception since English teachers can use a wide range of strategies for developing various 21st century skills including transversal ones among Computer Engineering and Information Technology undergraduates. The research is aimed at finding out Computer Engineering and Information Technology undergraduates' points of view on the importance of transversal skills for their future work and identifying effective strategies for their development in the English language classroom.

II. LITERATURE REVIEW

Many present-day researchers and practitioners who are engaged in Computer Engineering and Information Technology training emphasise the importance of so-called soft skills or skills of the 21st century to which one can refer transversal skills [1], [2], [3], [4]. And this we see on the official site of European Centre for the Development of Vocational Training, where along with the concept of "transversal skills" the following concepts as "basic skills", "soft skills", "non-cognitive skills", "socio-emotional skills" and "core skills" are used alternatively [5].

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8095>

© 2024 Nataliia Aristova, Oleksandr Malykhin, Liudmyla Dybkova. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

It should be also noted that CEDEFOP defines transversal skills as “learned and proven abilities which are commonly seen as necessary or valuable for effective action in virtually any kind of work, learning or life activity” [6]. There are six categories of transversal skills and competences which include core skills and competences; thinking skills and competences; self-management skills and competences; social and communication skills and competences; physical and manual skills and competences; life skills and competences.

In “Project Spotlight: Validation of Transversal Skills Across Europe (TRANSVAL-EU)” transversal skills which are equated with soft or transferrable skills are defined as “skills, knowledge and attitudes that can be used in a wide variety of situations, both in life and at work. The term “transversal” refers to the way these skills “cut across” different spheres and tasks, as they are not specifically related to a particular job role or knowledge area” [7]. Their implicit and intangible nature makes it difficult to create a unified list of transversal skills. For today the most commonly used transversal skills include problem-solving, communication, teamwork and leadership and these skills are better acquired through non-formal and informal learning.

Ritvanen points out that everyone has transversal skills but people often “find it difficult to make them visible...” [8]. In the context of work, employees with transversal skills are able “to handle conflicts, solve problems and interact with colleagues...” [9]. Moreover, people need these skills to achieve their full potential and become active and responsible members of the present-day society.

Maunsell claims that transversal skills are “also given many different names such as soft skills, employability skills, key skills, generic skills, 21st century skills and skills for life (to name just some)” [10, p. 2]. The researcher explains that transversal skills are “commonly understood as the ability to work in a team, to communicate effectively, to be proficient in foreign languages, to be entrepreneurial, to be able to think creatively and to be able to solve problems” [11, p. 2-3].

Caeiro-Rodríguez et al. introduce a similar idea and state that university students in the field of engineering “need to be prepared to address sustainable solutions to the complex problems faced in this century. They should become proficient problem solvers, able to work in multidisciplinary teams, ready to adapt to new technologies, and able to acquire new knowledge and skills when needed” [10, p. 29222].

“The Glossary of Education Reform” which equates the notion of “transversal skills” with the notion of “21st century skills” contains an exhaustive list of skills which are associated with transversal skills [11].

Let’s turn to one more source according to which, transversal or professional skills are “career competences that are not specific to a particular job, task, discipline or area of knowledge. They are skills that can be used in variety of work settings, and as such are necessary for engineering graduates’ successful transition into future jobs” [12].

Considering all this, we focus on such transversal skills as “perseverance, self-direction, planning, self-discipline,

adaptability, initiative” [13] since we do believe that English as a medium of instruction effectively contributes to their development.

III. RESEARCH METHODOLOGY

The research sample in this study included 217 first- and second-year Computer Engineering and Information Technology students who study English at two Ukrainian universities, namely, Kyiv National Economic University named after Vadym Hetman and Kyiv National University of Technologies and Design.

To find out Computer Engineering and Information Technology undergraduates’ points of view of the importance of transversal skills for their future work and to identify effective strategies for their developing in the English language classroom, the researchers developed a questionnaire which consisted of close-ended and open-ended questions and items on a 5-Likert scale.

The research was based on the following questions:

1. *Do you believe that English as a discipline promotes the development of the following transversal skills, namely, perseverance, self-direction, planning, self-discipline, adaptability, initiative?*

2. *Do you believe that such transversal skills as perseverance, self-direction, planning, self-discipline, adaptability and initiative are important for your future work?*

3. Please, rate the importance of the following transversal skills on a 5-Likert scale (1 – very unimportant, 2 – unimportant, 3 – neutral, 4 – important, 5 – very important): *perseverance, self-direction, planning, self-discipline, adaptability, initiative.*

4. *What activities used in the English language classroom contribute to the development of such transversal skills as perseverance, self-direction, planning, self-discipline, adaptability, initiative?*

The survey was conducted during the autumn semester of 2023/2024 academic years (between September-December 2023).

IV. FINDINGS

Fig. 1 shows the results concerning the first question of our research.

Thus, 168 respondents (77.42%) believe that English as a discipline promotes the development of the listed transversal skills. 37 respondents (17.05%) gave a negative answer to this question and 12 respondents (5.53%) found it difficult to answer this question.

Answering the second question “Do you believe that such transversal skills as perseverance, self-direction, planning, self-discipline, adaptability and initiative are important for your future work?”, 171 respondents (78.80%) answered positively, 15 respondents (6.91%) gave a negative answer to this question and 31 respondents (14.29%) found it difficult to answer this question. Fig. 2 visualises the results concerning the second question.

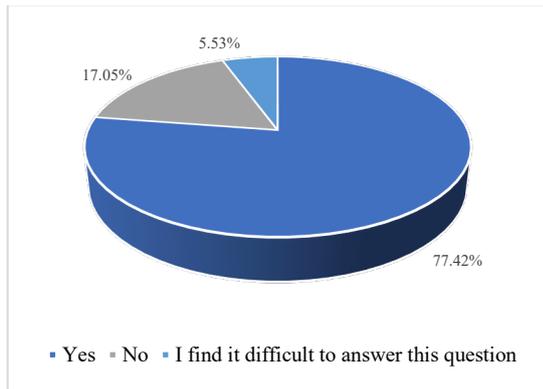


Fig. 1. Results concerning the importance of English as a discipline for promoting perseverance, self-direction, planning, self-discipline, adaptability, initiative.

Source: own study

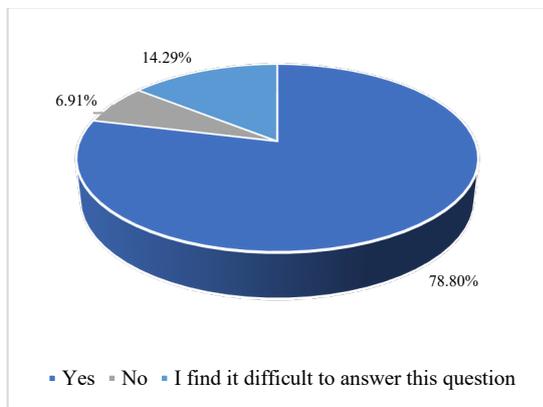


Fig. 2. Results concerning the importance of transversal skills on respondents' future work.

Source: own study

It should be noted that the respondents' opinions on the importance of selected transversal skills were measured from 'very unimportant' to 'very important' based on the 5-Likert scale intervals given in Table 1.

TABLE 1 INTERVAL LEVEL OF 5-LIKERT SCALE

Mean Interval	Opinion
1.00–1.80	Very unimportant
1.81–2.60	Unimportant
2.61–3.40	Neutral
3.41–4.20	Important
4.21–5.00	Very important

Source: own study

The results concerning the respondents' opinions on the importance of the selected transversal skills are presented in Table 2.

Thus, as shown by the results of our research, all the selected transversal skills are ranked as "very important" by the respondents, namely: perseverance (\bar{x} =4.63), self-direction (\bar{x} =4.47), planning (\bar{x} =4.52), self-discipline (\bar{x} =4.38), adaptability (\bar{x} =4.68), initiative (\bar{x} =4.48). Therefore, based on the results obtained we can assume that

present-day Computer Engineering and Information Technology undergraduates involved in our survey recognise the importance of the selected soft skills for achieving success at work.

TABLE 2 RESPONDENTS' OPINIONS ON THE IMPORTANCE OF SELECTED TRANSVERSAL SKILLS

Transversal skills	Variables					(\bar{x})	Overall Ranking
	1 (n)	2 (n)	3 (n)	4 (n)	5 (n)		
Perseverance	0	0	6	78	133	4.63	2
Self-direction	0	0	17	81	119	4.47	5
Planning	0	0	9	86	122	4.52	3
Self-discipline	0	0	21	92	104	4.38	6
Adaptability	0	0	3	64	150	4.68	1
Initiative	0	0	11	90	116	4.48	4

Source: own study
 n=217

Fig. 3 demonstrates the obtained results regarding the importance of the selected transversal skills.

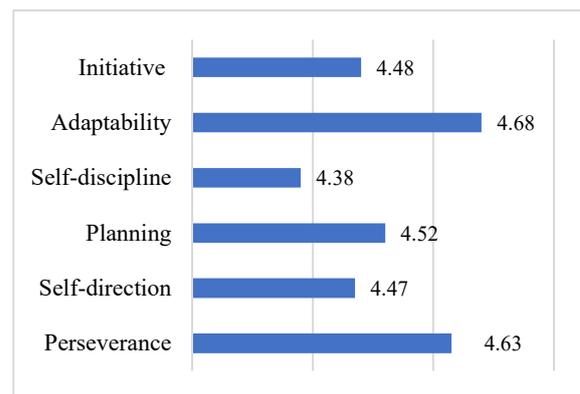


Fig. 3. Overall ranking of the selected transversal skills (\bar{x})

Source: own study

In the overall ranking of the selected transversal skills adaptability takes the first place (\bar{x} =4.68). The second place is given to perseverance (\bar{x} =4.63). Planning (\bar{x} =4.52) ranks 3rd in the overall ranking whereas initiative (\bar{x} =4.48) holds the fourth position. The fifth rank is given to self-direction (\bar{x} =4.47) and the sixth rank is given to self-discipline (\bar{x} =4.38).

The fourth question was targeted at identifying activities which in respondents' views contribute to the development of such transversal skills as perseverance, self-direction, planning, self-discipline, adaptability, initiative in the English language classroom.

In respondents' point of view, to develop such transversal skills as perseverance, self-direction, planning, self-discipline, adaptability and initiative English teachers have to use activities aimed at tracking their progress (for instance, reflective diary writing, peer evaluation, individual and group projects etc).

V. CONCLUSIONS

The research was targeted at finding out Computer Engineering and Information Technology undergraduates' points of view on the importance of transversal skills for their future work and identifying effective strategies for their development in the English language classroom. The results obtained enable us to conclude that the majority of respondents (77.42%) believe that English as a discipline is important for promoting the following soft skills as perseverance, self-direction, planning, self-discipline, adaptability, initiative. It should be also noted that the majority of respondents (78.80%) believe that such transversal skills as perseverance, self-direction, planning, self-discipline, adaptability and initiative are important for their future work.

The study may contribute to the improvement of Computer Engineering and Information Technology undergraduates' training by identifying effective strategies for the development of transversal skills in the English language classroom, namely:

Strategy 1 – *Teach students to set clear goals and to plan actions before undertaking the task.*

Strategy 2 – *Use a variety of time management techniques in the English language classroom.*

Strategy 3 – *Set clear deadlines for doing different tasks.*

Strategy 4 – *Regularly assess students' progress and involve students in various self-assessment activities.*

Strategy 1 – *Teach students to set clear goals and to plan actions before undertaking the task.* The majority of activities used in the English language classroom should be aimed at teaching students to set clear goals (short-termed and long-termed) and to plan their actions. The strict observance of the goals can help students be more motivated and adhere to the planned actions.

Strategy 2 – *Use a variety of time management techniques in the English language classroom.* The usage of time management techniques teaches students to prioritise tasks given in and outside the classroom, accomplish them quickly and meet deadlines without additional reminders.

Strategy 3 – *Set clear deadlines for doing different tasks.* Setting clear deadlines helps students schedule tasks effectively, optimise educational process and turn them into responsible learners. Moreover, students learn to identify priority tasks and achieve goals.

Strategy 4 – *Regularly assess students' progress and involve students in various self-assessment activities.* The

practical experience shows that the regular usage of different methods and techniques of assessment and self-assessment helps students identify reasons for the failures (in case they occur) and find ways to overcome them.

REFERENCES

- [1] O. Malykhin, N. Aristova, and S. Melikova, "Soft Skills Development Strategies for Computer Engineering and Information Technologies Undergraduate Students Devised in the Process of Learning English", in *ETR*, vol. 2, pp. 255-260, Jun. 2021, [10.17770/etr2021vol2.6602](https://doi.org/10.17770/etr2021vol2.6602).
- [2] O. Malykhin, N. Aristova, N. Dichek, and N. Dyka, "Formation of Top Job Skills of Tomorrow Among Computer Engineering and Information Technologies Undergraduate Students in the Process of Learning English", in *ETR*, vol. 2, pp. 249-254, Jun. 2021, [10.17770/etr2021vol2.6642](https://doi.org/10.17770/etr2021vol2.6642).
- [3] O. Malykhin, N. Aristova, and T. Opaliuk, "Didactic Potential Of Humanities In Developing Transformative Competencies Among Computer Engineering And Information Technology Undergraduates", in *ETR*, vol. 2, pp. 169-175, Jun. 2023, [10.17770/etr2023vol2.7227](https://doi.org/10.17770/etr2023vol2.7227).
- [4] M. Caeiro-Rodríguez et al., "Teaching Soft Skills in Engineering Education: An European Perspective," in *IEEE Access*, 2021, vol. 9, pp. 29222-29242, [10.1109/ACCESS.2021.3059516](https://doi.org/10.1109/ACCESS.2021.3059516).
- [5] CEDEFOP, "Transversal Skills and Competences," *European Commission and Cedefop*, 2021. [Online]. Available: <https://www.cedefop.europa.eu/hu/tools/vet-glossary/glossary/vakoverschrijdende-vaardigheden-en-competenties>. [Accessed: Nov. 16, 2023].
- [6] CEDEFOP, "Transversal Skills and Competences," *European Commission and Cedefop*, 2021. [Online]. Available: <https://www.cedefop.europa.eu/hu/tools/vet-glossary/glossary/vakoverschrijdende-vaardigheden-en-competenties>. [Accessed: Nov. 16, 2023].
- [7] "Project Spotlight: Validation of Transversal Skills Across Europe (TRANSVAL-EU)", July 6, 2023. [Online]. Available <https://digico.global/project-spotlight-validation-of-transversal-skills-across-europe-transval-eu/> [Accessed: Sept. 10, 2023].
- [8] M. Ritvanen, "Transversal skills – why and how to make them visible?," *European Lifelong Learning Magazine*, 17.07.2023. [Online]. Available <https://elmmagazine.eu/transversal-skills-why-and-how-to-make-them-visible/> [Accessed: Dec. 14, 2023].
- [9] P. Maunsell, "Principles of Best Practice for the Integration of Transversal Skills in the Curricula of Further and Higher Education Programmes," March 2023. [Online]. Available: <https://eolas.etbi.ie/server/api/core/bitstreams/63ac17dc-dd30-46c6-bb8a-4ede41e563cf/content> [Accessed: Sept. 14, 2023].
- [10] M. Caeiro-Rodríguez et al., "Teaching Soft Skills in Engineering Education: An European Perspective," in *IEEE Access*, 2021, vol. 9, pp. 29222-29242, [10.1109/ACCESS.2021.3059516](https://doi.org/10.1109/ACCESS.2021.3059516).
- [11] "21st century skills", The Glossary of Educational Reform, August 25, 2016. Available <https://www.edglossary.org/21st-century-skills/> [Accessed: Dec. 18, 2023].
- [12] "Professional Skills," LEARN Center for Learning Sciences, 2024. [Online]. Available https://learn.epfl.ch/wwd_learn/professional-skills/ [Accessed: Jan. 12, 2024].

Enhancing Students' Listening Comprehension Skills through AI-Based Podcast Activities: A Study in Self-Study Mode

Olha Chaikovska

Department of Foreign Languages
Higher Educational Institution
"Podillia State University"
Kamianets – Podilskyi, Ukraine
olgachaikovskaya@ukr.net

Olha Stoliarenko

Educational and Rehabilitation
Institute of Higher Education
"Kamianets-Podilskyi State Institute"
Department of Social Work,
Psychology and Socio-cultural
activity named after T. Sosnovska
Kamianets – Podilskyi, Ukraine
stolyarenko.ob@gmail.com

Nataliia Hlushkovetska

Department of Foreign Languages
Kamianets-Podilskyi Ivan Ohiienko
National University
Kamianets – Podilskyi, Ukraine
hlushkovetska@kpnpu.edu.ua

Iryna Semenishena

Department of Physics, Labour
Safety and Environmental
Engineering
Higher Educational Institution
"Podillia State University"
Kamianets Podilskyi, Ukraine line
isemenisina@gmail.com

Abstract. The increased number of learning hours for students' self-study in university ESP courses, on the one hand, and the high requirements for future engineers in the world labour market, on the other hand, confirm the necessity to foster students' ESP skills in a self-study mode. Thanks to the rapid development of educational technologies, studying any discipline can be made interesting and effective. Our study suggests that utilizing AI tools in engineering podcast activities can improve engineering students' listening comprehension skills in self-study mode. The post-study test designed with the help of the YT Class platform which generates assessment tests for video content, is compared across the control and experimental groups (52 third-year engineering students). The participants of both groups had experience using Ted podcasts in ESP learning and previous research proved the efficacy of implementing such activities in ESP classrooms with the first-year students of the Engineering and Technology Department. The final test based on the results of the processed podcasts was evaluated at 100 points, where the high score level was set at 60 points. In the

experimental group, 15 students scored more than 60 points, in the control group, 8 students received more than 60 points. To confirm or refute the hypothesis that the proportion of students who received more than 60 points in the experimental group is higher than in the control group, the Fisher criterion was used. The progress of the students in the experimental group was statistically proven. AI-based podcast listening activities of engineering students outside the classroom prove to be a significant tool for improving students' listening comprehension skills and inspiring curiosity and motivation to further development.

Keywords: AI tools, ESP skills, Ted podcasts, YT class platform; listening comprehension skills; Fisher's criterion

I. INTRODUCTION

Since Ukraine has declared its intention to become an equal partner in the framework of the Bologna Process, it is expected that Ukrainian universities will carry out the educational process under European standards of language proficiency. To complete the Bachelor's degree at the same time, the student is obliged to work effectively with the English language of the professional

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8085>

© 2024 Olha Chaikovska, Olha Stoliarenko, Nataliia Hlushkovetska, Iryna Semenishena.

Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

content. The current tendency in Ukrainian technical universities to minimize classroom hours and increase the hours for students' independent work indicates the necessity to implement ESP learning and teaching strategies that contribute to the development of students' personalized learning. Recent pedagogical experiments on applying technology in the educational process showed its effectiveness with engineering students in ESP classrooms, in particular. Nowadays, the implementation of artificial intelligence (AI) tools has strongly influenced English for Specific Purposes (ESP) teaching and learning. AI-powered systems can adapt to the individual needs and skill levels of learners, providing them with personalized learning experiences, analysing learners' performance and providing them with relevant, tailored learning resources, detailed feedback to learners on their speaking, writing, pronunciation, and grammar skills. In our opinion, university language instructors should explore the potential of AI tools to compensate for the lack of classroom hours and encourage engineering students' autonomous work in ESP learning.

In 2021 a group of scientists found and analyzed 454 papers indexed in Scopus and Web of Science according to PRISMA Statement. As a result, 22 papers devoted to the main use of AI in education were selected. The authors claim that AI is used for formative evaluation and automatic grading of students. Several studies examined the differences between the use of AI and its non-use [1]. Reviewing the related studies conducted on the implementation of AI tools in ESP learning revealed that AI offers great education opportunities and can serve as an effective tool for the preparation and implementation of teaching units and evaluation of students' written assignments [2].

Integrating AI writing tools (Quillbot, WordTune, Jenni, Chat-GPT, Paperpal, Copy.ai, and Essay Writer) can improve students' writing quality, content and organization [3, 4], the logical arrangement of ideas [4]. To improve the production of written text in English the researcher's laboratory designed an AI-based web application called "AI KAKU" [5]. Preliminary results of their study indicate that this application assists in structuring written texts. A study by Lam and Moorhouse [6] found that WordTune helps not only to improve grammar skills but also influences to reduce stylistic errors.

Several studies have demonstrated the efficacy of AI-based ESP learning in vocabulary acquisition. The students of the Business Department at the University of Bisha used the Dialogflow Chatbot in ESP online learning [7]. The results showed that the students in the experimental group who used the Dialogflow Chatbot outperformed their counterparts in the control group.

Classtime.com AI-based online testing platform was used with Economic Sharia Law students and explored the students' feedback on the effectiveness of the platform. The outcomes showed how these platforms have the potential to be useful instruments for evaluating students' knowledge and proficiency in language teaching [8]. AI-based ESP learning can also be used to create differentiated educational content to teach and learn business English. It can generate materials that arouse the curiosity of the learners regarding the correct use of specialized terminology [9]. AI visual generation tools were used to design AI-based teaching lesson plans in the

field of English for Specific Purposes (ESP), with a focus on Tourism at Spain University to facilitate the acquisition of subject-specific cultural and linguistic notions [10]. Authors claim that the possibilities that AI offers to education are enormous, especially for tutoring, assessment and personalization of education, and most of these are yet to be discovered [11]. Furthermore, technology and pedagogy must walk together [12].

The critical analysis of research in the field of AI in ESP learning allows us to declare its high practical value, especially for developing writing skills, profession-based vocabulary expansion, assessment and personalization of education. Although, most of these are yet to be discovered [11]. Therefore, we consider the YT Class platform which generates assessment tests for engineering podcast content a useful tool for improving students' listening comprehension skills.

Based on ESP teaching experience at "Podillia State University" the aim of the article is to explore the impact of the YT Class platform on improving profession-based listening comprehension skills.

II. MATERIALS AND METHODS

One of the simplest methods of testing the effectiveness of AI tools in ESP learning is post-test-only design. The research was conducted based on the "Podillia State University". In this design, we used two groups. Respondents were 52 third-year students from the Engineering and Technical Department. The experimental period lasted for five months (6th semester 2023) in a self-study mode. Due to the university syllabus, the students had a mandatory ESP course (2 academic hours a week). The correlation of classwork and self-study due to the syllabus was 1 to 2. Both groups had an equal number of ESP classes. The experimental and control groups were given a task to process 4 engineering podcasts devoted to Modern technology in agriculture, Combine harvesters, fertiliser machines, and Machines for flour production. The students of both groups had the experience of using technology such as the Quizlet platform for vocabulary acquisition and Ted podcasts in the 1st, 2nd, 3rd, 4th and 5th semesters. During this period of ESP learning podcast activities included multiple watching and listening, segmenting longer episodes into chunks, generating a list of terms, summarising and paraphrasing. Less frequent activities included letters to a podcaster, bingo, and posting comments.

To conduct the experiment the students of the experimental group were given instructions on using the YT Class platform and AI-mentor in engineering podcast activities. AI-mentor at the YT Class platform provides support in podcast content processing by answering questions, creating lists of terms, tests and different kinds of exercises. The control group also worked on the same podcasts and highlight the key points using the standard above-mentioned podcast activities. Both groups underwent the same test. To determine whether the experiment had a significant effect statistical analysis was used.

Participants of the pedagogical experiment agreed to participate in it without pressure. The experiment was conducted in compliance with all ethical requirements

III. RESULTS AND DISCUSSION

YT class is a free AI-based platform service. The language of the interface is English and registration is not obligatory. The main advantage of this service is its ability to supervise the students in working on podcasts in a self-study trajectory.

The post-test was made up of 40 questions based on 4 engineering podcasts, 10 questions for each video. We used the structure of the IELTS listening comprehension test. The questions tested the student's ability to understand the main ideas and factual information, the attitudes of speakers, and the ability to follow the development of ideas. The test included multiple choice questions, matching, diagram labeling, filling the gaps, sentence completion and short answer questions. The test was graded on a 100-point scale, where 60 points and above are defined as "passing" the test. In the experimental group, 15 out of 27 students passed the test, in the control group 8 out of 25. Can we assume that the proportion of students who passed the test in the experimental group is significantly different from the proportion of students who received 60 or more points in the control group? Therefore, we test the hypotheses formulated above. Fisher's test is designed to compare two samples in terms of the frequency of occurrence of the effect of interest to the researcher. It makes it possible to assess the significance of the difference between the fractions of both samples in which the effect was manifested. Since we have used only two gradations, namely, passing and failing the test, it is advisable to use the Fisher criterion. In addition, the size of the samples allows us to use this criterion. The proportion of students with "there is an effect" (passed the test) corresponds to an angle in the range from 0° to 180°, the comparison of the shares in the two samples becomes equivalent to the comparison of the angles 1 and 2. Next, we find the experimental value of the φ criterion. For convenience, we use MS Excel. The results of the statistical data analysis are shown in Table 1.

TABLE 1 THE RESULTS OF THE STATISTICAL DATA ANALYSIS

Groups	n	"Passed"	P_i	φ_i	$\varphi_{exp.} =$
Experimental	27	15	0,55 6	1,68 2	1,73; $\varphi_{cr.} = 1,64$ at $p \leq 0,05$
Control	25	8	0,32 0	1,20 3	$\varphi_{exp.} > \varphi_{cr.}$ H1 hypothesis is excepted

According to the table of critical values of Fisher's φ -Test, we find $\varphi_{cr.} = 1,64$ for the significance of $p \leq 0.05$. Hence, $\varphi_{exp.} > \varphi_{cr.}$, the experimental hypothesis is accepted – a significant difference in the proportion of those who coped with the task in the groups is obvious. Thus, the fact that the share of increased scores in the first group exceeds the share in the second group is statistically significant.

The present study investigated the impact of the YT class platform on improving engineering students' ESP listening comprehension skills in self-study mode. The study is an attempt to exploit the potential of both students' self-study provided by the ESP syllabus and technology to improve listening comprehension skills. Language instructors have to re-think the approaches to ESP teaching due to constant increase in hours for independent work in the ESP curriculum. Ideally, such amount of hours for ESP self-study may give students additional opportunities to practice and reinforce their language skills to delve deeper into the specific content areas of their ESP course. But most important, self-study encourages students to take ownership of their learning and become more independent learners. However, a lack of guidance, interaction, motivation and time management prevents them from getting good results in ESP courses in self-study mode. Besides, listening is one of the most challenging skills in foreign language acquisition, especially for non-native educators. Thereby it is preferable to utilize native experts' speech patterns in ESP class [14]. Profession-based podcast integration in the education process can assist in improving listening comprehension skills in professional contexts [13], [14]. In contrast, our study suggests that podcasts can be used by engineering students autonomously. To have a positive effect podcasts should be supplemented by more advanced tools. Thus our study is in line with [12] that education must engage technology to benefit ESP teaching and learning. We decided to go further in our research and use the technology that can supply the students with assistance, interaction, communication and feedback. Artificial Intelligence tools have all the above-mentioned features. Most of the researchers studied the students' writing, grammar skills, vocabulary acquisition, evaluating students' knowledge and generating lesson plans, while we tried to examine the impact of engineering podcast-based activities through the YT class platform on students' listening skills in the Ukrainian context.

Based on the experience gained in the course of the study we created some tips on implementing engineering podcasts through the YT class platform:

1. Engineering students should have prior experience in using technology in ESP learning. It is worth mentioning that it is very difficult for students to grasp complex engineering topics and terminology. That is why the knowledge of how podcasts work for foreign language purposes, and the types of pre- and post-podcast activities the students can use in their independent study can benefit their learning outcomes.
2. When teaching EFL during 1st and 2nd years of study we preferred to use mini podcasts (5-10 minutes). During the experiment, we used mid-length (20-40 minutes) engineering podcasts.
3. Provide the students with instructions on how AI mentor works. By offering personalized support, language assistance, comprehension aids, interactive activities, and progress tracking, AI mentor can enhance students' self-study experience with ESP podcasts and help them achieve their learning goals more effectively.

IV. CONCLUSIONS

Rapid technological advancements and Artificial Intelligence, in particular have revolutionized all aspects of our lives, including education. High demands for foreign language fluency among future engineers, on the one hand, and reduction of academic hours for ESP classroom learning, on the other hand, encourage university teachers to modify traditional teaching models by learning new digital tools, testing their effectiveness and implementing them into practice.

The conclusion from the present research is that the application of the YT class platform has a substantial influence on improving such language skills as listening comprehension in self-study mode, proved by the statistical analysis of the post-test outcomes. YT class platform and its AI mentor provided students with the simultaneous possibilities to provide personalized learning recommendations, offer language support (grammar and pronunciation assistance, creating vocabulary lists, tests and quizzes on podcasts, contextual explanations), assessing learning outcomes. Ultimately, the YT class platform is beneficial for students concerning the independent learning process. Further researches are claimed to study the attitude of engineering students towards applying the YT class platform in their self-study.

REFERENCES

- [1] V. González-Calatayud, P. Prendes-Espinosa, and R. Roig-Vila, "Artificial Intelligence for Student Assessment: A Systematic Review," *Applied Sciences*, vol. 11, no. 12, June 2021. [Online serial]. Available: <file:///C:/Users/ASUS/Downloads/applsci-11-05467-v2.pdf>. [Accessed Dec. 2, 2023].
- [2] D. Kovačević, "Use of ChatGPT in ESP Teaching Process," *In 22nd International Symposium INFOTEH-JAHORINA (INFOTEH)*, East Sarajevo, Bosnia and Herzegovina, 2023, pp. 1-5, <https://doi.org/10.1109/INFOTEH57020.2023.10094133>
- [3] Marzuki, U. Widiati, D. Rusdin, Darwin and I. Indrawati, "The impact of AI writing tools on the content and organization of students' writing: EFL teachers' perspective," *Cogent Education*, vol. 10, no. 2, 20 July 2023. [Online serial]. Available: <https://www.tandfonline.com/doi/epdf/10.1080/2331186X.2023.2236469?needAccess=true>. [Accessed Dec. 24, 2023].
- [4] T. Özgül, "The Influence of AI Writing Tools on the Content and Organization of Students' Writing: A Focus on EFL Instructors' Perceptions," *Journal of current debates in social sciences*, vol. 2, pp. 83-93. 2023. <https://doi.org/10.29228/cudes.71701>
- [5] J. M. Gayed, M. K. J. Carlon, A. M. Oriola and J. S. Cross, "Exploring an AI-based writing Assistant's impact on English language learners," *Computers and Education: Artificial Intelligence*, vol. 3, 25 February 2022. [Online serial]. Available: <https://www.sciencedirect.com/science/article/pii/S2666920X22000108?via%3Dihub>. <https://doi.org/10.1016/j.caeai.2022.100055>. [Accessed Oct. 04, 2023].
- [6] L. Ricky and B. Moorhouse, *Using Digital Portfolios to Develop Students' Writing: A Practical Guide for Language Teachers*, 1st ed. London: Routledge, 2022. [E-book] Available: T&F eBooks.
- [7] F. Qasem, M. Ghaleb, H.S. Mahdi, A. Al Khateeb, and H. Al Fadda, "Dialog chatbot as an interactive online tool in enhancing ESP vocabulary learning," *Saudi Journal of Language Studies*, vol. 3, no. 2, pp. 76-86, 2023. <https://doi.org/10.1108/SJLS-10-2022-0072>
- [8] F. Ningsih, "Classtime.com as an AI-Based Testing Platform: Analysing ESP Students' Performances and Feedback," *JOLIT Journal of Languages and Language Teaching*, vol. 11, no. 3, pp. 390-404, 2023. <https://doi.org/10.33394/jollt.v%vi%i.8286>
- [9] M. Enesi, F. Vrapı, and A. Trifoni, "Challenges of Teaching and Learning English Language for ESP Courses," *Journal of Educational and Social Research*, vol. 11, no. 4, 7 August 2021. [Online serial]. Available: <https://www.richtmann.org/journal/index.php/jest/article/view/12561>. [Accessed Nov. 09, 2023].
- [10] M. Coanca, "The role of artificial intelligence in teaching English for specific purposes," *The Free Library*, 14 February 2024. [Online serial]. Available: <https://www.thefreelibrary.com/THE+ROLE+OF+ARTIFICIAL+INTELLIGENCE+IN+TEACHING+ENGLISH+FOR+SPECIFIC...-a0770324351>. [Accessed Nov. 08, 2023].
- [11] M.P. Prendes Espinosa and V. González-Calatayud, "Interactive environments for involvement and motivation for learning," in *Video Games for Teachers: From Research to Action*, Payá, A., Mengual-Ándres, S., Eds. Mcragw Hill: Madrid, Spain, 2019, pp. 17-38.
- [12] M. Burkle and C. Cobo, "Redefining Knowledge in the Digital Age," *J. New Approaches Educ. Res.*, vol. 7, pp. 79-80, 2018.
- [13] O. Chaikovska, L. Zbaravska and T. Bilyk. "Podcasts in teaching EFL for students majoring in engineering", in *Proc. of 18th International Scientific Conference "Engineering for Rural Development, 2019, vol. 18, pp. 1915-1920.* <https://doi.org/10.22616/ERDev2019.18.N344>
- I. Humeniuk, O. Kuntso, N. Popel and Y. Voloshchuk, Y. (2021). *Mastering listening comprehension at ESP classes using Ted Talks,* *Advanced Education*, vol. 8, no. 17, pp. 27-34, 2021. <https://doi.org/10.20535/2410-8286.226733>

Environmental Impact of Waste in Dental Care: Educational Strategies to Promote Environmental Sustainability

Franz Tito Coronel-Zubiate
Faculty of Health Sciences
Universidad Nacional Toribio
Rodríguez de Mendoza
Chachapoyas, Peru
franz.coronel@untrm.edu.pe

Carlos Alberto Farje-Gallardo
Faculty of Health Sciences
Universidad Nacional Toribio
Rodríguez de Mendoza
Chachapoyas, Peru
carlos.farje@untrm.edu.pe

**Edward Enrique Rojas de la
Puente**
Faculty of Education and
Communication Sciences
Universidad Nacional Toribio
Rodríguez de Mendoza
Chachapoyas, Peru
edward.rojas@untrm.edu.pe

Abstract. Dental practice generates significant waste with significant environmental impact, but the lack of awareness and education about sustainability in dental waste management postulates challenges for public health and professional training, so effective educational strategies are needed to promote sustainable practices and environmentally responsible dental care. The study used a mixed longitudinal approach to evaluate changes in dental students. Data were collected from 15 students through surveys, interviews as well as documentary analysis. Educational strategies were designed and implemented, followed by rigorous statistical and qualitative analysis, ensuring validity and research ethics. After the course, a significant increase in knowledge was observed, with more than 80% of the students acquiring basic knowledge about the types of pollutants and their environmental impact. In addition, there was a positive change in attitudes, with more than 70% expressing greater awareness and two willingness to adopt sustainable practices in disposal management. Students also recognized the importance of caring for the environment, with more than 80% showing a greater willingness to implement sustainable practices in their future professional practice. Environmental education is fundamental to the promotion of sustainable practices in dental care. Educational strategies can generate significant changes in students' knowledge, attitudes and perceptions, influencing the adoption of more sustainable practices in clinical practice.

Keywords: *Dental practice, Environmental education, Environmental sustainability, Ethical responsibility, Waste management.*

INTRODUCTION

Dental practice, although essential for oral health care, carries a significant environmental impact due to the

generation of various wastes, such as amalgams, resins and chemicals [1]. In the context of the National University Toribio Rodríguez de Mendoza of Amazonas, the lack of investigators and low awareness of environmental sustainability in dental waste management represent a major concern. This situation postulates challenges both in terms of public health, due to possible contamination of the local environment, and in the training of future dental professionals, who may lack the necessary education on sustainable practices [2]. Therefore, the need to address this issue through effective research and educational strategies becomes imperative to promote environmentally responsible and sustainable dental care.

The importance of implementing educational strategies to foster environmental awareness and promote sustainable practices in dental clinic disposal management lies in several fundamental aspects that converge in both environmental, public health, and professional ethics [3]. First, dental practice generates a significant amount of waste that can have a negative impact on the environment if not properly managed. These disposals include mercury-containing dental amalgams [4], composite resins, radiographic relay chemicals, and other biological and chemical materials. Improper management of these wastes can result in soil, water, and air contamination, which in turn can affect the health of local ecosystems and surrounding communities [5].

In addition, the adoption of sustainable practices in dental clinic waste management can significantly contribute to the reduction of the environmental footprint of the dental practice [6]. By implementing measures to reduce, recycle, and reuse materials, as well as to minimize the generation of disposals, dental clinics can decrease their

Print ISSN 1691-5402
Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8100>

© 2024 Franz Tito Coronel-Zubiate, Carlos Alberto Farje-Gallardo, Edward Enrique Rojas de la Puente.

Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

environmental impact. From a public health perspective, proper management of dental waste is essential to prevent the spread of infectious diseases and protect the health of patients, clinical staff, and the general public [7]. Biological and chemical wastes generated in otologic practice may contain pathogens and toxins [8] that pose a health risk if not handled properly. Therefore, educating dental professionals on best practices for waste management is crucial to ensure a safe and healthy clinical environment. As healthcare professionals, dentists have a responsibility to protect the health and well-being of their patients, as well as to contribute to the well-being of society at large [9]. This includes an ethical responsibility to minimize the environmental impact of their practice and to act ethically and environmental responsibility.

Students' knowledge of the environmental impact of dental waste, their attitudes toward waste management and their willingness to adopt more sustainable practices [10], as well as their perceptions of the importance of caring for the environment in the context of dental care, are key aspects that can have a significant impact on clinical practice and overall environmental sustainability. By being informed about the different types of disposals generated in dental practice, as well as their potential impacts on the environment and public health, students are better equipped to make informed decisions and adopt sustainable practices in their future professional practice [11].

Students' attitudes toward environmental waste management play an important role in promoting sustainable practices [12]. If students show a positive attitude and a willingness to adopt sustainable practices, they are more likely to be motivated to implement changes in their clinical practice and work toward reducing their environmental footprint [13]. On the other hand, negative or indifferent attitudes may hinder efforts to promote environmental sustainability in dental practice.

Students' perceptions of the importance of caring for the environment in the context of dental care can influence their behavior and adoption of sustainable practices [14]. If students perceive that caring for the environment is an integral part of their role as health care professionals, they are more likely to consider environmental sustainability as a priority in their clinical practice and actively seek ways to minimize environmental impact [15].

From an internal perspective, they may indeed face barriers related to lack of awareness of the importance of environmental sustainability, resistance to change, lack of resources and adequate training, as well as concerns about the cost and feasibility of implementing sustainable practices in clinical practice [16]. In addition, trainees' personal attitudes and values toward the environment and sustainability may also influence their willingness to adopt more sustainable practices. Externally, barriers may be faced related to lack of institutional support, lack of clear policies and guidelines on sustainable practice in dental [17], as well as limitations in the infrastructure and resources available in dental clinics. In addition, factors such as time pressure, clinical workload and patient demands may also hinder the implementation of sustainable practices in daily practice.

Changes in students' knowledge, attitudes, and behaviors after implementation of educational strategies

demonstrate a significant increase in knowledge about environmental impact, as well as a positive change in attitudes toward waste management and adoption of more sustainable practices [18]. Previous studies have shown that education and awareness about effective tools to promote changes in knowledge, attitudes, and behaviors related to environmental sustainability in different contexts, including medical and dental care [19]. By providing students with a comprehensive education on the importance of environmental sustainability in ontological practice and fostering more sustainable attitudes and behaviors, we can work toward a more environmentally conscious and responsible dental practice and society as a whole [20].

The purpose of the study was to contribute to the development of more sustainable practices in dental care by evaluating the effectiveness of educational strategies designed to promote environmental awareness and the adoption of sustainable practices among dental students. By addressing the lack of previous research in this area and recognizing the need for environmental awareness and action in dental practice, the study sought to provide empirical evidence on the effectiveness of educational interventions to improve students' knowledge, attitudes, and behaviors related to waste management and environmental sustainability. With this purpose in mind, it was hoped that the results of the study would help inform future educational policies and programs at the Universidad Nacional Toribio Rodriguez de Mendoza de Amazonas and other similar educational institutions, as well as promote a more environmentally conscious and responsible ontological practice.

MATERIAL AND METHODS

Study design:

A mixed approach was chosen, combining qualitative and quantitative methods to obtain a complete and in-depth understanding of the phenomenon studied. A longitudinal study design was employed to collect data two points in time and assess changes in students' knowledge, attitudes, and behavior over time [21].

Population and Sample:

The target population of the study was the 15 students enrolled in the clinical course of the Faculty of Stomatology of the National University Toribio Rodriguez de Mendoza of Amazonas. Since this population constitutes the totality of students in the clinical courses, sampling was not applied, since all available students were evaluated. This guaranteed the total representativeness of the students in the study. The sample size was considered adequate to allow for rigorous statistical analysis of the data, while maintaining a pre-established level of confidence and precision.

Data Collection:

A combination of data collection methods was used, including surveys, semi-structured interviews, and documentary analysis. A structured questionnaire was designed to assess students' knowledge, attitudes toward environmental sustainability, and practices related to waste management in dental care. Semi-structured interviews were conducted to delve deeper into specific topics and

capture more detailed perceptions of the participants. In addition, existing educational materials and institutional documents related to teaching environmental sustainability at the University were analyzed.

Implementation of educational strategies:

Educational strategies were designed and implemented based on the findings of the literature review and the needs identified in the student population. These strategies included workshops, seminars, printed educational materials and online resources designed to promote environmental awareness and encourage sustainable practices in dental care.

Data Analysis:

Descriptive and inferential statistical analysis of quantitative data collected through surveys was conducted using techniques such as frequency, correlation, and regression analysis. The qualitative data obtained from the interviews and documentary analysis were analyzed using thematic content analysis to identify patterns, emerging themes and relationships between the data.

Validation and Reliability:

Steps were taken to ensure the validity and reliability of the data, including triangulation of methods, peer review, and verification of the consistency of findings across different sources and data collection techniques.

Ethical Considerations:

Ethical approval was obtained prior to conducting the study. The informed consent of the participants was guaranteed and the principles of confidentiality and anonymity were respected in the handling of the data.

RESULTS

Knowledge of environmental pollutants:

Prior to the competition, an initial assessment of students' knowledge of environmental pollutants was carried out using a questionnaire designed to assess understanding of the different types of pollutants generated in dental practice and their impact on the environment. The results revealed that 0% of the students had knowledge on this topic before receiving the specific education.

After the course, a second evaluation was performed to measure the change in the students' knowledge. A significant increase in knowledge was found, with more than 80% of students gaining basic knowledge about the types of contaminants, including biological, chemical, and radioactive disposals, generated in the dental practice and how they can affect the environment. Students demonstrated an understanding of the risks associated with improper management of these wastes and the importance of proper management to minimize environmental impact.

Attitudes towards waste management and environmental sustainability:

Prior to the course, student attitudes toward waste management and environmental sustainability were assessed through surveys designed to measure student perceptions of the importance of adopting sustainable practices in clinical practice. The results indicated that 0%

of the students had positive attitudes toward this topic prior to receiving the specific education.

Subsequent to the course, a second evaluation was conducted to determine if there had been a change in the students' attitudes. A significant positive change was observed, with more than 70% of students expressing an increased awareness and willingness to adopt sustainable practices in waste management in clinical practice. Students showed a renewed commitment to the importance of environmental sustainability in their future professional practice.

Perceptions of the importance of caring for the environment:

Prior to the course, students' perceptions of the importance of caring for the environment in the context of dental practice were assessed using surveys designed to measure students' perceptions of the ethical responsibility to protect the environment. The results indicated that 0% of the students considered this topic important prior to receiving the specific education.

After the course, a second evaluation was conducted to determine if there had been a change in the students' perceptions. A significant change was found, with over 80% of students recognizing the importance of caring for the environment and the need to adopt sustainable practices in their future professional practice. Students demonstrated a deeper understanding of their ethical responsibility to protect the environment and a greater willingness to implement sustainable practices in their clinical practice.

DISCUSSION

The present investigation focused on evaluating the impact of educational strategies to promote environmental sustainability in dental practice among university students. With the aim of addressing the lack of awareness about the disposals derived from dental care and their environmental impact, a course was designed to provide specific education on the subject. The results obtained revealed significant changes in students' knowledge, attitudes and perceptions, indicating the potential of environmental education to promote more sustainable practices in dental care.

First, there was a notable increase in students' knowledge of environmental pollutants associated with dental practice. Prior to the course, no students had basic knowledge about the types of pollutants generated in the dental practice and how they can affect the environment. This finding suggests that targeted education can be effective in closing the knowledge gap and sensitizing students to environmental challenges in their future professional practice [22].

In terms of attitudes towards disposal management and environmental sustainability, the results also showed a positive change. Before the course, none of the students had positive attitudes towards waste management and environmental sustainability. However, after the course, more than 70% of the students expressed an increased awareness of the importance of adopting sustainable practices in waste management and showed a willingness to implement them in their clinical practice. This suggests that environmental education can significantly influence students' attitudes [23], and foster a greater commitment to

sustainability in dental practice. In line with previous research highlighting the importance of environmental education in the healthcare setting, our study aligns with the findings of Al-Qarni [24], who demonstrated that the implementation of educational interventions increased knowledge about eco-friendly dentistry among dental professionals and students. Likewise, Lopez-Medina et al. [25] emphasized the need for comprehensive training in sustainable health care, evidencing student demands for more training in low environmental impact practices. This supports the importance of our educational intervention to address the lack of knowledge and awareness of waste management in dentistry.

Our findings also agree with the results of Revankar et al. [12], who found a high level of knowledge among dental students about biological waste management, suggesting that students may be receptive to environmental education in this field. However, it is crucial to note that, although students may have prior knowledge, our educational intervention achieved a significant increase in knowledge about environmental contaminants associated with dental practice. This underscores the effectiveness of targeted educational strategies to close the knowledge gap and sensitize students to environmental challenges in their future professional practice.

Regarding perceptions of the importance of caring for the environment, the results were also encouraging. Before the course, none of the students considered it important to care for the environment in the context of dental practice. However, after the course, more than 80% of the students recognized the importance of caring for the environment and the need to adopt sustainable practices in their future professional practice. This finding emphasizes the importance of environmental education in dental education and its ability to influence students' perceptions of the ethical responsibility to protect the environment [26].

These results are consistent with the findings of Mayta-Tovalino et al. [15], who showed that dental students in Peru have a high level of knowledge and awareness of the need for proper management and/or recycling of biomedical waste from dental products. Although no significant variables were found to be associated with this relationship, this suggests that the students are well informed about waste management, which reinforces the importance of environmental education in the training of health professionals. Likewise, the results of Gershber et al. [20] indicate that dental students in the United States recognize the importance of environmental sustainability in dental practice, although most reported limited knowledge in this field. This highlights the need to integrate content related to environmental sustainability into dental educational programs to ensure that future professionals are prepared to address environmental challenges in their clinical practice. On the other hand, Chen et al. [27] found that pharmacy students in Australia lack knowledge of sustainable environmental pharmacy practices and have limited standing to content related to this topic in their curricula. These findings underscore the importance of including environmental sustainability content in healthcare educational programs, not only in dentistry, but also in other healthcare-related disciplines. Taken together, these studies support the importance of environmental education in the training of health care professionals and

highlight the need to integrate content related to environmental sustainability into dental and pharmacy education programs to promote more sustainable practices in health care.

Despite the encouraging results, it is important to recognize the challenges and limitations associated with implementing sustainable practices in dental care [28]. barriers identified by students included lack of awareness or education about sustainable practices, costs associated with implementing more sustainable technology, and resistance to change by clinical staff. These challenges underscore the need to address not only the education of students, but also the ongoing training of clinical staff and the creation of an enabling environment for the adoption of sustainable practices.

CONCLUSION

The results of this study emphasize the crucial role of environmental education in promoting more sustainable practices in dental care. The implementation of specific educational strategies can lead to significant changes in students' knowledge, attitudes, and perceptions, which in turn can influence the adoption of more sustainable practices in clinical practice. However, continued efforts are needed to address the challenges and limitations associated with implementing sustainable practices and to ensure lasting commitment to environmental sustainability in dentistry.

REFERENCES

- [1] A. K. Subramanian, D. Thayalan, A. I. Edwards, A. Almalki, and A. Venugopal, "Biomedical waste management in dental practice and its significant environmental impact: A perspective," *Environ. Technol. Innov.*, vol. 24, no. 101807, p. 101807, 2021.
- [2] B. Duane et al., "Environmentally sustainable dentistry: a brief introduction to sustainable concepts within the dental practice," *Br. Dent. J.*, vol. 226, no. 4, pp. 292–295, 2019.
- [3] J. K. Debrah, D. G. Vidal, and M. A. P. Dinis, "Raising awareness on solid Waste Management through formal education for sustainability: A developing countries evidence review," *Recycling*, vol. 6, no. 1, p. 6, 2021.
- [4] A. Musliu, L. Beqa, and G. Kastrati, "The use of dental amalgam and amalgam waste management in Kosova: An environmental policy approach," *Integr. Environ. Assess. Manag.*, vol. 17, no. 5, pp. 1037–1044, 2021.
- [5] B. Duane, R. Stancliffe, F. A. Miller, J. Sherman, and E. Pasdeki-Clewer, "Sustainability in dentistry: A multifaceted approach needed," *J. Dent. Res.*, vol. 99, no. 9, pp. 998–1003, 2020.
- [6] S. Naz, S. Naqvi, S. Jafry, and S. Asim, "Knowledge, attitude and practice regarding management of health care waste among private dental practitioners," *J. Pak. Med. Assoc.*, no. 0, p. 1, 2019.
- [7] R. Khanna, Y. Konyukhov, N. Maslennikov, E. Kolesnikov, and I. Burmistrov, "An overview of dental solid waste management and associated environmental impacts: A materials perspective," *Sustainability*, vol. 15, no. 22, p. 15953, 2023.
- [8] L. Abdallaoui Maan et al., "Infectious healthcare waste management among private dental practitioners in the Rabat-Salé-Kénitra region, Morocco: A cross-sectional study on knowledge, attitudes, and practices," *J. Med. Life*, vol. 16, no. 7, pp. 1084–1092, 2023.
- [9] B. Duane et al., "Embedding environmental sustainability within the modern dental curriculum— Exploring current practice and developing a shared understanding," *Eur. J. Dent. Educ.*, vol. 25, no. 3, pp. 541–549, 2021.
- [10] T. Singh, T. R. Ghimire, and S. K. Agrawal, "Awareness of biomedical waste management in dental students in different dental colleges in Nepal," *Biomed Res. Int.*, vol. 2018, pp. 1–6, 2018.

- [11] B. Kamble, P. Tompe, N. Pande, U. Manohar Radke, and B. Acharya, "A systematic review to evaluate knowledge, attitude, and practice regarding biomedical waste management among dental teaching institutions and private practitioners in Asian countries," *J. Int. Soc. Prev. Community Dent.*, vol. 10, no. 5, p. 531, 2020.
- [12] V. D. Revankar, C. Ponnusamy, A. Subramanian, A. M. Noon, M. Subhashini, and M. Saravanaraja, "Knowledge of biomedical waste management amidst the clinical students of Dental College, Tamilnadu state, India – A cross sectional observational study," *J. Pharm. Bioallied Sci.*, vol. 15, no. Suppl 1, pp. S711–S714, 2023.
- [13] E. Joury et al., "Exploring environmental sustainability in UK and US dental curricula and related barriers and enablers: a cross-sectional survey in two dental schools," *Br. Dent. J.*, vol. 230, no. 9, pp. 605–610, 2021.
- [14] R. Ranjan, R. Pathak, D. Singh, M. Jalaluddin, S. Kore, and A. Kore, "Awareness about biomedical waste management and knowledge of effective recycling of dental materials among dental students," *J. Int. Soc. Prev. Community Dent.*, vol. 6, no. 5, p. 474, 2016.
- [15] F. Mayta-Tovalino, A. Diaz-Soriano, W. Gallo, S. Luza, A. Munive-Degregori, and R. Bocanegra, "Knowledge and awareness of effective recycling of dental materials and waste management among Peruvian undergraduate students of dentistry: A logistic regression analysis," *J. Int. Soc. Prev. Community Dent.*, vol. 10, no. 3, p. 309, 2020.
- [16] N. Martin, M. Sheppard, G. Gorasia, P. Arora, M. Cooper, and S. Mulligan, "Awareness and barriers to sustainability in dentistry: A scoping review," *J. Dent.*, vol. 112, no. 103735, p. 103735, 2021.
- [17] N. Martin, M. Sheppard, G. Gorasia, P. Arora, M. Cooper, and S. Mulligan, "Drivers, opportunities and best practice for sustainability in dentistry: A scoping review," *J. Dent.*, vol. 112, no. 103737, p. 103737, 2021.
- [18] S. Thakar, N. Kinariwala, D. Pandya, N. H. Parekh, N. K. Patel, and A. Patel, "Awareness and constraints towards the implementation of green dentistry amongst dental students and private practitioners of west India," *J. Pharm. Bioallied Sci.*, vol. 15, no. Suppl 2, pp. S1287–S1290, 2023.
- [19] S. S. Khanna and P. A. Dhaimade, "Green dentistry: a systematic review of ecological dental practices," *Environ. Dev. Sustain.*, vol. 21, no. 6, pp. 2599–2618, 2019.
- [20] N. C. Gershberg, J. Lee, J. K. Murphree, A. Parchure, and D. M. Hackley, "US students' perceptions on environmental sustainability in dental school," *J. Dent. Educ.*, vol. 86, no. 4, pp. 482–488, 2022.
- [21] A. K. Kiani et al., "Methodology for clinical research," 2022.
- [22] H. Jamal et al., "Exploring the perception of dental undergraduate students and faculty on environmental sustainability in dentistry: A cross-sectional survey in 26 dental schools in Saudi Arabia," *Dent. J.*, vol. 11, no. 4, p. 103, 2023.
- [23] O. Durnall, N. Martin, S. Mulligan, and J. Dixon, "Environmental sustainability: the attitudes and experiences of UK students in the oral health care profession," *Br. Dent. J.*, 2024.
- [24] M. A. Al-Qarni, "Awareness of Eco-friendly dentistry among dental faculty and students of king Khalid university, Saudi Arabia," *J. Clin. Diagn. Res.*, 2016.
- [25] I. M. López-Medina, C. Álvarez-García, L. Parra-Anguita, S. Sanz-Martos, and C. Álvarez-Nieto, "Perceptions and concerns about sustainable healthcare of nursing students trained in sustainability and health: A cohort study," *Nurse Educ. Pract.*, vol. 65, no. 103489, p. 103489, 2022.
- [26] S. Veress, B. Kerekes-Máthé, and M. Székely, "Environmentally friendly behaviour in dentistry," *Med. Pharm. Rep.*, vol. 96, no. 2, pp. 199–205, 2023.
- [27] E. Y. H. Chen, C. Forrester, A. M. McEvoy, and J. Singleton, "Pharmacy students' perceptions on environmental sustainability in pharmacy education and practice," *Explor. Res. Clin. Soc. Pharm.*, vol. 12, no. 100366, p. 100366, 2023.
- [28] C. M. C. Volgenant, S. Bras, and I. F. Persoon, "Facilitators and barriers to implementing sustainability in oral health care," *Int. Dent. J.*, vol. 72, no. 6, pp. 847–852, 2022.

Modern Perspectives in Bulgarian Engineering Education Through the Prism of Experts From the IT sector (Empirical study)

Gergana Sl. Dimcheva
Management in communications
Department, University of
Telecommunications and Post,
Sofia, Bulgaria
g.dimcheva@utp.bg

Ivaylo Ts. Stoyanov
Management in communications Department,
University of Telecommunications and Post,
Sofia, Bulgaria
i.ts.stoyanov@utp.bg

Abstract. We are witnessing a confluence of technology, information, communication and artificial intelligence that emphasizes the importance of soft skills, communication skills, critical thinking, problem solving, teamwork in engineering. This, in turn, necessitates an emphasis on interdisciplinary training by educational institutions in the preparation of engineering personnel, in accordance with the requirements of business in the IT field. The research was conducted on the territory of the city of Sofia in the Republic of Bulgaria, where a significant number of small and medium-sized IT companies are positioned with opportunities to hire graduating students and accordingly, the experts working in them to assess their competences, but also to assess the requirements of those for training of engineering staff from universities in the IT sector. From this point of view the purpose of the publication is to establish from a certain group of respondents some modern perspectives in Bulgarian engineering education from the point of view of business representatives. Based on the purpose of the study a questionnaire was drawn up and sent to respondents to assess what knowledge and skills future IT engineers should possess. This necessitated the use of a quantitative approach through an online survey that was randomly sent to 24 small and medium-sized IT enterprises. The completed and returned surveys are from 59 experts, representatives of 16 enterprises. The research showed that IT business experts need IT engineering personnel who have not only narrowly specialized knowledge in the relevant professional field, but also interdisciplinary ones with a wide range of work and decision-making skills.

Keywords: Engineering education, IT sector, empirical study, modern perspectives

I. INTRODUCTION

The rapid development of modern information and communication technologies and innovations in IT practice have widened the gap "needs of business - training of engineering personnel". This set new requirements and

challenges in the training of engineering IT specialists, which also reflects the educational system in the Republic of Bulgaria. The emergence of new technological applications, related not only to the dynamics of the development of artificial intelligence, but also to modern IT technologies, forced not only universities worldwide, but also those in the Republic of Bulgaria to adapt to a change in approach and in general the model for training in modern IT specialties. The leadership of the visionary higher schools realized the need to change the curricula and programs to follow the new and unique educational and practical trends in the IT sphere worldwide. They were the catalyst for numerous scientific publications, as a result of the application of artificial intelligence, modern IT technologies and software products in corporate practice.

II. THEORETICAL RESEARCH AND SOME ASSUMPTIONS REGARDING MODERN PERSPECTIVES IN BULGARIAN ENGINEERING EDUCATION IN THE IT SECTOR

In the world scientific literature, the issue of engineering education is becoming more and more relevant, as in recent years scientific production has been published with a different context, both in terms of the training and preparation of engineering personnel, and concerning current problems and issues in the relevant educational system [1], [2], [3], [4]. The general tone of the publications advocates the idea of quality engineering education through basic knowledge in the relevant engineering field, the creation of programs and initiatives to stimulate learning in engineering sciences, developing professional competencies for lifelong learning, etc. [5], [6], [7]. The theoretical preparation of science engineering students is linked to the acquisition of competencies from real practice, the acquisition of knowledge and skills that will help them to adapt more easily in their early career from their work activities, the acquisition of experience through mentoring relationships, etc. n. [8], [9], [10], [11], [12].

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8082>

© 2024 Gergana Dimcheva, Ivaylo Stoyanov. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

In order to respond to the new educational trends in the IT industry, a large part of the modern and responsive universities have adapted their educational documentation and training practice according to the needs of the business. Proceeding from the application of new technological solutions in the business practice of modern IT companies and the scientific response in the literature, in the general effect of this activity, priority directions for training IT engineering personnel in the educational system were identified. In recent years, there has been an unprecedented interest in the introduction of disciplines that are the object of scientific and practical-applied interest in the universities, namely:

- *Artificial Intelligence (AI)*. It caused a particular boom in the field of IT technology, mainly through the emergence of OpenAI ChatGTP and Google's Gemini, as well as the development of AI by companies such as Microsoft, Apple, Alphabet, etc. The rapid development of AI and its application in all spheres of public life and business [13], [14], [15], imposed high standards for its study at universities by future engineers in the field of the IT industry. The modern aspects of AI are a prerequisite for acquiring new knowledge not only about the technical parameters of the process and the technology of work, but also about the ethical aspects of its application, so that AI is of help to man, not to eliminate him from his inherent professional, psycho-social and communication activities.

- *Internet of Things (IoT)*. Cutting-edge technological solutions, such as AI, blockchain technologies, 5G and others, create new possibilities for the application of intelligent connecting devices that are part of the IoT. As IoT [16], [17] is seen as a new technology to automate, manage and control public and business operations through smart objects interacting with each other with other Internet-enabled devices, they are increasingly being introduced as academic subjects in universities. This is necessitated by the modern requirements to build a network of physical devices, vehicles, appliances and other physical objects embedded with sensors, software and network connectivity to collect and share data in an attempt to build "smart factories" or "smart public buildings and objects".

- *Blockchain Technology (BT)*. With the growth of databases as a result of the development of business technology, a mechanism is needed to share data and information in an appropriate business network. In corporate structures where data and information are key, both in terms of their internal business processes and customer relationships, blockchain technology creates records and history of databases that are interconnected and can only be used by authorization of network members. Since blockchain technology is increasingly used in the digitalization of companies business transactions [18], [19], academic disciplines are also being studied at universities that prepare IT specialists to work in a blockchain network.

- *Additive processes (AP)*. Relate to the creation of three-dimensional objects from a digital file by laying down successive layers of material until the object is created, with the exception of volumetric 3D printing [20], [21]. Studying disciplines related to additive processes is important in preparing IT professionals to work with

specialized 3D software for modern manufacturing technology.

- *Virtual Reality (VR)*. It has an essential role in various aspects of society and business, as it uses computer modeling and simulation of various objects so that through interactive devices a real idea of the objects can be obtained in a virtual way through an artificial 3-D visual or other sensory environment [22], [23]. The study of disciplines related to virtual reality allows creating IT professionals to represent objects in a three-dimensional computer-generated environment.

- *Modern IT directions*. They are related to the preparation of IT engineers in the field of programming, big data, network technologies, information and cyber security, cloud computing, use of software applications and platforms for virtual work, application of interdisciplinary areas in IT technologies, etc. [24], [25], [26].

From the point of view of engineering education in the IT industry, it is clear that the requirements for the training and realization of highly qualified engineers are greater than ever, because the development of IT technologies is at such a peak level that it is necessary to acquire new knowledge and skills that are beneficial not only to the cold ones who are trained in the IT specialties, but also to the business. In fact, in the conditions of higher education in the Republic of Bulgaria, several key moments stand out, which define a trend in the last few years in the field of the IT sector, with the following basic prerequisites:

First, students graduating from universities have relatively good practical and less theoretical training in the field of IT technologies, dictated by the so-called technological generation of children, who from an early age begin to use and adapt to the available technology (computers, smartphones, tablets and other technical devices). In essence, this is a prerequisite for them to develop technical knowledge and skills which, at a later stage of their studies, will help them to be rewarded with modern technical competences in higher education. The problem here, which in time will affect their professional commitments and relationships, is the lack of so-called "soft skills" (which is one of the priorities of the business according to data from the survey) because the emphasis is on the technical part of the technology and relevant applications, ignoring basic communication requirements to reconcile them with the human activity of communication (even virtually).

Second, the training of engineering specialists in the field of IT technologies requires a new approach that not only corresponds to new requirements in terms of technology, meets business practice and creates added value, but also develops "soft skills". Despite the fact that we are in the age of machines, and AI is gaining more and more speed in various areas of the public sphere and business, interpersonal and administrative processes (even through the use of technical devices) cannot yet be excluded from work of people, regardless of the advancement of technology. Although the Covid-19 pandemic has shown that people are already highly dependent on technology that facilitates work processes and communication at a distance, it reinforced another fact - along with technical ("hard") skills, "soft" skills are also needed, which already are not a supplement, but a

concomitant part of the work of the human factor with technology. We have already witnessed from business practice that modern IT companies work digitally in the implementation of various strategic and operational business projects, hold project meetings, IT specialists participate in virtual teams, occupy managerial positions, lead people, etc. In addition, it is already perceived as a narrow-minded understanding that IT specialists work only with technical devices, because today they increasingly need to understand human resources, business indicators for the formation of added value, digital marketing, finance and investments, etc. All this requires them to have not only "hard", but also "soft" skills, especially when they communicate with people and must show leadership qualities and potential or be entrepreneurs with financial literacy, regardless of whether this will be in a conventional or digital workplace environment.

Third, the training of engineering specialists in the field of IT technologies requires a close relationship with the users of personnel, in order to establish not only the need for a certain type of IT experts, but also to maintain the interest and aspiration of students to study in the field of information and communication technologies. This relationship with business (users of personnel) must have a multifaceted application and correspond to the strategic vision and policy of the universities in the Republic of Bulgaria for conducting high-quality training in the field of IT technologies. In the general context of the educational service in IT specialties and the preparation of qualified IT engineering personnel, regular meetings with business representatives should be held, personal attention should be paid to training and practical work with students, student symposia, days of "open doors", business-shared resources for training and practical activities and initiatives, practical internships, etc.

Fourthly, the training of engineering specialists in the field of IT technologies also requires a change in the education model itself, which from a strong emphasis on technical knowledge and skills should be adapted to interdisciplinary scientific fields that create basic technical competencies in the field of IT technologies, but also to develop the "soft skills" among the students - the future IT engineers. This means regularly updating the study documentation for the relevant specialties, requesting the opinion of business experts and, of course, following good practices in foreign higher education institutions. The role of the teaching staff in the education of students in IT specialties should not be underestimated, i.e. with the change of curricula and programs, disciplines should be laid down that also cover "soft skills", as well as be tied to the technical requirements for education in the IT field.

Fifth, with the change of curricula and programs in universities and the basic study documentation for engineering majors in the field of IT technologies, not only the emphasis of teaching should be changed, but also the knowledge and skills of the academic staff themselves. They are also part of this process and must adapt to the new realities of business, to be scientifically grounded in the theory of the relevant issue and tied to the needs of real business.

- *High level of teaching from the academic community, according to the new requirements and the*

practical application of IT technologies in corporate business. Since high technologies are developing at a rapid pace in society and business, new technological solutions and practical applications for the IT industry are constantly emerging, therefore conventional and current knowledge and skills are already daily replaced by new, more up-to-date ones, according to the needs of the corporate business structures. This means that the knowledge and competences of the academic staff must meet the future needs of the IT industry, because the maxim that what is needed today, tomorrow has already lost its meaning, and sometimes is inapplicable, justifiably applies. The academic staff in the field of engineering IT education and, accordingly, the management of the universities must follow the principle of what is needed as knowledge and skills of the students, according to what is sought as competencies in real business. And here there is usually a discrepancy between academic teaching in the IT sphere and the real needs of business, which often do not correspond with the capabilities of the academic staff to respond to the new challenges facing the training of engineers in the IT industry. This, of course, reflects not only the quality of education and training of IT engineers in universities, but the connection with practice is also broken, and as a result, graduating students are leaving, whose knowledge and skills are not needed because they do not correspond to modern conditions in IT the business.

- *Integration in the educational and scientific process of experts from practice.* Not a small part of the universities in the Republic of Bulgaria rely only on available academic staff, which is not always a prerequisite for a high quality educational service and, above all, bringing students to the knowledge of current trends and technological innovations in the IT industry. In fact, this is a prerequisite for the appearance of the above-mentioned statement that what the academic staff does to train students - future IT engineers can lead to disastrous results, which also reflect the general understanding of the quality of higher education, if only of theoretical training and teachers do not have serious experience in companies or do not practice in real business. In other words, education and science in the IT sphere require not only academic staff to work on research and teaching at the university, but experts from practice to train the future engineers in the IT sphere of novelties, specificity, technology and process management in the real IT business. Therefore, one of the requirements for achieving a high quality of education (and scientific activity) in IT majors at universities in the Republic of Bulgaria is the attraction of experts from real practice, who will participate not only in the educational process of students, but also to provide support through coaching of colleagues from the academic staff for modern achievements and results in IT practice.

III. EMPIRICAL ATUDY OF MODERN PERSPECTIVES IN BULGARIAN ENGINEERING EDUCATION THROUGH THE PRISM OF EXPERTS FROM THE IT SECTOR

The presence of business in the training process is essential for future personnel in the labor market, especially in the IT industry. As it became clear, the dynamic development of information and communication technologies required the acquisition of new knowledge and skills by the trainees. This, in turn, requires improvement and renewal of study courses and disciplines

in universities preparing engineering personnel. Obtaining up-to-date and modern knowledge allows future engineers to quickly adapt to working conditions in business organizations. Businesses rely on a skilled and educated workforce to drive innovation, productivity and economic growth. This was also confirmed by the results of the study. A total of 16 small and medium enterprises from the IT sector offering software solutions were surveyed. In this sense, the investigated enterprises carry out basic activities such as: design, development, implementation and maintenance of integrated information systems, software solutions in the field of business (finance, accounting, human resources, project management), specialized IT systems, etc.

The question arises, "To what extent does engineering education in Bulgaria meet the modern requirements of business?" In this regard, regarding the preferences of business organizations from the IT sector in Bulgaria regarding what knowledge and skills future engineering personnel should possess, an empirical study was conducted among 59 experts from a total of 16 small and medium-sized organizations (Fig. 1)¹, part of the results of which are presented in the following figures.

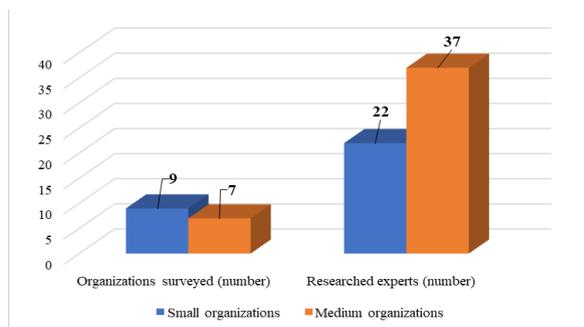


Fig. 1. Researched organizations and experts

Bulgarian educational institutions do not manage to cope so quickly with the technological progress, necessitating a change in the curricula and disciplines in which engineering personnel are trained. Unfortunately, in the majority of higher education institutions, the rate of change in educational documentation lags significantly behind the rate at which business requirements for new knowledge and skills change. This also makes an impression from the following figure (Fig. 2), where the responses of the surveyed experts predominate, according to which the engineering disciplines and their content are not sufficiently adequate to the modern requirements of business - a total of 56% of the surveyed responded with "Rather not" - 45% and No - 11%. Only 30% answered with "Rather yes" - 21% and Yes - 9%.

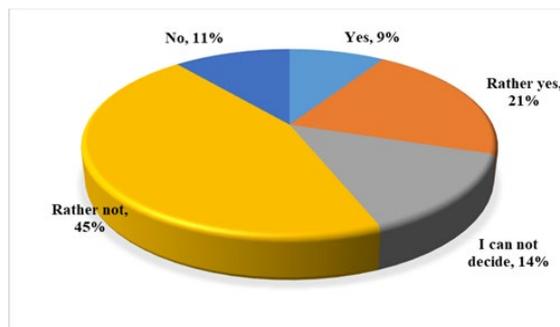


Fig. 2. Answer to the question "Do you think that the studied engineering disciplines and their content are adequate to the modern requirements of business?"

These results indicate that educational institutions should reorient their strategy towards building a close relationship with business, even more so. It is necessary that this relationship be strongly expressed from secondary education and then continue in higher education institutions as well. The Triangle "Secondary Education - Higher Education - Business" represents the interaction between three fields, each of which plays an important role in the selection of future personnel for career development and contributes to the overall development of society.

Close interaction and cooperation between business organizations and universities allows:

- ✓ **Of business organizations** - the hiring of prepared engineering personnel with up-to-date knowledge and skills;
- ✓ **Of universities** - maintaining adequate information on the state of the labor market and rapid adaptation of engineering personnel by developing modern training courses that meet the modern requirements of business.

There is no doubt that the rapid pace of technology will not lead to change in organizations related to human resources. Moreover, with the emergence of new technological applications, a number of business processes are automated, several categories of jobs appear and / or merge, as well as the emergence of new ones. Many of these new professions are the product of artificial intelligence [27, 28].

This is precisely why business organizations require universities to include in their curricula training in the field of modern technological applications. This is also shown by the results of the conducted survey, where artificial intelligence takes precedence - 52 of the respondents believe that it is AI that should have priority in the preparation of engineering personnel, followed by augmented reality applications (46 respondents) and in third place blockchain technologies (34 answered) (Fig. 3).

¹ Small and medium-sized enterprises are those with less than 50 employees and between 50 and 250 people, Law on Small and Medium-

sized Enterprises in the Republic of Bulgaria, [Online]. Available: <https://lex.bg/laws/ldoc/2134682112>. [Accessed: Jan. 5, 2024].

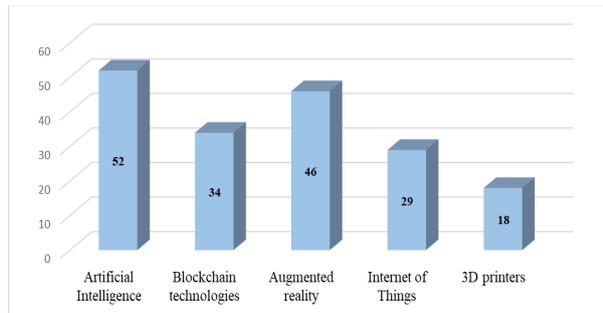


Fig. 3. Answer to the question "In your opinion, which modern technological applications should be given priority in the training of engineering personnel?" (More than one answer is possible)

In addition, the implementation of modern AI-related technologies increasingly requires employees to have a skill set and navigate areas such as ethics, leadership, emotional intelligence, change management [27], as well as knowledge and skills in the field of human resources, digital marketing, project management.

And if a few years ago the technical disciplines/sciences studied in the engineering majors were strongly advocated, to date they are only a fundamental component in the preparation of engineering personnel. Business needs are increasingly in the area of personal qualities and knowledge from other areas (Figs. 4 and 5).

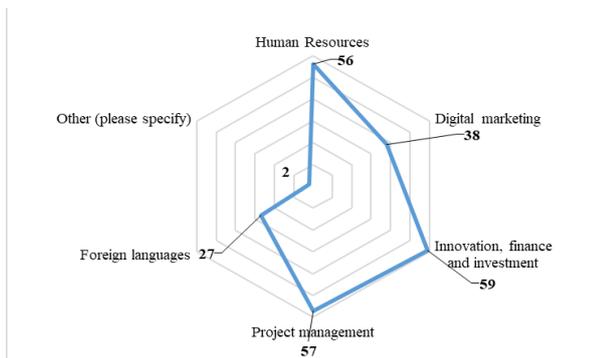


Fig. 4. Results of an answer to the question "In which of the specified fields, in addition to knowledge in the field of engineering (technical knowledge), do engineers need to have?" (More than one answer is possible)

It can be seen from fig. 4, with full unanimity, respondents indicated that engineers should also have knowledge of innovation, finance and investment (59 respondents), followed by project management (57 respondents) and human resources (56 respondents). This fact is not accidental. Any change in modern organizations is already carried out with the help of project management and human resources, which in turn requires the possession of specific knowledge and skills in these areas.

To survive in an increasingly competitive environment, businesses need personnel who can manage change, a challenge facing 21st century engineers. Engineering graduates in this new era must be able to move from technology to solutions and from solutions to operations. This requires a wide range of skills [27]. Good intuition and other personal qualities such as "teamwork skills", creativity, good judgment and effective communication are becoming increasingly valued and sought after [29].

We are witnessing an amalgamation of technology, information, communication and artificial intelligence, which emphasizes the importance of soft skills, communication skills, critical thinking, problem solving, teamwork. These are exactly the requirements of the business for the future engineering personnel, which is also evident from the results indicated in the following figure (Fig. 5).

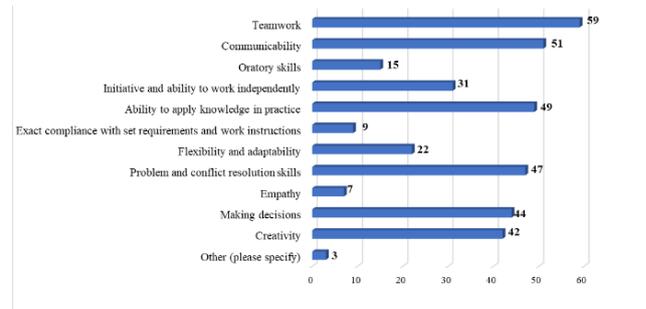


Fig. 5. Results of an answer to the question "What soft skills and personal qualities do you think engineering graduates need to possess?" (More than one answer is possible)

As we can see from the fig. 5, the first three places are occupied by teamwork skills - unanimously 59 respondents, followed by communication skills (51 respondents) and the ability to apply knowledge in practice (49 respondents). Skills such as: problem and conflict solving (47), decision making (44) and creativity (42) were also preferred by more than half of the experts surveyed.

The increased presence of experts from practice in the process of training engineering personnel in universities is extremely important. The partnership with business ensures that the curricula are in line with the current needs of the IT industry. This helps to develop skills and competencies that are directly related to labor market requirements, making graduates more employable. The preferred forms of partnership by IT business organizations and a higher education institution are indicated in the following table (Table 1).

TABLE 1 RESULTS OF THE ANSWER TO THE QUESTION: "WHAT FORMS OF PARTNERSHIP SHOULD THERE BE BETWEEN YOUR ORGANIZATION AND A UNIVERSITY PREPARING ENGINEERING PERSONNEL?" (MORE THAN ONE ANSWER IS POSSIBLE)

Forms of partnership	Number of respondents
Provide mentorship during the practical training and student internships provided for in the curricula of the engineering majors	58
Conduct periodic meetings with graduate students for career prospects and job positions	43
Conducting annual "open days" supporting professional orientation for students	36
Provision of paid student internships	52
Development of joint research projects	38
Participation of experts from practice	56

It can be seen from the table that almost all surveyed experts (58 respondents) prefer to be involved in the learning process, through mentoring during practical training and providing student internships, as well as active participation of teachers from practice (56 respondents). In

this way, the business provides future engineers with hands-on experience by involving them in real projects and applications. The holding of annual "open days" supporting professional orientation for students as a form of partnership between an organization and a university preparing engineering personnel occupies the last place - 36 answered.

IV. CONCLUSION

Obviously, the rapid development of IT technologies and software products in society and business require modern companies to have highly qualified IT specialists. This process is invariably related to the preparation of IT engineering personnel from the universities to respond with knowledge and skills to the new challenges in the IT sector and the needs of employers. All this is related to a two-dimensional process of the education system and business, which must cooperate. The purpose of this publication is set precisely in this context, i.e. to conduct a survey among IT experts from randomly selected small and medium-sized organizations in the Republic of Bulgaria in order to evaluate and analyze the requirements and needs of business from IT engineering specialists, according to the possibilities of the educational system and higher schools to prepare for real practice qualified engineers in the IT sector.

The following main contributions have been achieved as a result of the publication:

- Based on a study of the scientific literature on the problem, some assumptions regarding the modern perspectives in the Bulgarian engineering education in the IT sector have been derived.

- Through the survey, the requirements and needs of the business of a certain sample of respondents (IT experts from small and medium-sized Bulgarian business organizations) were established, regarding modern perspectives in Bulgarian engineering education and the training of IT engineers. In summary, it can be noted that employers in the Bulgarian IT business require highly qualified engineering personnel who have knowledge in accordance with the new trends in IT technologies, from which it follows that universities should adapt their documentation and qualification of the academic staff to the avant-garde theoreticians - application processes in the IT sector. On the other hand, there is a tendency to change the approach to education and training of IT engineers by emphasizing interdisciplinary training from educational institutions, in accordance with the requirements of business in the IT sector. In this regard, in addition to technical skills, IT engineers must also be trained in "soft skills" such as communication, collaboration and adaptability in the rapidly changing work environment.

- The conducted preliminary research on the requirements and needs of the business of a certain sample of respondents (IT experts from small and medium-sized Bulgarian business organizations), regarding modern perspectives in Bulgarian engineering education and the training of IT engineers, is a prerequisite for generating information for a future large-scale study on the relationship "education-business" in the IT sector.

REFERENCES

- [1] L. Gutierrez-Bucheli, G. Kidman and A. Reid, "Sustainability in engineering education: A review of learning outcomes", *Journal of Cleaner Production*, Vol. 330, 2022, 129734, <https://doi.org/10.1016/j.jclepro.2021.129734>
- [2] D. Gürdür Broo, O. Kaynak and S. M. Sait, "Rethinking engineering education at the age of industry 5.0", *Journal of Industrial Information Integration*, Vol. 25, January 2022, 100311, <https://doi.org/10.1016/j.jii.2021.100311>
- [3] M. Gheisari, B. Becerik-Gerber and C. Sturts Dossick, "Emerging learning technologies for future of work and education in engineering", *Advanced Engineering Informatics*, Vol. 56, 2023 101775, <https://doi.org/10.1016/j.aei.2022.101775>
- [4] G. Downey et al. "The Globally Competent Engineer: Working Effectively with People Who Define Problems Differently". *Journal of Engineering Education*, 2006, Vol. 95, pp. 107-122, <https://doi.org/10.1002/j.2168-9830.2006.tb00883.x>.
- [5] T. Richter and B. Kjellgren, "Engineers of the future: student perspectives on integrating global competence in their education", *European Journal of Engineering Education*, 2023, pp.1-18, <https://doi.org/10.1080/03043797.2023.2298319>
- [6] G. Renuka, "Innovative teaching and learning strategies for materials engineering education", *Materials Today: Proceedings*, Vol. 81, Part 2, 2023, pp. 1000-1005, <https://doi.org/10.1016/j.matpr.2021.04.350>
- [7] S. Craps, M. Pinxten, H. Knipprath, and G. Langie. "Exploring Professional Roles for Early Career Engineers: A Systematic Literature Review", *European Journal of Engineering Education*, 2021, Vol. 46, pp. 266-286, doi: <https://doi.org/10.1080/03043797.2020.1781062>
- [8] D. de Campos, L. de Resende and A. Fagundes, A. "The Importance of Soft Skills for the Engineering". *Creative Education*, 2020, Vol. 11, pp. 1504-1520, <https://doi.org/10.4236/ce.2020.118109>.
- [9] V. Ajit and P. Deshmukh, "Factors Impacting Employability Skills of Engineers". *International Journal of Science and Research*, 2013, Vo. 2, pp. 30-32.
- [10] L. Ortiz-Marcos, L. Ignacio Ballesteros-Sánchez, A. Hernández Bayo, R. Rodríguez-Rivero and G. Guillerme, "Assessment of Global Competence of Engineers for a Sustainable World". Evidence from TA VIE Project, *Sustainability*, 2021, 13 10.3390/su132212924 (12924).
- [11] K. Davis, B. Jesiek and D. Knight, "Exploring scenario-based assessment of students' global engineering competency: Building evidence of validity of a China-based situational judgment test", *Journal of Engineering Education*, 2023, 10.1002/jee.20552, 112, 4, (1032-1055).
- [12] J. Lucena, G. Downey and K. Beddoes, "What is Engineering for? A Search for Engineering beyond Militarism and Free-markets, What is Global Engineering Education For? ", 2022, 10.1007/978-3-031-02125-1_6, (361-383).
- [13] A. Mathew, "Is artificial intelligence a world changer? A case study of OpenAls ChatGPT". *Recent Progress in Science and Technology*, Volume 5, Number 25, 2023, pp. 35-42, <https://doi.org/10.9734/bpi/rpst/v5/18240D>.
- [14] J. Holström, "From AI to digital transformation: The AI readiness framework", *Business Horizons*, Vol. 65, 2022, pp. 329-339, <https://doi.org/10.1016/j.bushor.2021.03.006>
- [15] A. Wilkins, "Clever chatbots launched AI boom", *New Scientist*, Vol. 260, 3469-3470, 2023, p. 22, [https://doi.org/10.1016/S0262-4079\(23\)02328-X](https://doi.org/10.1016/S0262-4079(23)02328-X).
- [16] S. Sahoo, K. Sahoo, B. Sahoo and A. Gandomi, "A learning automata based edge resource allocation approach for IoT-enabled smart cities", *Digital Communications and Networks*, 2023, <https://doi.org/10.1016/j.dcan.2023.11.009>.
- [17] A. Čolaković, "IoT systems modeling and performance evaluation", *Computer Science Review*, Vol. 50, 2023, 100598, <https://doi.org/10.1016/j.cosrev.2023.100598>.
- [18] C. Schinckus, "The good, the bad and the ugly: An overview of the sustainability of blockchain technology", *Energy Research & Social Science*, Vol. 69, 2020, 101614, <https://doi.org/10.1016/j.erss.2020.101614>.

- [19] A. Pal, C. Tiwari and N. Haldar, "Blockchain for business management: Applications, challenges and potentials", *The Journal of High Technology Management Research*, Vol. 32, 2021, 100414, <https://doi.org/10.1016/j.hitech.2021.100414>.
- [20] S. Panda, K. Rath, S. Mishra and A. Khang, "Revolutionizing product development: The growing importance of 3D printing technology", *Materials Today: Proceedings*, 2023, ISSN 2214-7853, <https://doi.org/10.1016/j.matpr.2023.10.138>.
- [21] S. Altıparmak, V. Yardley, Z. Shi and J. Lin, "Extrusion-based additive manufacturing technologies: State of the art and future perspectives", *Journal of Manufacturing Processes*, Vol. 83, 2022, pp. 607-636, <https://doi.org/10.1016/j.jmapro.2022.09.032>.
- [22] G. Karnchanapayap, "Activities-based virtual reality experience for better audience engagement", *Computers in Human Behavior*, Vol. 146, 2023, 107796, <https://doi.org/10.1016/j.chb.2023.107796>.
- [23] Y. Yang, S. Deb, M. He and M. Kobir, "The use of virtual reality in manufacturing education: State-of-the-art and future directions", *Manufacturing Letters*, Vol. 35, Supplement, 2023, pp. 1214-1221, <https://doi.org/10.1016/j.mfglet.2023.07.023>.
- [24] Y. Zheng, "Optimization of computer programming based on mathematical models of artificial intelligence algorithms", *Computers and Electrical Engineering*, Vol. 110, 2023, 108834, <https://doi.org/10.1016/j.compeleceng.2023.108834>.
- [25] P. Bajdor, "Cloud Computing in Terms of Sustainable Development – Evaluation and Mutual Relations", *Procedia Computer Science*, Vol. 225, 2023, pp. 347-356, <https://doi.org/10.1016/j.procs.2023.10.019>.
- [26] F. Shaikh and M. Siponen, "Information security risk assessments following cybersecurity breaches: The mediating role of top management attention to cybersecurity", *Computers & Security*, Vol. 124, 2023, 102974, <https://doi.org/10.1016/j.cose.2022.102974>.
- [27] D. Broo, O. Kaynak and S. Sait, "Rethinking engineering education at the age of industry 5.0", *Journal of Industrial Information Integration*, Vol. 25, 2022, 100311, <https://doi.org/10.1016/j.jii.2021.100311>.
- [28] M. Sollosy and M. McNerney, "Artificial intelligence and business education: What should be taught", *The International Journal of Management Education*, Vol. 20, 2022, 100720, <https://doi.org/10.1016/j.ijme.2022.100720>.
- [29] M. Fleming, "AI is changing work—and leaders need to adapt." *Harvard Business Review*, March, 2020. [Online]. Available: <https://hbr.org/2020/03/ai-is-changing-work-and-leaders-need-to-adapt>. [Accessed: Feb. 1, 2024].

Education In The Era Of Smart Cities: Transformation And Opportunities

Vihra Dimitrova

Faculty of Telecommunications and
Management
University of Telecommunications
and Post
Sofia, Bulgaria
v.dimitrova@utp.bg

Nikolay Nikolov

Faculty of Telecommunications and
Management
University of Telecommunications
and Post
Sofia, Bulgaria
n.nikolov@utp.bg

Todor Gospodinov

Faculty of Telecommunications and
Management
University of Telecommunications
and Post
Sofia, Bulgaria
t.gospodinov@utp.bg

Abstract. The concept of the smart cities is closely related to the opportunities of smart education that reflects how advanced technology enables learners to acquire knowledge and skills more effectively, efficiently, and conveniently. The role of smart education is to support learners in the 21st century to meet and successfully cope with the challenges of a digitalized society, including developing problem-solving skills. The aim of the paper is to examine the role of the education in modern smart cities, from the quadruple helix model perspective. Smart education has become an important strategy for building a smart society, as an essential part of the model, including collaborative innovation and interaction among government, academia, business and society. By the use of technologies and innovation, the modern educational institutions could promote not only student satisfaction with the learning process, but also support the development of sustainable smart and knowledge-based cities.

Keywords: education, innovation, smart city, technologies

I. INTRODUCTION

The concept of smart cities is associated with the use of information and communication technologies (ICT) in the infrastructures of cities to improve living conditions, promote economic development and reduce the harmful impact of climate change and the environment. The main aspects in the construction of smart cities are the achievement of intelligence in city management, infrastructure, health care, transport, education, energy use and the provision of utility services [1]. Smart cities aim to promote sustainable economic growth, improve citizens' quality of life and optimize infrastructure, through the use of data and smart technologies. Global trends in the development of smart cities are aimed not only at the use of technologies in the form of various sensors, hardware and software, smart meters, access control, video surveillance, power and lighting management, sensors, firmware and others that provide information and real-time

data [2], but also integrating the latest technological advances, such as the Internet of Things (IoT), big data, machine learning, fifth generation (5G) networks, various robotic and automated systems, electric vehicles and so called [3] [4]. The purpose of the article is to highlight the importance of smart cities in the field of education and to analyse the possibilities for introducing innovations and technologies in the education.

Digital technologies have enormous potential to help increase the quality, equity and effectiveness of higher education. Realizing the full potential of digitization requires a rethinking of the policy framework, including ways of funding, additional training and quality assurance. An adequate strategic framework of digitization, monitoring and ensuring quality education is needed. A modernized digital learning ecosystem requires a renewed, shared understanding among leaders and stakeholders about an effective smart education model [5].

II. MATERIAL AND METHOD

The material includes a review of scientific research of the smart cities and education as part of the quadruple helix model. The innovation process in education has been analyzed. The following scientific methods were used in the research process - analysis and synthesis, descriptive analysis.

III. RESULTS AND DISCUSSION

A. Smart cities and the Quadruple model perspective

Smart cities aim to improve the quality of life of citizens through the use of technology. However, the information and communication technologies are only part of the equation of smart cities development. "Social innovation, which creates new social forms and forms of cooperation in society, is also essential. In this context, the capacity of municipalities to involve the various stakeholders

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8084>

© 2024 Vihra Dimitrova, Nikolay Nikolov, Todor Gospodinov. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

(entrepreneurs, academics, non-governmental organisations and citizens) in planning and implementation processes should be emphasised, as well as their ability to agree on the best solutions for development, responsibilities and investments as a result of common efforts” [6].

The engagement of the main stakeholders – government, academia, business and society - could be analyzed, considering the Quadruple helix model (Fig. 1). The Quadruple helix concept is presented as an innovation environment where stakeholders create partnerships among business, society, government institutions and research organizations.

The government and public authorities in general, have the task to provide the appropriate legal framework, policies and strategies. The main leadership and funding should be provided by the industry. Research and educational institutions participate in the process with knowledge transfer and scientific research. End-users must be motivated to actively participate in the open innovation process feedback process.

✓ **Government.** The role of public actors is to facilitate interactions by providing arenas and funding. Modernizing the digital learning ecosystem must involve human capacity building strategy and public investments [7]. Smart cities are also closely related to regions and the regional innovation strategies. There is a variety of evidence and good practices confirming that the regions and the cities are of crucial importance in the innovations’ development process, by creating industrial clusters, competence centres, incubators, technological parks and various formal and informal innovation spaces. The successful regions and cities become European and global innovation centres, technological networks and value chains [8].

✓ **Academia.** The HEI’s can play a significant role in: unlocking the intellectual and financial resources; deal with the unemployment and low skills; accessible higher education; upgrading the skills and acquiring of new skills; employment opportunities. attracting talented students and staff; promoting exchanges; collaboration between universities and the private sector; knowledge exchange between researchers and business. Therefore, universities need to engage themselves in sustainable development activities, arrange workshops and projects in cooperation with private, public, and civil sectors, in order to offer students an experience in solving real-life problems [9].

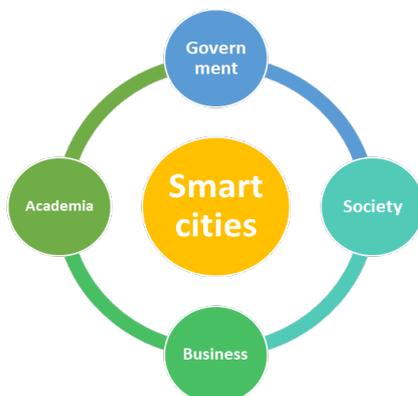


Fig. 1. Quadruple helix model, applied to smart cities.

✓ **Business.** Contributes with: regional partnerships; training and research consultancies; student placements; research incubators; using regional, national and European funding mechanisms; development of entrepreneurial skills; development of network and cluster organisations; development of intellectual property.

✓ **Society.** HEI’s could have a significant impact through delivering culture-based learning programmes, infrastructure (e.g. museums, galleries, music venues) and building infrastructure that improves and enhances the local area which in turn makes it more attractive to populations alike. Another important aspect is the building of vivid learning communities.

As part of the model, the personalized and on-demand service for teachers and students based on data interoperability is provided by the government and business. The last presents also a mechanism for collaborative innovation to promote the supply of open educational resources across regions for equal and inclusive education, while the new mode of educational governance will be empowered by AI and big data.

In regard to the quadruple helix model, the smart cities become real and actual “living labs”. Living labs are considered as a research approach where end-users are partners in the innovation process. Urban living labs function as an “explicit form of intervention” to intentionally contribute to the city sustainable development on the basis of “knowledge and learning” [10]. The phases of the innovation life cycle in living labs must be properly identified and managed, starting from the idea, the creation of products and services, and reaching the transfer of technology. From an organizational point of view, the living laboratory, in addition to the necessary infrastructure, financial and human resources, must have its own internal rules for management and functioning, including procedures for monitoring and active participation of end-users.

As the environment and environmental protection are essential part of the smart city concept, we could go further in conceptualizing the interconnections among the different model components. The Quintuple helix model builds on the quadruple, including our natural environment (Fig. 2). The connection between smart education, smart cities and environment, could be summarized as follows:

✓ **Environment.** Possible contribution: the Green Impact scheme; reducing waste and increasing recycling; increasing energy efficiency and reducing carbon emissions; increasing sustainable procurement; increasing sustainable transport; improving communications relating to sustainability; promotion of sustainable travel through public transport discounts and facilities and support for cyclists; satisfying the majority of the universities’ electricity needs from sustainable sources; researchers’ teams dealing with global issues; research in environmental sciences; sustainability as a guiding principle.

The smart city concept will evolve in the future and the next development stage will be “knowledge-based city”. That is why the knowledge and education will gain even more importance. Knowledge-based city will be the basis for sustainable development, accentuating the significant process of “transforming knowledge resources into local development” [11].

B. Education in the context of the smart cities

Education is one of the areas of focus in smart cities because it is recognized as a crucial factor in empowering citizens and facilitating their more active role in various initiatives to make cities smart [12]. The presence of creative thinking and an appropriate level of education are among the factors that correlate with urban intelligence, which is why cities cannot achieve intelligence without creativity, education, knowledge and learning [13]. Smart education is a broad term for learning in today's digital age that reflects how advanced technology enables learners to acquire knowledge and skills more effectively, efficiently and conveniently. Education 4.0 refers to the future design and vision of learning, using the "digital technologies, personalized data, open-source content, connectivity" [14], developing creativity and innovative thinking. Modern education must be compatible with the knowledge and technological progress, required in smart cities. Purposeful change should make learning more interesting, collaborative and oriented towards the development of talents and skills, allowing students to solve different problems [15]. Smart education must accommodate the uniqueness of learners and provide more freedom in terms of pace and access to data and learning resources. This is only possible if the learning content and the teaching methods used are changed. Smart education is a learning model adapted to new generations of digital learners. Compared to traditional classroom teaching models, smart education is an interactive, collaborative, and visual model designed to increase student engagement and enable teachers to adapt to students' learning skills, interests, and preferences [16]. The digitalization of education has become a necessity in the last few years. Distance learning in an electronic environment during the two-year COVID-19 pandemic further strengthened the digitalization of educational processes.



Fig. 2. Quintuple helix model, applied to smart cities.

By complementing traditional education with e-learning, the use of learning management systems and e-learning platforms have become the standard for educational institutions, especially in higher education [17]. Although the pandemic situation is now a part of our past, improved e-learning practices in the learning process are undergoing further development and e-learning has entered its next, more mature stage [18]. The introduction of artificial intelligence (AI), augmented reality (AR) and virtual reality (VR) in education will become compulsory in the near future. Smart learning is related to the use of modern technologies for teaching and evaluating the

acquired knowledge. Despite its proximity, smart education should not be equated with digital education, because its essence is advanced digital education and its characteristics are related to more adaptation of the learning content and teaching effectiveness, compared to the characteristics of modern students. Smart learning is about learning in interactive, intelligent and personalized learning environments, including, augmented reality, cloud computing and social networking services.

The key elements in planning and developing smart education are: upgrading ICT infrastructure for education (e.g., broadband network, 5G, Wi-fi) and upgrading smart campuses with cyber and physical spaces (e.g., AI, IoT, VR/AR laboratories; data visualization; deploying security facilities). 5G technology integrates with the Internet of things, big data, AI, machine learning, etc. to serve the field of education and promote the development of smart education.

An example of the connection between smart cities and education are two of the "5G projects for smart communities" financed by the European Commission. The construction of a 5G mobile network (MPN) is supporting new functional approaches to education and training at universities and hospitals in Palermo, Italy and the University Hospital of Frankfurt in Germany to create a sustainable healthcare system, optimize learning and training processes of students and innovative solutions for monitoring and organizing hospital logistics.

C. Innovations and technologies in the education

The development of technologies makes them an increasingly important part of education, as the use of ICT tools in the learning process allows combining technologies with modern teaching methods and tools. Technological equipment (hardware and software) and various ICT means are used in training and education.

The use of ICT tools in the educational process allows not only to motivate students for active participation in the learning process, but also encourages their desire to continuously seek new knowledge and self-improvement. The development of technologies and their entry into education leads to the creation of new teaching methods, such as:

- Virtual classroom - where the learning process is organized in electronic form. The virtual classroom allows the teacher to share learning content, provide additional learning resources, communicate with students, assess their knowledge, and conduct online meetings in real time. The use of virtual classrooms increased by 3600% in the month of March 2020 and by 9000% at the end of the month of September 2020 [19]. This process has been largely driven by the shift to online learning courses, but the use of e-learning platforms and students' use of alternative learning content formats has also increased dramatically.

- Video conference meeting - cloud technologies allow synchronous learning and video conference connection between teacher and students. Such technologies and tools are Google Hangouts/Google Meets, Microsoft Teams/Meets, Zoom, etc.

- Shared Classroom - Virtual classroom functionality that allows content to be shared with another teacher or

students. It can be used when conducting a lesson on one topic in several school classes or when conducting interdisciplinary lessons.

- Flipped classroom - the specificity of using a flipped classroom is that the conduct of a typical lesson and the assignment of homework assignments are switched. The method is based on cloud technologies, and the provision of learning materials by the teacher to students is carried out by sharing them as text and audio files or using resources from a created virtual classroom. When using the method, links (hyperlinks) that the teacher provides to the students and that contain information related to the studied content can also be used.

- Project-based learning in an electronic environment – learning that is personally oriented and aims to acquire new knowledge through the manifestation of creativity on the part of students. Activities included include independent information seeking, content research and evaluation, learning project development, and more. The main elements of project-based learning are searching and retrieving information, critically evaluating information resources in the online space, and performing team tasks. The training provides an opportunity to acquire knowledge by finding a solution and researching a given question, using interactive means to visualize the content presented by the students.

- Multi-Media Text Sets – a method where all learning resources on a specific topic are organized in one place and made accessible to students. The learning resources used can be in different formats – text files, presentations, audio and video files.

ICT-based teaching methods allow attracting the interest of students, easier mastery of knowledge and its permanent assimilation. Through ICT means, the teacher can apply a metacognitive approach in teaching, aimed at mastering knowledge, skills and competences through analysis, reflection and self-improvement. Internet and ICT-based methods allow various opportunities for their use in education, being constantly developed and enriched.

Technology is the intersection of smart cities and education, and their dependence is growing, and two main dimensions can be distinguished. The first is in the context of remote access to resources, tools and technologies via Internet, and the second is the training of experts for the development of smart cities themselves. In one of the fastest growing universities in Bulgaria - the University of Telecommunications and Post, a variety of platforms and applications are used in students' training, especially in the field of Engineering. Table 1 includes the main ones, based on various modern technologies - cloud computing for data storage, peer-to-peer for video communication, container-based for writing code and immediate execution, and others. Practice shows that they improve the efficiency, flexibility and productivity of the educational process.

Technological developments also require the creation and updating of an appropriate legal framework, including on digital learning content and digital competence. Regarding the digital skills of teachers at all levels of education, the European Commission's Digital Competence Framework for Teachers (Dig Comp Edu) [20] defines and describes the skills that teachers should

acquire in order to teach and introduce innovations through the use of digital technologies.

The digital transformation requires the adoption of standards for digital learning content creation and strategy for improving the digital competence, both for teachers and students. A mechanism and more efforts are needed in order to promote, both teachers' and students' digital literacy, awareness, computational thinking, digital learning and information social responsibility, through relevant curriculum and practice. According to the European Commission "digital competence" refers to "effectively and critically use information and technology for training, self-development and active participation in society [20]". The Dig Comp framework 2.2. encompasses 5 different areas: Information and data literacy; communication and collaboration; digital content creation; safety; problem solving.

TABLE 1 USE OF ICT'S IN EDUCATION

Application	Type of technology, use and discipline		
	Technology	Use	Discipline
Google Drive	Cloud computing	Data storage	All disciplines
Unicloud.utp.bg	Cloud computing	Data storage	All disciplines
Zoom	Peer-to-peer	Video conference	All disciplines
Github	Git	Developer community	Software quality assurance
Pastebin	Content-hosting	Code sharing	Fundamentals of programming
W3schools	Content-hosting	Training	Fundamentals of programming
Python.org	Content-hosting	Training	Fundamentals of programming
Sololearn	Content-hosting	Training	Object-oriented design
Learn SQL	Content-hosting	Training	Databases
Replit	Browser based	REPL / IDE	Object-oriented design
SQL Online	Browser based	IDE	Databases
Online Python	Browser based	IDE	Object-oriented design
Jira	Browser based	Project Management	Software quality assurance

The digital competence of the academic staff and students significantly influences the introduction of new technologies in education by harmonizing digital learning methods, intercultural interaction and equal access to higher education.

D. Opportunities and challenges

In the modern educational process, information and communication technologies are not the only object of study, but a means through which the educational process is implemented. The wide penetration of technologies in the whole society, turn them into a tool used by students, even from the initial stage, which requires updating the way of teaching the learning content to increase learning motivation. The use of ICT tools in the teaching of individual subjects allows not only to increase the motivation of the students, but also the acquisition of digital competences and the achievement of digital literacy. The

variety of ICT-based teaching methods and the effectiveness of their use confirm the fact that in a digital environment, students' knowledge is mastered more easily, while being durable and functional, and the educational process is defined as conscious and motivated. The use of ICT solutions provides conditions for the application of a metacognitive approach in teaching, through which students' attention is directed to mastering competencies through reflection, analysis and self-improvement.

Along with these opportunities, there are some challenges for integrating emerging ICT technologies into teaching and learning, e.g. inclusion and equality problems, technology governance, ethics, accountability, transparency and security of smart technologies, etc. The challenges of introducing smart education are caused by the lack of sufficient ICT resources in various educational institutions and need for digital literacy improvement. The above basic digital skills provide new opportunities for obtaining information by students, promoting independent learning, research and analysis of various information sources. At all levels of the educational system, the benefits of using digitization in the learning process include also intellectual, mental and emotional aspects. Social-emotional skills, such as self-awareness, self-management, social awareness, relationship skills (and responsible decision-making skills will be crucial in the digital age.

The solution to these challenges could be found in the quadruple helix model - in an effective collaboration among government, business, academia and society.

E. Policies and strategies

Innovations in the field of education have been born out of the development of modern society and the technological revolution. Revolutions 4.0 and 5.0 are bringing more and more products and services based on robotics, artificial intelligence, the Internet of Things (IoT) and big databases into everyday life. It is increasingly assumed that today's students will work in occupations that do not yet exist. Future professions require new knowledge and competences, which should be provided to learners through an innovative approach in education, to promote the acquisition of different competences and creative thinking. It is necessary to make sustainable reforms in order to achieve smart education, in view of the interests of modern students and technological progress.

Due to the COVID-19 pandemic and the consequent, unprecedented expansion of remote and online learning models, education leaders have recognized the urgency to modernize the digital learning ecosystem in order to provide inclusive and equitable educational opportunities to all students in the new era. Public authorities have a key role in the process of deploying, maintaining and updating the necessary infrastructure, as well as in establishing criteria and guidance around creating or curating quality digital educational resources. Another important political aspect is the adoption of a legal framework for the protection of personal information. In this regard, a proper mechanism for safety of networks and connection should be provided. The policies and strategies should ensure the full participation and inclusion of people regardless of their ethnicity, origin, cultural and religious identity, gender, age, socioeconomic status, physical ability or

other criteria that may lead to the marginalization of certain populations. Smart learning environments have the ability to provide just-in-time learning that is based on the broad capabilities and levels of adaptation and greater specification of student learning conditions [21]. The role of smart education is to support learners in the 21st century to meet and successfully cope with the challenges of a digitalized society, including developing the ability for problem-solving [22].

With regard to the twin transition, European Commission aims at "adapting education and training systems to match a rapidly transforming technological and socio-economic reality as well as supporting labour mobility across sectors" [23]. A complete revision of the curricula, the training methods and the possibilities of new technologies should be done. The development of a smart education plan for teaching and learning will promote the ability of learners, educators and citizens to adapt to an uncertain, complex and ever-changing world. Therefore, the strategical incentives for multi-sector partnerships will be crucial for contributing and sharing the knowledge and resources for the public good.

IV. CONCLUSION

The innovation process of the smart education is related to the "new era transition process", along with the preparation of the students as lifelong, empowered learners, ready to rapidly adapt to the labour market. Therefore, a strategy for collaborative innovation to promote the supply of open educational resources across regions for equal and inclusive education is needed. All the stakeholders – government, academy, business and society - should interact in the process of educational modernization.

Smart education has become an important strategy for building a smart society and is an essential part of the quadruple helix model, applied to smart cities. It is important to provide the necessary mechanisms and approaches for promoting both teachers' and students' digital literacy, awareness, computational thinking, digital learning and information social responsibility through relevant curriculum and practice. The innovative teaching methods and strategies such as hybrid education, learning and assessment, support the deep infusion of ICT into education. Like any other ecosystem in nature, the educational ecosystem needs balance to be sustainable. By the use of technologies and innovation, the modern educational institutions could promote not only student satisfaction with the learning process, but also support the development of smart and knowledge-based cities.

ACKNOWLEDGMENTS

The article has been made possible with the financial support of Project No NID 30-294/14.03.2024 by UTP – Sofia.

REFERENCES

- [1] M. Iqbal. Smart City in Practice: Learn from Taipei City. *Journal of Governance and Public Policy*. Vol. 8, No 1, 2021, pp. 50-59.
- [2] F. Zhao, Fashola, O. Olarewaju, T. Onwumere, I. Smart city research: A holistic and state-of-the-art literature review. *Cities*, volume 119, 2021. <https://doi.org/10.1016/j.cities.2021.103406>.

- [3] A. Ojo., Z. Dzhusupova & E. Curry. Exploring the Nature of the Smart Cities Research Landscape. In R. Gil-Garcia, T. A. Pardo, & T. Nam (Eds.). *Smarter as the New Urban Agenda: A Comprehensive View of the 21st Century City*. Springer, 2015, pp. 1-8
- [4] J. Okello, J. Akoko, Smart city trends and innovations shaping. The future of cities. *Scientific papers of silesian university of technology. Organization and management series No. 169*, 2023, pp. 553-558. <http://dx.doi.org/10.29119/1641-3466.2023.169.3>
- [5] N. Tri., P. Hoang & N. Dung. Impact of the industrial revolution 4.0 on higher education in Vietnam: challenges and opportunities. *Linguistics and Culture Review*, 5(S3) , 2021. pp 1-15. <https://doi.org/10.37028/lingcure.v5 nS3.1350>
- [6] OECD. *Enhancing The Contribution Of Digitalisation To The Smart Cities Of The Future*. 2019.
- [7] L. Darling-Hammond, et al. *Empowered Educators: How High-Performing Systems Shape Teaching Quality Around the World*. San Francisco, CA: Jossey-Bass. 2017. ISBN 9781119369608.
- [8] <http://www.mi.government.bg/files/useruploads/files/innovations/manualnovember2012.pdf> [Accessed 20 Feb, 2024]
- [9] I. Gigauri, V. Vasilev and Z. Mushkudiani, In pursuit of sustainability: towards sustainable future through education. *International Journal of Innovative Technologies in Economy*, 2022, (1(37), p. 7. https://doi.org/10.31435/rsglobal_ijite/30032022/7798
- [10] H. Bulkeley, L. Coenen, N. Frantzeskaki, C. Hartmann, A. Kronsell, L. Mai, and Y. V. Palgan. *Urban living labs: Governing urban sustainability transitions*. *Current Opinion in Environmental Sustainability*, 2016, 22, pp. 13–17.
- [11] R. V. Knight, Knowledge-based development: Policy and planning implications for cities. *Urban Studies*, 1995, 32(2), pp. 225–260.
- [12] I. Hirju and R. Georgescu, The Concept of Learning Cities: Supporting Lifelong Learning through the Use of Smart Tools. *Smart Cities* 2023, 6, pp. 1385-1397. <https://doi.org/10.3390/smartcities6030066>
- [13] A. Molnar, Smart cities education: An insight into existing drawbacks. *Telematics and Informatics*. Volume 57, 2021. <https://doi.org/10.1016/j.tele.2020.101509>
- [14] E. Mukul. and G. Büyük'ozkan. Digital transformation in education: A systematic review of education 4.0. *Technological forecasting and social change*, 194 (2023), 122664, pp. 1- 21.
- [15] B. Williamson. Educating the smart city: Schooling smart citizens through computational urbanism. *Big Data & Society*, 2015, pp. 1-13. DOI: 10.1177/2053951715617783.
- [16] K. Demir, Smart education framework. *Smart Learn. Environ.* 8, 29, 2021. <https://doi.org/10.1186/s40561-021-00170-x>
- [17] R. Zhuang, H. Fang, Y. Zhang, A. Lu and R. Huang, Smart learning environments for a smart city: from the perspective of lifelong and lifewide learning. *Smart Learning Environments*, 4:6, 2017, DOI 10.1186/s40561-017-0044-8.
- [18] S. Lee, K. Lee, Smart teachers in smart schools in a smart city: teachers as adaptive agents of educational technology reforms. *Learning, media and technology*, 2023. <https://doi.org/10.1080/17439884.2023.2207143>
- [19] Blackboard [online]. [Accessed 13 March 2023]. Available from: <https://www.blackboard.com/go/best-practices>
- [20] European Commission, Directorate-General for Education, Youth, Sport and Culture, *Key competences for lifelong learning*, Publications Office, 2019, [Accessed 20 Jan, 2024] <https://data.europa.eu/doi/10.2766/569540>
- [21] J. Tham, G. Verhulsdonck. Smart Education in Smart Cities: Layered Implications for Networked and Ubiquitous Learning. *IEEE Transactions on Technology and Society*, vol. 4, no. 1, pp. 87-95, 2023, doi: 10.1109/TTS.2023.3239586.
- [22] S. Parusheva, S. Bobek, S. Sternad. Sustainable Higher Education: From E-Learning to Smart Education. *Sustainability*, 15, 2023. <https://doi.org/10.3390/su151310378>
- [23] COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL 2022 Strategic Foresight Report Twinning the green and digital transitions in the new geopolitical context. COM/2022/289 final. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52022DC0289&%3Bqid=1658824364827> [Accessed 10 Feb, 2024].

Canva Platform: Visual Content for Developing Writing Skills of Prospective Engineers in ESP Classes

Natalia Dmitrenko

Department of Foreign Languages
Vinnytsia Mykhailo Kotsiubynskyi
State Pedagogical University
Vinnytsia, Ukraine
nataliadmitrenko0302@gmail.com

Iryna Shkola

Department of Foreign Languages
and Teaching Methods
Berdyansk State Pedagogical
University
Berdyansk (Zaporizhzhia), Ukraine
ireneshkola@gmail.com

Bohdana Saliuk

Department of Foreign Languages
and Teaching Methods
Berdyansk State Pedagogical
University
Berdyansk (Zaporizhzhia), Ukraine
bohdanasaliuk@gmail.com

Violetta Panchenko

Department of Foreign Philology
Municipal Establishment "Kharkiv
Humanitarian Pedagogical
Academy" of Kharkiv Regional
Council
Kharkiv, Ukraine
violazmyov@gmail.com

Svitlana Neshko

Foreign Languages Department
Ukrainian State University of
Railway Transport
Kharkiv, Ukraine
neshko.inyazdep@gmail.com

Abstract—This article explores the integration of visual content technologies, with a specific focus on the Canva.com platform, to enhance the teaching of English for specific purposes (ESP) to prospective engineers. The primary goal of the authors was to investigate the effectiveness and benefits of using Canva.com for developing writing skills among prospective engineers through a mix of theoretical research and practical implementation in an educational setting. For this purpose, they implemented targeted activities via Canva.com, provided classroom observations, conducted a literature review, and administered a questionnaire survey with 50 engineering students, which helped to analyze students' work and demonstrate the impact Canva had on the development of students' writing abilities. Canva's user-friendly interface and visually appealing templates support the mastery of writing, covering various formats like resumes, cover letters, essays, and engineering blueprints. The article not only highlights the potential of Canva.com but goes further to present concrete examples of activities tailored for prospective engineers. Models of both individual visual storytelling and collaborative endeavours, exemplified by the "Evolution of Railway Technology" project, showcase the platform's versatility in facilitating engaging and educational experiences. In addition to these activities, the authors provide insightful assessment criteria and teaching tips, offering valuable guidance on effectively incorporating Canva.com into the classroom. By seamlessly integrating visuals into writing activities, the authors emphasize the

transformative impact on prospective engineers, encouraging them to express ideas more effectively and imaginatively. The Canva.com platform emerges as a dynamic and indispensable tool in ESP classes, cultivating an environment that not only stimulates creativity but also provides structured templates that empower students to navigate the intricacies of writing with confidence. Consequently, the article advocates wholeheartedly for the effective integration of Canva.com in English language instruction for prospective engineers, presenting a compelling avenue to elevate both their writing skills and overall language proficiency.

Keywords—Canva.com, enhanced learning, ESP classes, prospective engineers, visual content, writing skills.

I. INTRODUCTION

The use of visual content in language learning of prospective specialists has gained significant attention in recent years. It has been recognized as an effective approach to engage learners, enhance their understanding, and promote their writing skills. One platform that offers a range of visual content creation tools is Canva.com.

The development of network interaction technologies enables the modernization of the educational process and makes learning open and accessible to all participants: students, teachers, and university administration.

Print ISSN 1691-5402
Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8075>

© 2024 Natalia Dmitrenko, Iryna Shkola, Bohdana Saliuk, Violetta Panchenko, Svitlana Neshko.

Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

However, there are still problems that need to be addressed. For example, most mobile application opportunities are still not researched enough by the teaching staff. That is why the question of studying the possibilities of using the services provided by the Canva.com platform for individual and group work during ESP (English for Specific Purposes) classes becomes particularly relevant.

The question of implementing computer technologies in English language education of prospective specialists has been explored in the works of Blake, Dmitrenko et al., Gilakjani et al., Hidayat et al. [1] – [4], and others. It is emphasized that their usage contributes to improving learning, enhancing students' cognitive activity, and developing information culture. Lailiyah and Cahyono study the possibilities of applying cloud technologies and network interaction in language-enhanced education, Zhang, Zilka, et al. (2019) [5] – [7], and others.

Canva.com is a versatile online platform that provides users with access to a wide array of design templates, graphics, images, and fonts. It offers a user-friendly interface, making it accessible to both teachers and students. According to Anwar's research [8], it was found that the Canva application can be used for various learning purposes, allowing users to create a wide range of materials to support learning goals. According to a study conducted by Al Khoeri et al. [9], Canva.com is a graphic design application that effectively assists students in designing a variety of creative ESP materials online. The use of Canva in this study also is applied in the form of creating an infographic containing blog content. Given blog also can be used as media to facilitate students to practice writing [10].

One of the main advantages of Canva.com is its ability to stimulate students' creativity and imagination [11]. It allows users to design visually captivating presentations, infographics, posters, and other materials that can be used to support writing activities [12]. By incorporating eye-catching visuals, students are motivated to express their thoughts and ideas more effectively in writing [13].

With the help of the service, teachers can create a virtual classroom, educational presentations, infographics, tables, flashcards, lesson plans, and more [14] in ESP classes. Mastering writing skills in English is a priority for many students in higher education institutions, as they need to learn to express their thoughts in the professional sphere clearly and concisely [15]. Writing is considered a fundamental academic skill and is often considered the most challenging to acquire compared to reading, listening, and speaking. Naturally, students with good writing skills are more successful at expressing their ideas and achieving their goals in enhanced learning. Therefore, developing writing skills brings multiple benefits and contributes to success in life [16].

According to works of Melinia and Nugroho, Nurhidayat, Santiana et al., Suhartono and Laraswati [17] – [20], in enhanced learning writing by means of Canva.com, a specific vocabulary range, grammar, and the ability to organize and develop ideas are required. Ready-made templates for comics (storytelling) help students clearly visualize the development of a plot and think about what to write. These templates provide a

structured framework that assists students in planning their writing and ensuring coherence in their storytelling. By utilizing such templates, students can enhance their ability to organize their ideas effectively and present them sequentially and engagingly.

Furthermore, Canva.com offers various templates specifically designed for educational purposes. These templates can be customized to suit specific writing tasks, such as creating resumes, cover letters, essays, or storyboards. Students can choose from a wide range of designs and layouts, making the process of writing more engaging and enjoyable.

However, the use of the Canva.com platform for educational purposes remains on the periphery of scientific research, which has prompted the relevance of our study. Therefore, *the study aims* to highlight the features of using the Canva.com platform for developing the writing skills of prospective engineers in ESP classes.

II. MATERIALS AND METHODS

To investigate the effectiveness of Canva.com in developing writing skills for prospective engineers in ESP classes, a mixed-methods approach was employed. The study involved a comprehensive literature review to establish the theoretical foundation and identify existing research in the field of technology-enhanced language learning and visual content creation tools.

The primary data collection methods included a questionnaire survey titled "Benefits of Using Canva.com to Develop Writing Skills in ESP Classes," administered to 50 students from the "Engineering" educational program at the Ukrainian State University of Railway Transport. The questionnaire consisted of Likert-scale, multiple-choice, and open-ended questions, enabling participants to share their experiences, perspectives, and suggestions regarding the use of Canva.com in developing writing skills.

Additionally, the researchers implemented targeted writing activities and projects on the Canva.com platform in their ESP classes over two semesters of the 2022-2023 academic year. These activities focused on visual storytelling, collaborative writing endeavors, and creating visually appealing content such as resumes, cover letters, essays, and engineering blueprints. Classroom observations and analysis of student work produced using Canva.com were conducted to assess the impact on writing skills, creativity, and overall language proficiency.

Example of Visual Storytelling activity via Canva.com:

Objective: Develop narrative writing skills and creativity through visual storytelling using Canva.com.

Instructions: 1) Divide the students into pairs or small groups. 2) Explain to the students that they will create a visual story using Canva.com. 3) Provide them with the following guidelines: a. Choose a specific theme or setting for their story (e.g., a haunted house, a futuristic city, etc.). b. Create a storyboard with a sequence of events using Canva presentation templates or custom-sized designs. c. Each group member should contribute to the story by writing a different part of the narrative (e.g., introduction,

conflict, resolution). d. Incorporate visuals, such as images, illustrations, and icons, from Canva's extensive library to enhance the storytelling. e. Pay attention to the coherence and flow of the story, ensuring that each part connects smoothly. f. Write descriptive and engaging text for each scene, using dialogue, action, and sensory details to bring the story to life. g. Experiment with different font styles, colors, and layouts to match the mood and tone of the story. 4) Allow time for the students to collaborate, plan, and create their visual stories on Canva.com. 5) Once the stories are complete, have each group present their visual story to the class. 6) Encourage the students to narrate their stories, explaining the sequence of events and the characters' actions and emotions. 7) Facilitate a discussion after each presentation, asking the class to provide feedback and share their interpretations of the stories.

Conclude the activity by discussing the importance of visual elements in storytelling and how they can enhance the overall impact of a narrative.

The teacher can modify this activity by adjusting the complexity of the storytelling task or incorporating specific language targets, such as using descriptive adjectives, past tense verbs, or conditional sentences. Canva.com's design features and templates offer a creative platform for students to develop their narrative writing skills while integrating visually appealing elements into their stories. One tip is to use specific storytelling topics around which the characters of the stories can grapple with problems like: a) The origins of a particular field of engineering (e.g. civil, mechanical); b) The need for innovation to solve a practical problem; c) How early engineers developed solutions with simple tools and materials; d) The evolution of an engineering wonder (e.g. steam engine, bridge design) through different historical periods; e) How pioneering engineers contributed to major innovations that impacted society.

By centering the narratives around these engineering-related issues, teachers can provide more meaningful contexts for students to apply their expanding English proficiency. The storytelling process will engage their imagination to devise plot lines and technical solutions, while also learning new vocabulary and structures. With Canva's multimedia options, the next generation of engineers can express their creativity visually. Another important thing that the teachers have to think about is assessment. When they assess students' visual storytelling writing activity created through Canva.com in an English language class, the teachers should consider the following assessment criteria: 1) Evaluate the organization and coherence of the visual story. Assess if the story has a clear beginning, middle, and conclusion and if the sequence of events is logical and well-developed. 2) Assess the language proficiency demonstrated in the written content of the visual story. Evaluate the accuracy and appropriateness of vocabulary, grammar, sentence structure, and overall language fluency. 3) Evaluate the level of creativity and originality demonstrated in visual storytelling. 4) Assess the visual appeal and aesthetic quality of the Canva design. 5) Evaluate how well students followed the guidelines, requirements, and themes or prompts. Assess if the visual story reflects the assigned topic, demonstrates an understanding of the

storytelling objective, and meets the length or content requirements specified. 6) Assess the overall engagement and impact of the visual story. Consider if the story effectively engages the viewer, elicits an emotional response, and effectively communicates the intended message or theme. 7) Assess the use of descriptive language, dialogues, figurative expressions, and other creative language techniques to enhance the storytelling experience. 8) If students are required to present their visual stories, assess their presentation skills, including clarity of speech, confidence, and ability to effectively communicate the story to the audience. 9) Encourage students to reflect on their work and provide a self-assessment of their strengths, areas for improvement, and the challenges they encountered during the visual storytelling process. Consider their ability to analyze and evaluate their work.

Provide prospective engineers with clear assessment criteria before they begin the visual storytelling activity, so they understand the expectations and can self-assess their work. Offer constructive feedback to guide their improvement and highlight areas where they have excelled.

Another valuable feature of Canva.com is collaboration. It allows prospective engineers to work together on group projects or peer editing activities. They can share their designs, provide feedback, and collaborate in real-time, fostering a sense of teamwork and encouraging the development of writing skills through effective communication.

Collaborative writing: Canva's collaborative features enable prospective engineers to work together on writing projects in real-time, allowing them to share ideas, critique each other's work, and learn from each other's writing styles.

For example, the teacher can use the activity "Green Building Technologies", "Solar-Powered Community", "Evolution of Railway Technology" or "Bridge Design Evolution" – groups detail the historical development of an aspect like suspension, beam, arch, or truss bridges. Students use images, charts, and factual accounts to compare milestone innovations that drastically increased spans and load-bearing abilities over time. Instructors allow time for the students to explore Canva.com's design tools and templates, providing support and guidance as needed.

A. Sample

Topic: Evolution of Railway Technology

Objective: Develop technical writing and visual communication skills by creating an animated timeline documenting key innovations in railway history.

Instructions:

Divide students into groups, and assign each a period (e.g. Early Railways, Golden Age Steam Locomotives, Diesel Transition, High-Speed Rail).

Using Canva, create an animated multi-page timeline template.

Guide students to include:

Iconic images, patent diagrams, and maps

Fact boxes on milestone inventions (e.g. track gauges, air brakes)

Quotes/anecdotes about pioneering engineers

Descriptions of how technologies enabled longer routes, higher speeds, and capacities

Sections on iconic locomotives and infrastructure projects

Comparative charts showing the evolution

Taglines/headers conveying the theme of that era

Encourage a cohesive visual narrative across groups documenting the rapid progress of railways.

Have groups present their section and its significance in the broader timeline to the class.

This ties in historical and technical knowledge with the multi-modal communication skills expected of engineers. The roles and innovations frame an engaging storyline for language learning.

Encourage class discussion and interaction, allowing students to ask questions and share their thoughts about the different destinations.

Conclude the activity by reflecting on the importance of descriptive writing in promoting travel destinations and how visual elements can enhance written communication. The instructor can adapt this activity by choosing different topics or objectives, such as creating persuasive advertisements, designing informative posters, or developing storyboards for short narratives. Canva.com offers a wide range of templates and tools to support various writing activities in an engaging and visually appealing way.

B. Participants

The presented method of teaching storytelling by means of Canva was implemented in the education process in order to improve English writing skills of prospective engineers in Ukrainian State University of Railway Transport (Ukraine). The researchers selected a representative sample of university students engaged in remote online learning to ensure the study's findings could be generalized to a broader population. 50 students from the educational program "Engineering" participated in it during two semesters of 2022-2023 academic year.

C. Procedure

At the end of the second semester in order to investigate the students' perception towards the use of Canva in improving writing skills, the questionnaire "Benefits of Using Canva.com to Develop Writing Skills in ESP Classes" was conducted. These instruments included Likert-scale, multiple-choice, and open-ended questions, enabling participants to share their experiences, perspectives, and suggestions in-depth.

The participants of the study were informed about the purpose and the structure of the questionnaire and assured that their names would not be used in the study reports.

III. RESULTS AND DISCUSSION

Preferably After analyzing the results of the questionnaire, it was discovered that prospective engineers perceived Canva as an effective means of support in developing writing skills in ESP classes (table 1).

TABLE 1. BENEFITS OF USING CANVA.COM TO DEVELOP WRITING SKILLS IN ESP CLASSES

No	Benefits of Canva.com	Strongly Agree	Agree	Disagree	Strongly Disagree
		(%)	(%)	(%)	(%)
1	a visually engaging platform that captures students' attention	18	76	4	2
2	a visually engaging platform that stimulates students' creativity	12	72	12	4
3	Canva motivates to express ideas more effectively and imaginatively	8	74	14	4
4	Canva offers various design templates and tools that enable students to create visual stories	16	76	4	4
5	Canva helps learners develop their skills in interpreting and creating visual information, which is essential in their professional context	10	76	10	4
6	Canva stimulates collaborative writing projects	12	74	10	4
7	Canva simulates real-world design scenarios	10	74	12	4
8	Canva helps to convey complex ideas concisely	10	72	14	4
9	Canva helps to select appropriate visuals to support writing and engage the audience through effective visual representations.	16	78	4	2

According to the results of the questionnaire, it can be stated that using Canva.com to develop writing skills in ESP classes offers numerous benefits. Canva.com provides a visually engaging platform that captures prospective engineers' attention and stimulates their creativity. By incorporating visuals into writing activities, students are motivated to express their ideas more effectively and imaginatively. Canva.com offers various design templates and tools that enable students to create visual stories. This allows them to develop narrative writing skills, practice structuring their ideas, and convey their thoughts in a compelling and engaging manner.

Through writing captions, dialogues, or descriptions in their designs, students can reinforce vocabulary, grammar, and sentence structure, thereby improving their overall language proficiency. Visual storytelling using

Canva.com helps prospective engineers develop visual communication skills, which are vital in various professional and academic contexts. They learn to convey complex ideas concisely, select appropriate visuals to support their writing, and engage the audience through effective visual representations.

Thus, analyzing the scientific studies devoted to the use of Canva.com in the English language enhanced learning [1] – [20], as well as taking into account the authors' experience of applying Canva.com in the process of teaching English writing, it is considered to provide some teaching tips for using Canva.com for ESP classes for prospective engineers:

1. Begin by providing a brief overview of Canva.com and its features to familiarize students with the platform. Demonstrate how to navigate the website and access the various design tools and templates.

2. Break down the process of using Canva.com into clear and manageable steps. Provide instructions and demonstrate each step to ensure prospective engineers understand how to create their visual content effectively.

3. Share model examples created using Canva.com to inspire prospective engineers and give them an idea of what they can create. Show them different design options, layouts, and color schemes to encourage creativity and experimentation.

4. Emphasize the importance of planning before diving into the design process. Encourage prospective engineers to brainstorm ideas, outline their content, and gather relevant materials (such as images or text) before starting their Canva project. This will help them stay organized and focused throughout the design process.

5. Incorporate language learning objectives. For example, if the focus is on vocabulary expansion, encourage prospective engineers to include target words in their designs. If the aim is to practice writing skills, guide students to write descriptive captions or engaging text to accompany their visual content.

6. Promote peer collaboration by encouraging prospective engineers to work together or provide feedback on each other's designs. This can enhance teamwork, foster language practice, and encourage creativity as students share ideas and perspectives.

7. Create opportunities for prospective engineers to showcase their Canva creations. Display their designs in the classroom, share them digitally, or organize a presentation session where students explain their design choices and the content they created. Celebrate their efforts and provide constructive feedback to support their growth.

8. After completing the Canva activity, have prospective engineers reflect on their learning experience. Ask them to evaluate their designs, identify strengths and areas for improvement, and share what they have learned about visual communication and language use through the process.

9. Encourage prospective engineers to explore other digital design tools and platforms similar to Canva.com.

This will allow them to broaden their digital literacy skills and provide alternative options for visual content creation.

10. Remember to adapt these tips to fit the specific needs and proficiency level of prospective engineers in ESP classes. By incorporating Canva.com into your ESP classes, the teacher can engage students, foster creativity, and provide them with valuable language practice opportunities in a visually appealing context.

IV. CONCLUSIONS

Canva.com facilitates collaborative learning by allowing prospective engineers to work together on design projects and simulate real-world design scenarios, helping students understand how visuals are used for communication and persuasion in various industries and professions. This exposure prepares them for future academic and professional endeavors.

The targeted activities presented in this study, such as visual storytelling, collaborative writing projects, and the creation of visually appealing content like resumes, cover letters, essays, and engineering blueprints, have demonstrated the versatility and effectiveness of Canva.com in enhancing writing skills.

By incorporating Canva.com into ESP classes, educators can provide a dynamic and engaging environment for prospective engineers to develop their writing skills. The platform's visual nature enhances creativity, promotes language practice, and equips students with valuable digital literacy and visual communication skills that are essential in today's globalized world.

REFERENCES

- [1] W.-K. Chen, *Linear Networks and Systems*. Belmont, CA: Wadsworth, 1993, pp. 123-135. R. J. Blake, "Current trends in online language learning." *Annual Review of Applied Linguistics*, vol. 31, 2011, pp. 19-35, <https://doi.org/10.1017/S026719051100002X>.
- [2] N. Dmitrenko, O. Voloshyna, S. Kizim, K. Mnyshenko and S. Nahorniak, "Smart Education in the Prospective Teachers' Training." *CTE Workshop Proceedings of ACNS Conference on Cloud and Immersive Technologies in Education*, vol. 10, 2023, pp. 38-53, <https://doi.org/10.55056/cte.v10>.
- [3] P. Gilakjani, N. B. Sabouri and A. Zabihiemran, "What are the barriers in the use of computer technology in EFL instruction?" *Review of European Studies*, vol. 7(11), 2015, pp. 213- 221, <https://doi.org/10.5539/res.v7n11p213>.
- [4] D. N. Hidayat, J. Y. Lee, J. Mason, and T. Khaerudin, "Digital technology supporting English learning among Indonesian university students." *Research and Practice in Technology Enhanced Learning*, vol. 17(1), 2022, pp. 23-27, <https://doi.org/10.1186/s41039-022-00198-8>.
- [5] M. Lailiyah and B. Y. Cahyono, "Indonesian EFL Teachers' self-efficacy towards Technology Integration (SETI) and their use of technology in EFL teaching." *Studies in English Language Teaching*, vol. 5(2), 2017, pp. 344-357, <https://doi.org/10.22158/selt.v5n2p344>.
- [6] X. Zhang, "Application of Cloud Computing Assisted Instruction in English Teaching." *Journal of Physics. Conference Series*, vol. 1881(3), 2021, pp. 032025, <https://doi.org/10.1088/1742-6596/1881/3/032025>.
- [7] G. C. Zilka, I. D. Rahimi and R. Cohen, "Sense of Challenge, Threat, Self-Efficacy, and Motivation of Students Learning in Virtual and Blended Courses." *American Journal of Distance Education*, vol. 33(1), 2019, pp. 2-15, <https://doi.org/10.1080/08923647.2019.1554990>.

- [8] K. Anwar, "The Perception of Using Technology Canva Application as a Media for English Teacher Creating Media Virtual Teaching and English Learning in Loei Thailand." *Journal of English Teaching, Literature, and Applied Linguistics*, vol. 5(1), 2021, pp. 62–69, <http://dx.doi.org/10.30587/jetlal.v5i1.2253>.
- [9] F. Al Khoeri, W. Nuraini, R. Ramdani and S. Agum, "The implementation of Canvas to enhance English teaching and learning," in: *Proceedings International Conference on Education of Suryakencana*, 2021, pp. 315–320, <https://doi.org/10.35194/cp.v0i0.1366>.
- [10] D. Rister and T. Bourdeau, "Collaborative Writing and Presenting: A course template for teaching students how to collaborate on communication projects across all classroom modalities." *Communication Teacher*, vol. 1-7, 2021, pp. 345–351, <https://doi.org/10.1080/17404622.2021.1889011>.
- [11] T. N. Fitria, "Using Canva as media for English Language Teaching (ELT) in developing creativity for Informatics students' ELT Echo." *The Journal of English Language Teaching in Foreign Language Context*, vol. 7(1), 2022, pp. 58–68, <https://doi.org/10.24235/eltecho.v7i1.10789>.
- [12] N. L. Fauziyah, J. P. Widodo and S. N. Yappi, "The use of "Canva for Education" and the students' perceptions of its effectiveness in the writing procedure text." *Budapest International Research and Critics Institute-Journal*, vol. 5(1), 2016, pp. 6368–6377, <https://doi.org/10.33258/birci.v5i1.43596368>.
- [13] M. S. Hadi, L. Izzah and Q. Paulia, "Teaching writing through Canva application to enhance students' writing performance." *Journal of Languages and Language Teaching*, vol. 9(2), 2021, pp. 228–235, <https://doi.org/10.33394/jollt.v%vi%i.3533>.
- [14] M. Larasati and A. Rustandi, "Empowering student's creative writing ability by using Canva (A case study research in one junior high school in Ciamis)." *Journal of English Education Program*, vol. 9(2), 2022, pp. 101–110, [https://doi.org/10.25157/\(jeep\).v9i2.8548](https://doi.org/10.25157/(jeep).v9i2.8548).
- [15] A. Yundayani, S. Susilawati and C. Chairunnisa, "Investigating the effect of Canva on students' writing skills." *English Review: Journal of English Education*, vol. 7(2), 2019, pp. 169–176, <https://doi.org/10.25134/erjee.v7i2.1800>.
- [16] J. Harmer, *The Practice of English Language Teaching*. Fourth Edition. England: Pearson Longman, 2001.
- [17] S. Melinia and N. Nugroho, "Creating a video using Canva application as an English learning media of recount text material." *Journal of English Education*, vol. 2(2), 2022, pp. 118–129, <https://doi.org/10.30998/jedu.v2i2.6644>.
- [18] E. Nurhidayat, "Utilizing Canva As Digital Tools To Teach Grammar in Remote Learning Period." *Journal of English Language Learning*, vol. 5(2), 2021, pp. 95–99, <https://doi.org/10.31949/jell.v5i2.3413>.
- [19] S. Santiana, D. Silvani and R. Ruslan, "Optimizing LMS CANVAS for interactive online learning perceived by the students." *Journal of English Education and Teaching*, vol. 5(4), 2021, pp. 529–543, <https://doi.org/10.33369/jeet.5.4.529-543>.
- [20] S. Suhartono and I. Laraswati, "The use of visual media in teaching writing. English Education." *Journal of English Teaching and Research*, vol. 1(1), 2016, pp. 45–49, <https://doi.org/10.29407/jetar.v1i1.274>.

Algorithm for determining photoresist characteristics

Georgi Dobrev

Technical University of Sofia, Plovdiv
Branch, 25 Tsanko
Dyustabanov.str.,4000
Plovdiv, Bulgaria
dobrev.1975@abv.bg

Nikolay Paunkov

Technical University of Sofia,
Plovdiv Branch, 25 Tsanko
Dyustabanov.str.,4000
Plovdiv,Bulgaria
nick123@tu-plovdiv.bg

Radoslava Terzieva

Technical University of Sofia,
Plovdiv Branch, 25 Tsanko
Dyustabanov.str.,4000
Plovdiv,Bulgaria
radoslava.terzieva@abv.bg

Misho Matsankov

Technical University of Sofia, Plovdiv
Branch, 25 Tsanko
Dyustabanov.str.,4000 Plovdiv,Bulgaria
misho.ivanov@abv.bg

Iva Naydenova

Technical University of Sofia,
Plovdiv Branch, 25 Tsanko
Dyustabanov.str.,4000
Plovdiv,Bulgaria
iva.naydenova@abv.bg

Dilyana Budakova

Technical University of Sofia,
Plovdiv Branch, 25 Tsanko
Dyustabanov.str.,4000
Plovdiv,Bulgaria
dilyana_budakova@yahoo.com

Abstract. This paper presents data from a photoresist study. Computational models have been developed to determine basic physical characteristics. A software algorithm for their derivation has been developed. Models for the calculation of basic characteristics such as integral sensitivity, efficiency, photoresist activation energy are presented. A number of statistical and mathematical analyses are presented.

Keywords: photoresistor, photocurrent, the intrinsic photoeffect.

I. INTRODUCTION

Photoresistors are elements sensitive to light and are used in the automation of machines and processes in various industries, they are also part of optocouplers that provide galvanic separation of electrical circuits. The study of their characteristics is important from the point of view of the expected results when including them in controllers for managing various technological processes,[1],[2],[3],[4],[5],[6].

The research presented in this article is applicable and suitable for teaching students from various specialties such as electronics, automation and others,[1],[2].

A methodology for calculating the main characteristics of photoresistors and their experimental investigation is presented.

The purpose of this paper is to study the basic characteristics and derive models for their calculation.

The created computational methodology and experimental scheme is intended to support the students' training.

The purpose of the presented model with a photoresistor is to use it to construct programmable controllers for measuring illumination in workshops and laboratories. Also to develop 3D models similar to those mentioned in literature sources [7],[8],[9],[10],[11],[12],[13],[14],[15].

II. MATERIALS AND METHODS

In order to experimentally examine the characteristics, it is necessary to use a specialized model, through which the scheme presented in Fig. 1 is realized.

The model itself is a cylinder made of impermeable material. At the two ends of the cylinder, respectively, the light source, representing a lamp with an incandescent filament, is located, and at the other end, a photoresistor and a lux meter are located, with the help of which the illuminance $-L, \text{lux}$ is read.

Print ISSN 1691-5402
Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8073>

© 2024 Georgi Dobrev, Nikolay Paunkov, Radoslava Terzieva, Misho Matsankov, Iva Naydenova, Dilyana Budakova.
Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

The length of the cylinder, respectively the distance between the light source and the photosensitive element is $r = 21$ cm. In the middle, at equal distances, a filter is placed to achieve a uniform distribution of light along the section of the cylinder.

The light energy emitted is of a wavelength determined by a spectrometer, in the white light spectrum $\lambda=600\text{nm}$ [3]. The photoresist used has an area of $S=0.005\text{m}^2$. The experiment was carried out with illuminance varying from 0 lx to 2990 lx. The measured dark resistance is $R\ 360\text{k}\Omega$. An autotransformer is used to vary the supply voltage of the light source from 0 to 230V. This makes it possible to adjust the luminous flux energy - $Q[\text{W}/\text{m}^2]$ and the intensity - $J[\text{cd}]$ incident on the surface of the photocell.

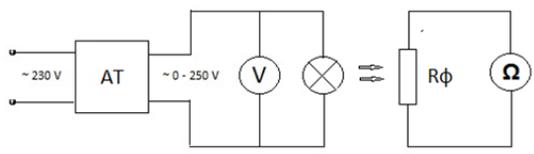


Fig.1 Schematic diagram of photo resistor

The light source has a fixed frequency in the visible light spectrum. Wien's law (1) states that.

$$T = \frac{2,9 \cdot 10^{-3}}{\lambda} = \frac{0,002898}{600 \cdot 10^{-9}} = 4816\text{K} \quad (1)$$

To calculate the frequency $f[\text{Hz}]$, we use :

$$f = \frac{c}{\lambda} = \frac{3 \cdot 10^8 \text{ m/s}}{600 \cdot 10^{-9} \text{ m}} = 5 \cdot 10^{14} \text{ Hz} \quad (2)$$

The main characteristic of the photoresist is its efficiency, which depends on the absorbed luminous flux - $\Phi, [\text{lm}/\text{m}^2]$ per 1 second [1],[2],[4]. This allows us to analyze the experimental data obtained in Fig. 2 where the resistance $R, [\Omega]$, depends on the illuminance - L [lux], area- $S, [\text{m}^2]$ of the photoresistor and illumination time - t, sec .

$$\Phi = LSt, W / m^2 \quad (3)$$

The resistance drops exponentially from $360\text{k}\Omega$ to $1.85\text{k}\Omega$ at light intensities- J, cd from 1cd to 83.8cd in Fig.2. After measuring the illuminance L, lux , we use relation (8) to calculate the intensity J, cd of the incident light. With the help of an ammeter, we also measured the magnitude of the current flowing through the photoresistor.

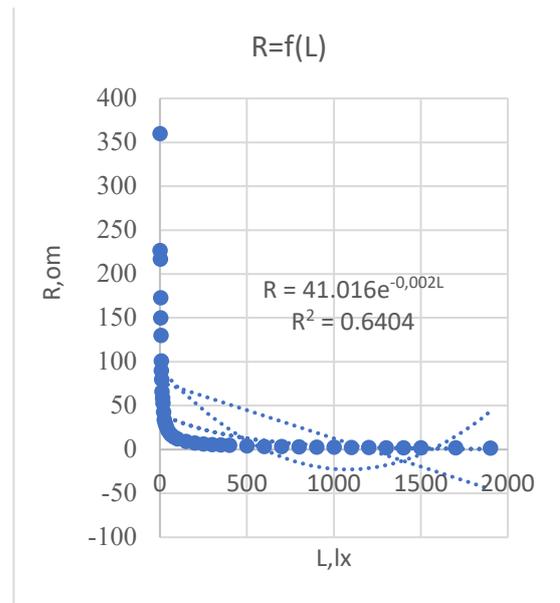


Fig.2 Photoefficiency

To observe an internal photoeffect, it is necessary to determine the separation work - A (4) and the number of photons - n (5), where[5]:
 $h = (6,62517 \pm 0,00023) \cdot 10^{-34} \text{ J.s}$

$$\frac{h\nu}{e^-} = A \quad (4)$$

$$n = \frac{\Phi}{h\nu} \quad (5)$$

For the separation work which is 2 eV, we could write :

$$A = \frac{\Phi, W / m^2}{n_{ph} e^-} \quad (6)$$

Here it is good to indicate the dependence of the measured current on the intensity. From Fig.3 it can be seen that, the maximum measured current is 2.63mA.

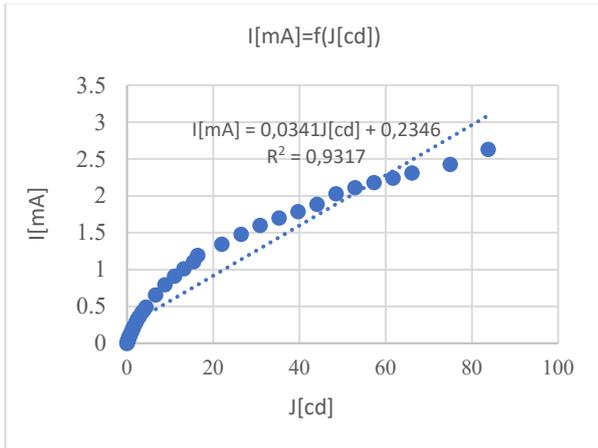


Fig.3 Dependence of the current flowing through the photoresistor on the intensity J[candela]

In the case of photocells, the main characteristic is the integral sensitivity-k, which calculates are the current flowing through the photoresistor - I,[mA] from the photometric characteristics intensity and incident energy flux- Φ per unit area (3) per unit time - t .

$$I = k\Phi \quad (7)$$

Using Lambert's law (8) where and the results obtained for the intensity of light J,cd in Fig. 3, the integral sensitivity-k (10) is 1.3 mA/lm at 217 k Ω .

$$L = \frac{J,cd}{r^2} \cos \theta \quad (8)$$

$$\Phi = \frac{JS}{r^2} \quad (9)$$

$$k = \frac{r^2 I}{JS}, \frac{mA}{lm} \quad (10)$$

After certain substitutions :

$$k = \frac{I}{Ane^-} \quad (11)$$

An Integrated Development Environment (IDE), visual studio 2023, was used to develop a programming model for calculating the sensitivity coefficient-k.

```
using System;
using System.Collections.Generic;
using System.ComponentModel;
using System.Data;
using System.Drawing;
using System.Linq;
using System.Text;
using System.Threading.Tasks;
using System.Windows.Forms;
namespace GeorgiDobrev23
{
    public partial class Form1 : Form
    {
        public Form1()
        {
            InitializeComponent();
        }
        private void btn_CalculateJ_Click(object sender, EventArgs e)
        {
            double Er2, cos_alpha, r2I, JS;
            Er2 = Convert.ToDouble(tbE.Text)*
            Math.Pow(Convert.ToDouble(tbr.Text),2);
            cos_alpha = Math.Cos( (Convert.ToDouble(tbAlpha.Text)
            * (Math.PI) ) / 180);
            J.Text = Convert.ToString( Er2 / cos_alpha);
            r2I = Math.Pow(Convert.ToDouble(tbr.Text), 2) *
            Convert.ToDouble(tblI.Text);
            JS = Convert.ToDouble(J.Text) *
            Convert.ToDouble(tbsS.Text);
            k.Text = Convert.ToString(r2I/JS);
        }
    }
}
```

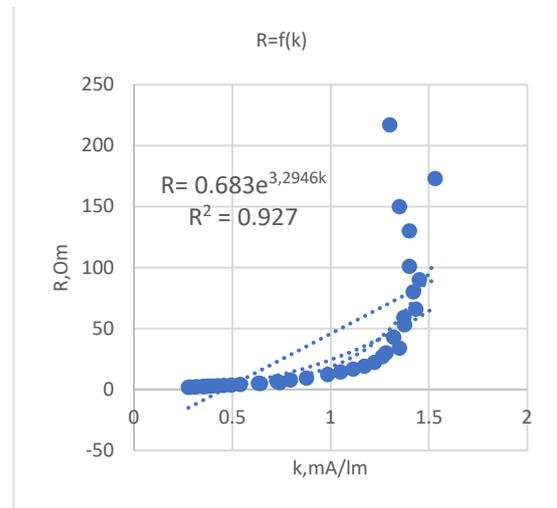


Fig.4 Integral sensitivity coefficient for photoresist.

The photoresist operates at a temperature of 298K⁰, this gives us the opportunity to calculate the width of the forbidden zone ΔW , we use the classical relation (11) and the results in Fig. 4.

$$R_{max} = R_{min} e^{\frac{U}{k_B T}} \quad (12)$$

where:

$$\kappa_B = 1,38 \cdot 10^{-23} J/K / 1,6 \cdot 10^{-19} C = 8,625 \cdot 10^{-5} eV/K$$

For the energy of the molecules we obtain:

$$\kappa_B \cdot T = 8,625 \cdot 10^{-5} eV/K \times 298 = 0,0257 eV \quad (13)$$

$$\ln\left(\frac{360 k\Omega}{1,47 k\Omega}\right) = \frac{U}{0,0257} \quad (14)$$

Therefore, we look for an existing relationship between the measured resistance-R and the voltage-U in Fig.5.[6]

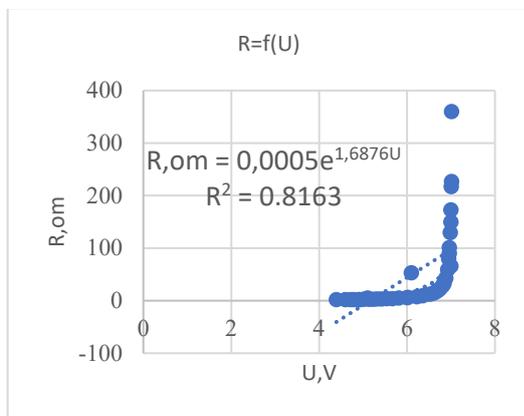


Fig.5 Characteristic of resistance variation R(U) for photoresistance

For the width of the forbidden zone ΔW we use a Fermi-Dirac distribution (13) which gives us a reason to write.

$$U = \frac{\Delta W}{2} \quad (15)$$

The calculated value is: $\Delta W = 0,63 eV$

The electrical power generated is 0.012W.

III. RESULTS AND DISCUSSION

We investigate the existence of a correlation relationship between photocell resistance and illuminance [lux] and number of photons [peta photons] and current through the photocell [mA] using SPSS 25.0 with correlation and regression analysis.

Statistical methods are applied to establish dependencies describing these relationships between these quantities. With the help of statistical methods, conclusions can be drawn about the nature and strength of the investigated relationships under certain conditions .

Regression and correlation analysis are commonly used in research to obtain analytical relationships that describe the relationships between quantities[8]. They are methods for analysing statistical relationships and dependencies. Correlation analysis measures the strength of the relationship under investigation between a dependent variable Y and one or more independent variables X. Regression analysis can be used to determine the type of function that shows the dependence of the random variable Y on the independent variable X[9]. The result of its application is a regression equation that describes the relationship between the dependent variable Y and the independent variable X[10].

We evaluated the adequacy of the models in the dependencies at the significance level of the F criterion. These models are considered sufficient if the significance is less than 0.05 . If the models meet this criterion, we also decipher the statistically significant values of the regression coefficients. The univariate regression models examine the correlation between two phenomena (factors) Y and X. Typically, Y is the response variable (outcome) and X is the predictor variable. The universal form of the univariate regression model is given by the equation

$$Y_i = f(X_i, e_i) \quad (16)$$

where:

Y_i - is the response or outcome variable,
 X_i - is the predictor variable or factor,
 e_i - is the stochastic component in the model.

Study of the dependence of photocell resistance R [kΩ] as a function of illuminance [lux],(1),(2).

For the quantities photocell resistance R [kΩ] and illuminance [lx] we obtained the following results:

TABLE 1 ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	92,451	1	92,451	8373,895	,000
Residual	,408	37	,011		
Total	92,860	38			

The independent variable is L[lx].

TABLE 2 COEFFICIENTS

	Unstandardized Coefficients		Standardized Coefficients Beta	t	Sig.
	B	Std. Error			
ln(L[lx])	-,704	,008	-,998	-91,509	,000
(Constant)	346,009	13,408		25,807	,000

The dependent variable is ln(R[kΩ]).

TABLE 3 MODEL SUMMARY

R	R Square	Adjusted R Square	Std. Error of the Estimate
,998	,996	,995	,105

The independent variable is L[lx].

Table 3 Model Summary gives the value of the correlation coefficient (R) of 0.998, indicating a strong correlation between the predictor variable X (illuminance [lx]) and the response variable Y (photocell resistance R [kΩ]).[11] The coefficient of determination (R-squared) quantifies the degree of influence of the predictor X on the result Y. It is 0.996 (99.6%), which means that 99.6% of

the variations in the photocell resistance R [kΩ] can be attributed to the different values of illuminance [lx]. The uncertainty factor is calculated using the formula 100% - R square (100% - 99.6% = 0.4%). This value measures the influence of factors other than X on the result Y. A value of 0.4% means that 0.4% of the variation in photocell resistance R [kΩ] is influenced by factors other than illuminance [lx]. The parameters of this model are statistically significant as the significance values are less than 0.05, confirming the adequacy of the model to study the relationship between the variables[12]. Column B of the Coefficients table contains the values of the non-standardised regression coefficients for the attribute factor. The value of these coefficients indicates the degree of change in photocell resistance R [kΩ] for a unit increase in luminance factor [lux]. Only those regression coefficients are interpreted whose significance level (significant.) in the coefficients table is lower than the selected level of agreement sig (<0.05).

The function that describes the relationship between the predictor variables and the response variable has the general form:

$$Y = b_0(x_1^{b_1})\epsilon_i, \quad (17)$$

where:

Y - is the response variable;

b_0 - a constant that has no clear scientific interpretation;

b_1 - is a coefficient that provides information about the correlation relationship sought for factor X_1 ;

ϵ_i - random error;

The dependence is non-linear but can be linearised by logarithmisation.

This makes it easier to interpret the regression coefficients.

The dependence has the form:

$$\text{Photocell resistance } R \text{ [k}\Omega\text{]} = 346.009 * \text{Illuminance [lx]}^{(-0.704)} * \epsilon_i$$

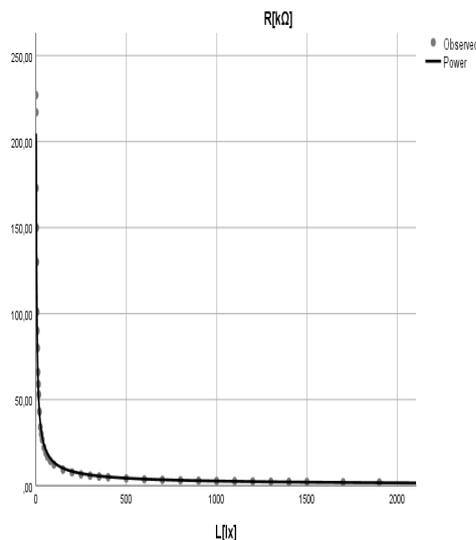


Fig. 6 Photocell efficiency obtained with SPSS.

Study of the relationship between the number of photons [peta photons] and the current passing through the photocell [mA]. The results obtained were recorded for the photon flux [peta photons] and the current through the photocell [mA]:

TABLE4 DESCRIPTIVE STATISTICS

	Mean	Std. Deviation	N
I[mA]	,8865897436	,8666568773	39
Nf[peta phot]	6463,267	8407,9205	39

TABLE 5 CORRELATIONS

	I[mA]	Nf[peta phot]
Pearson Correlation	I[mA]	1,000
	Nf[peta phot]	,966
Sig. (1-tailed)	I[mA]	,000
	Nf[peta phot]	,000
N	I[mA]	39
	Nf[peta phot]	39

TABLE 6 MODEL SUMAARY

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	,966 ^a	,932	,930	,2286422783	,932	509,443	1	37	,000

a. Predictors: (Constant), Nf[peta phot]

The Model Summary table, the correlation coefficient R is recorded as 0.966. This means that there is a robust correlation between the predictor variable X (number of photons [peta photons]) and the response variable Y (current through the photocell [mA]). The coefficient of determination (R-squared), which measures the strength of the influence of the predictor X on the response Y, is 0.932 (93.2%). This means that 93.2% of the variation in the current passing through the photocell [mA] can be attributed to the different values of the photon quantity factor [peta phot]. The uncertainty factor is calculated using the formula 100% - R square (100% - 93.2% = 6.8%). This value quantifies the influence of factors other than X on the result Y. A value of 6.8% means that 6.8% of the variation in the current passing through the photocell [mA] is influenced by factors other than the number of photons [peta photons].

TABLE 7 ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	26,609	1	26,609	509,443	,000 ^b
	Residual	1,933	37	,052		
	Total	28,542	38			

a. Dependent Variable: I[mA]

b. Predictors: (Constant), Nf[peta phot]

The parameters of the model are statistically significant as the p-values are less than 0.05, indicating that the model is suitable for studying the relationship between the variables.

TABLE 9 COEFFICIENTS

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Nf[petaphot]	9,953E-5	,000	,966	22,571	,000
(Constant)	,243	,046		5,246	,000

Column B of the coefficients table contains the non-standardised regression coefficients for the characteristic factor. This figure shows the change in photocell current [mA] when the factor, number of photons [petaphotons], is increased by one. Only those regression coefficients with a significance level (p-value) in the coefficients table below the selected confidence level (<0.05) are interpreted.

The function that describes the relationship between the predictor variables and the response variable is usually expressed as:

$$Y = b_0 + b_1x_1 + \epsilon_i, \tag{18}$$

where:

Y - is the response variable;

b_0 - is a constant that has no clear scientific interpretation;

b_1 - is a coefficient that carries information about the correlation sought for a factor X_1 ;

ϵ_i - is a stochastic error;

The relation has the form

$$\text{Current through the photocell [mA]} = 0.243 + 9.953E-5 * \text{Number of photons [petaphotons]} + \epsilon_i$$

Evaluation of the regression coefficients:

$b_0 = 0.243$ - has no simple scientific interpretation, but includes unaccounted for influences of existing factors, measurement inaccuracies, biases due to the use of inappropriate models.

$b_1 = 9.953E-5$ gives an indication of the desired correlation relationship between factor X_1 and outcome Y. This value is non-zero, implying a correlation between the factor (independent variable) X_1 , which in this case is the number of photons [petaphot], and the outcome (dependent variable) Y (current through the photocell [mA]). The value of the regression coefficient also indicates the change in the theoretical value of the result variable when the factor variable is increased by one unit. In conclusion, we can say that there is a robust correlation between the number of photons [petaphot] and the current through the photocell [mA]. If we increase the number of photons [petaphotons] by 1, the theoretical value of the current through the photocell [mA] increases by 9.953E-5". This dependence is shown graphically in Figure 7.

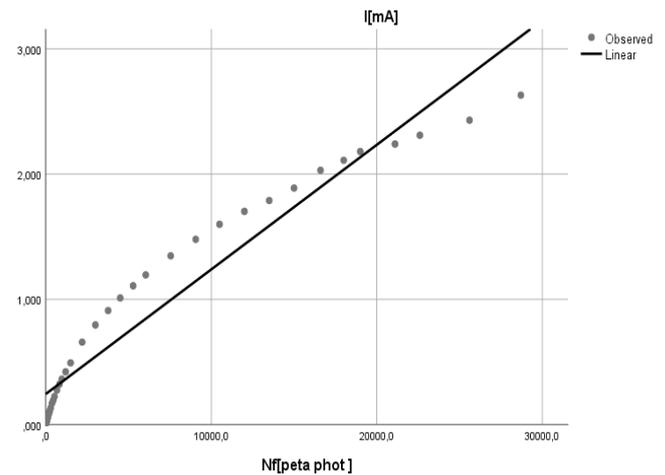


Fig.7 Photocurrent efficiency (number of quanta of current generated)

The results of the correlation and regression analysis show that

1. There is a strong positive relationship between the photocell resistance R [kΩ] and the illuminance [lx]. This is shown by the value of the correlation coefficient R, which is close to 1 (R= 0.998).

2. The value of the coefficient of determination $R^2=0.996$ indicates that 99.6% of the variation in the dependent variable Y is due to the influence of the independent factor variable X, and the remaining 0.4% to 100% is due to the influence of random factors not included in the model.

3. The regression equation relating photocell resistance to illuminance is as follows

$$\text{Photocell resistance R [k}\Omega\text{]} = 346.009 * \text{Illuminance [lx]}^{(-0.704)} * \epsilon_i.$$

4. There is a robust correlation between the number of photons [petaphot] and the current flowing through the photocell [mA]. The correlation coefficient is R= 0.966.

5. The coefficient of determination $R^2=0.932$ indicates that 93.2% of the variation in the current through the photocell [mA] is due to the influence of the number of photons [petaphot] and the remaining 6.8% to 100% is influenced by other factors.

6. The regression equation, which gives the relationship between the current through the photocell and the number of photons, has the following form

$$\text{Current through the photocell [mA]} = 0.243 + 9.953E-5 * \text{Number of photons [petaphot]} + \epsilon_i.$$

In (14,15,16,17) the authors devoted considerable space to a detailed description of the theory and mathematical apparatus of regression and correlation analysis. In the present paper, the emphasis is not so much on the theoretical foundations of the analyses described, but on the practical application of these statistical methods to solve a specific problem.

IV. CONCLUSIONS

The models and statistical analysis presented address the intrinsic photoeffect phenomenon. This provides an opportunity for a number of assignments and laboratory exercises in the classroom. The presented methodology considers an algorithm for calculating basic characteristics for all photocells. The presented mathematical algorithm could be considered in 3D simulations. Also for designing electronic circuits for controlling various processes in mechanical engineering.

V. ACKNOWLEDGEMENTS

The authors acknowledge the support of Technical University of Sofia.

REFERENCES

- [1] A. Chip, A. Ahmed, S. Arya., Semiconductor Photoresistors, Optical Properties and Applications of Semiconductors, DOI: 10.1201/9781003188582-6, 2023
- [2] S. Zhu, S. Zhao, L. Chan, Q. Fang, The European Physical Journal Plus 138(11) DOI: 10.1140/epjp/s13360-023-04660-4, 2023
- [3] M. Aburas, A. Esper, P. Bernaudin, A. Drouart, F. Esnault, A. G. Ghribi, H. Savaujs, M. Stodel, IEEE Transactions on Applied Superconductivity PP(99):1-4, DOI: 10.1109/TASC.2024.3356434, 2023
- [4] L. Yue, Z. Mao, Q. Wu, Y. Li, Y. Li, Physical model-based ArF photoresist formulation development, AIP Advances 14(2), DOI: 10.1063/5.0186648
- [5] P. Lochner, J. Kerski, A. Kurzmann, A. Wieck, A. Ludwig, A. Lorke, Internal photoeffect from a single quantum emitter, DOI: 10.1103/PhysRevB.103.075426, 2021
- [6] J. Lee, P. Asenov, R. Phyner, E. Kao, S. Amoroso, A. Brown, X. Lin, V. Moroz, IEEE Transactions on Electron Devices PP(99):1-7, DOI: 10.1109/TED.2024.3357615, 2024
- [7] V. Bakarzhiev, S. Sabev, K. Chukalov, P. Kasabov "Research into the accuracy of holes in 3D printing using taguchi method environment technologies resources, proceedings of the international scientific and practical conference "3.36-40 DOI: 10.17770/ETR2023VOL.7254., 2023
- [8] V. Bakarzhiev, S. Sabev, P. Kasabov, K. Chukalov "Research into 3D printing layer adhesion in abs materials, environment technologies, resources, proceedings of the international scientific and practical conference," 3.41-45. DOI: 10.17770/ETR2023VOL3.7255, 2023., 2023
- [9] A. Abraham, B. Dai, Correlation and Regression Analyses, Research Methods in the Dance Sciences, DOI: 10.5744/florida/9780813069548.003.0014, 2023
- [10] R. Hirsh, Regression analyses, DOI: 10.1007/978-3-031-41914-0_9, 2023
- [11] V. Chukwunye, C. Onyenekwe, A. Abidemi, Technological and Scientific Advancement in Developing Countries: The Role of Physical Sciences At: Nnamdi Azikiwe University, Awka, 2023
- [12] A. Nirmal, D. Jauaswari, P. Kachare, Statistically Significant Duration-Independent-based Noise-Robust Speaker Verification, International Journal of Mathematical Engineering and Management Sciences, DOI: 10.33889/IJMEMS.2024.9.1.008, 2024
- [13] H. Huang, 3D Animation Simulation Based on Computer Virtual Simulation Technology, DOI: 10.1007/978-981-99-7011-7_18, 2024
- [14] R. Yudira, V. Morales, S. Cisneros, J. Perez, F. Sandoval, R. Carrillo, S. Perez, S. Ibarra, T. Sander, O. Cisneros, O. Perez, 3D Simulation-Based Acoustic Wave Resonator Analysis and Validation Using Novel Finite Element Method Software, Sensors Update 21(8):1-18, DOI: 10.3390/s21082715, 2021
- [15] J. Ye, A. Loi, A. Lai, G. Betta, Journal of Instrumentation DOI: 10.1088/1748-0221/18/11/C11021, 2023

The impact of technology on changes in labor markets and competences

Mirosław Grewiński

Department of Social Sciences
Korczak University -
Academy of Applied Sciences in
Warsaw
Warsaw, Poland
mgrewinski@gmail.com

Marek Kawa

Department of Social Sciences
Korczak University -
Academy of Applied Sciences in
Warsaw
Warsaw, Poland
m.kawa@uczelnia.korczaka.pl

Abstract. The paper examines an importance of AI and e-technologies and their key roles in such unexpected situation as COVID-19 and the emergence and progress of artificial generative technology. The authors propose diagnosis of Polish labor market which had to answer to both challenges of last years: technological and civilizations changes as well as post-pandemic time. The situation of currently required skills in Polish labor market under conditions of AI emergence and acceleration is treated as similar to circumstances in education, where one of the most needed skills became communication competences and dealing with IT, ICT, new media and AI technologies. The authors also raise a pivotal issue of new required skills and competences of coping with e-technologies: many jobs will be eliminated whilst others will be created. This means that future workers should be prepared to change their jobs and, perhaps, to work for more than one employer at the same time. The main method of research which is involved within the article is a desk research and review of the latest data and reports.

Keywords: Polish labor market, pandemic, skills, competences, new technologies, remote and distance work, AI (artificial intelligence), robotization, labor market, Covid-19 pandemic, professions, competences.

I. INTRODUCTION

As each generation of young people entering the labor market in Poland, but also in the world, face new unpredictable challenges. Next to the inevitable and ominous consequences of the next, fourth - innovative and industrial revolution such as stagflation, de-globalization, increasing globalization tensions, post-pandemic quasi-recessions or a new wave of unemployment, there are ominous and unoptimistic predictions regarding the robotization and mechanization of the labor market in services, production, and even art and film (The recent strike by actors and screenwriters in Hollywood stemmed from fears that their professions would be dominated and eliminated by AI.).

Young people, because of their nature, perceive such trends and directions more optimistically than analysts or observers, because they become a critical part of the development and implementation of AI generative technology. Will there be, as has been the case in history in times of acceleration and change, a natural generational conflict regarding the approach to professional competences and the future labour market? What is significant is the appearance of recent appeals, statements and manifestos to suspend work on the development of AI, which are motivated even by experts and producers themselves, innovators of this industry - Sam Altman from ChatGPT or Dennis Hassabis from Deep Mind 1. They seem to be contradictory in their attitude and tone: on the one hand, they express concern about getting out of control of AI technology, which is de facto still unknown in its multiple effects, but on the other hand, the ambivalence of these behaviours reveals the need of powerful managers to create publicity and build an image [1]. The New York Times published information about the enormous threat that artificial intelligence may pose in the future. To put it bluntly, representatives of main AI companies such as OpenAI, Alphabet (Google DeepMind), Anthropic and many other laboratories working on AI warn that artificial intelligence may become an existential threat to humanity and should be treated as a social risk on an equal footing with climate extinction and pandemics or weapons of mass destruction. The very high recent activity of AI industry leaders also corresponds to the above-mentioned apocalyptic-pessimistic enunciations and decisive reactions of politicians in the EU institutions, the White House and the American Congress, in order to at least, if not strictly control, then at least regulate or almost slow down the dynamic direction of the fourth and the fifth industrial revolution or the so-called Industry [2]. Such a sort of peak of emotions and tensions around AI technology, or rather side effects of these struggles, can be observed, for

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8080>

© 2024 Mirosław Grewiński, Marek Kawa. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

example, in the case of the "conflict" between OpenAI shareholders and S. Altman himself and a group of almost 700 employees supporting his former CEO, who threatened to leave for the competition; The background of the dispute is probably the generational approach to the future of the use of AI - a dilemma that will haunt us for a long time: strict regulation and control of the implementation of artificial intelligence or its further spontaneous progress.

Interestingly, mostly the West or countries with transparent legislation process face a great challenge of defining the framework, legal basis, limits of interference and the scope of AI's operation in the functioning of these societies. It is worth noting that already in this year (2023), representatives of ChatGPT were questioned before the Senate committees of the United States Congress in May and July, and this is certainly not their first summons before the hearings of the American Congress, which also awaits other creators and technology companies of AI industry; similarly, in the EU Parliament and in the EU Commission, intensive legislative work to regulate the use of AI is already being completed (Sam Altman from Open AI has threatened that if regulations in the EU as the "AI Act" go too far, he will withdraw ChatGPT from the EU area). There is also a concern on the argument among the most important companies as OpenAI, Google – the owner of You Tube, Meta over digital data rights and corporate policies, especially it has to do with gathering copyrighted data from the internet.

In the text the authors will try to examine an importance of AI and e-technologies and their key roles in such unexpected situation as COVID-19 and the emergence and progress of artificial generative technology. Also, the authors will propose a short diagnosis of Polish labor market which had to answer to both challenges of last years: technological and civilizations changes as well as post-pandemic time. Referring to Polish as well as global labour market the authors point out new required skills and competences of coping with e-technologies. In this context there will be presented, based on a few chosen reports and desk research, which jobs/posts will be eliminated whilst others will be created.

A. What will be the competences after the challenges - COVID-19 and AI?

Recently, especially during the Covid-19 pandemic, there have been more and more comparisons that often point too hastily in the context of developing artificial intelligence, what professions can be replaced by robots and AI. However, one should be careful not to make too hasty judgments, but vigilance and patience in this respect is also advisable. In this context there is not without reason that the modernization of Polish qualifications was introduced legislatively a few years ago. It began with the adoption of the Act of December 22, 2015 on the Integrated Qualifications System [3], which involved the adoption of common rules regarding qualifications operating in various areas. The integrated system consists, on the one hand, of elements already functioning in Polish social and economic area, and on the other hand, new instruments enabling effective integration of the entire system, the most important of which are the Polish

Qualifications Framework (PRK) and the Integrated Qualifications Register (ZRK), in which all qualifications are included in the integrated system. To all qualifications included in the integrated system are also assigned the levels of the Polish Qualifications Framework (PRK level). In the same time both phenomena are driving and influencing skills and labour market in Poland: the development of communication technologies, facilitated by the COVID-19 pandemic, also indirectly accelerated the development in the field of artificial intelligence, which could easily replace humans more effectively, regardless of sanitary or antiseptic regulations and restrictions. Almost a decade ago (2012), the indicators of professional development and competences, or long-learning (lifelong learning) were not optimistic yet: the highest rates of adult learning for many years were recorded in the Scandinavian countries, where over 25% of adult inhabitants for the last four weeks have been learning in a formal or non-formal way. Already a few years ago, before the coronavirus pandemic and its variants came up, some experts had predicted that more than one third of the competencies (35%) that are considered key to today's workforce would change in the near future [4]. The fourth industrial revolution has already brought us innovative and groundbreaking solutions and means such as advanced robotics, autonomous transport, artificial intelligence, e-learning, advanced e-commerce services, biotechnology... etc., although not all of these phenomena are yet widespread. As predictions continue to indicate, the open "door" of transformation and evolution of forms of work can no longer be closed. Therefore, from the perspective of technological changes affecting the labor market and employment structure, it is worth to specify that we are in a period of transition from technology 4.0, based on wireless communication (mobile devices or computers) connecting people and objects and integrating physical and virtual worlds over realistic time (e.g. compatibility of sensors, control, navigation and driving software for Uber, Tesla and Nissan autonomous driving technologies) to technology 5.0, which is still largely a mystery when it comes to implementation.

However, today we can point to certain phenomena and technological revelations, such as solutions and models integrating lasers, radars, high-power and sharp cameras based on solar energy or alternative energy sources. Certainly, the revolutionary aspect of WEB 5.0 in the social and human resources context will be the evolution of the globalized network in an emotive direction, disturbingly replacing the employee, e.g. machines that are able to decode virtual content and react to it, and then autonomously decide on the appropriate action (so-called smart cars, smart house...etc.). In the social and human resources aspect, a virtual reality or hyperreality may even lead to replacing an employee a real person with a hologram or "avatar". Analysts of future competences expect that the future demand for work will focus on unusual and innovative variants of professions requiring high qualifications, interpersonal and creative skills, but on the other hand, not in every case the employee will be able to be replaced by artificial intelligence. Occupations, which require low qualifications and the so-called "non-routine" work - such as catering or security services - will still require human staff [5]. However, if new administrative and office

applications result in a reduction in the number of administrative staff and a simplification of bureaucratic procedures, then their implementation and service will require the work of new specialists. To create "smart" applications, software must be powered with knowledge in a format that they can read. New knowledge base structures should be created and implemented by specialists. Building, for example, multilingual knowledge bases and then training in such software will be one of the future professions that will replace routine office work. It can be argued that the digital revolution will cause young people to spend even more time in complete physical isolation, and crisis or pandemic lockdown situations, such as we witnessed meantime in pandemic time, may strengthen this direction of development. Today's crisis in child and adolescent psychiatry in Poland is also the result of prolonged Covid isolation - both in schools and in labour market. More and more professions requiring individual work with data, knowledge resources and performing cognitive tasks combined with virtual communication with others (both people and machines) will inevitably lead to a revolution in human relations, communication and forms of employment. The COVID-19 pandemic has had an unprecedented, far-reaching impact on economies and societies around the world; it led to a decline in economic activity, loss of work and income, and, consequently, a sharp increase in unemployment and underemployment. Subsequently, supply disruptions and lack of demand have also had a devastating impact on labor markets with huge incomes, productivity and job losses, especially in the hardest-hit sectors such as tourism and manufacturing. The crisis also generated serious re-allocations of employment between sectors, and in the phase of recovery and return of economic activity, it became necessary to implement the prepared recovery and stimulus package, also based on well-prepared staff, especially those equipped with new competences and skills necessary to cope and solve previously unknown problems. The COVID-19 pandemic has not only disrupted educational processes, including vocational education, but also revealed and aggravated unresolved shortcomings remaining from before the crisis, such as lack of technological infrastructure and digital connectivity, gaps in competences, online teaching and learning, shortage of digital skills and qualified workers in given industries, unequal access to education and training among students and employees, lack of digital and pedagogical resources, lack of educational platforms and support services, and financial constraints. The pandemic and post-pandemic have accelerated the development of new competencies. Placing emphasis on this educational element of personal and professional preparation will become a joint responsibility of governments, social partners and individuals, as it will affect directly onto mitigating the economic crisis and its side effects, and will also support activities in getting people back into employment through partial retraining and changing completely occupation, building their future employment resilience. Many reports have already confirmed that the coronavirus pandemic has not only exposed but also exacerbated the "digital divide", including the digital skills gap, between countries, between urban and rural areas, and between women and men. Women, young people, older people and migrant workers have been

particularly hard hit in this light. In the United States, despite trillions of dollars in stimulus and social programs, several million women (2022) did not return to employment: for example, in one year – February of 2020-2021, 2.4 million women left the American labor market [6]; especially young mothers - choosing the comfort of hybrid or online work and raising their children rather than the intensive professional career model that has been promoted for decades. The pandemic and even more post-pandemic situation revealed the following further shortcomings - especially soft skills noticed by employees in their daily work, i.e. identification of stress and emotions in employees, proper cooperation with other entities and services, effective managing the remote assistance delivery. Interesting, but the period of the pandemic has reevaluated not only the approach of professional duties and careers aiming "at all costs", prioritizing more the "work balance", the quality of the workplace environment and the employee market, but also raised in the hierarchy of professional competences and professions activities in the area of support, emotional counseling and broadly understood help.

As previous research indicates, the success of an organization is less influenced by the organizational structure, but increasingly by the unique, innovative competences of the people who create it and its leaders. This increasingly also applies to public organizations, including social policy entities. Of course, there is no one best definition of leadership, but it may be worth quoting the definition proposed by Gary A. Yukl - "leadership is a process in which an individual exerts intended influence on other individuals in order to designate, structure and facilitate the activities and relationships occurring in group or organization" [7]. For a long time, considerations on leadership in public institutions treated leaders primarily as administrators whose task was to maintain existing bureaucratic systems, not to create innovations or take the risks associated with introducing changes. Meanwhile, modern times also encourage and even sometimes force leaders of managing staff and human resources to look for innovative solutions, expand work balance and bear the risks associated with transforming social reality.

Among many concepts of leadership and business management, an interesting proposition is the use of the concept of servant leadership. Servant leadership means serving both your customers and your colleagues. A leader leads, but his strength is motivation and very good relationships with his co-workers, to whom he gives space and freedom, also to make mistakes. Servant leadership is essentially responsible leadership, where the interest of the whole or the group is more important than self-interest. An important element of leadership is transformation, i.e. striving for change while maintaining the perspective of long-term development and ethical actions [8]. Young management staff, for example in the area of social assistance services, consulting, care... etc. stated that the competences of the supervising staff of the social welfare system that should be improved in the context of the COVID-19 crisis in terms of leadership are mainly: facilitating (creating conditions) for changes and innovations, as well as interpersonal and communication skills. Analytical and critical thinking skills also turned

out to be extremely important. The consequence of these leadership gaps is a suggestion for young supervising staff in the context of the COVID-19 crisis, but also before the pandemic, to build relationships with other institutions in the system to increase the quality and quantity of services provided, create partnerships, connections, work in interdisciplinary and task teams and establish alliances with enterprises, the non-governmental sector, local authorities, etc. There are still, although on a smaller scale, instruments that can influence the improvement of the competences of young management staff. Already at the recruitment level, it is worth paying attention to the candidates' non-formal qualifications [9]. Job recruitment should focus on two factors: concentration on formal qualifications (documentation confirming educational and professional preparation) and the so-called soft competences - or "social and emotional intelligence", increasingly emphasized in foreign language literature, which in Polish education are constantly not mentioned much and discussed in the teaching process at all levels of the educational system. Currently, there is an ongoing discussion at the international and national level - what will be more important in the future of competences - whether "dry", formal qualifications or skills such as empathy, communication, interpersonal skills, teamwork, assertiveness, listening skills, argumentation skills, suggestiveness ...etc.

In this context of the future of key competencies, it is worth quoting Mario Reich, who claims that the future will be determined by competencies and therefore, in each sphere of life, it is worth seriously considering defining the desired competencies of staff and ways of developing them. According to the Swiss scientist, the best employees, regardless of the industries they represent, will be those who combine the following competencies [10]:

1. Personal competences: SELF - these are innate and digital abilities, verbal and written communication, negotiations, critical thinking, future thinking, imagination, creative problem solving, innate entrepreneurship; personal development.

2. Social competences (OTHERS). These are the skills of building and maintaining relationships, partnership in life, successful parenting, cooperation, trust and respect, responsibility and empathy.

3. Professional competences (WORK). These are such competencies as efficiency, effectiveness, value creation, adaptability, cooperation, co-creation, entrepreneurship, and specific professional and managerial competencies.

This is one of the many propositions of categorization of groups of currently needed competencies in rather general approach of daily life aspects.

B.AI is already changing the labor market and the competencies highly within needed

It seems necessary to acquire new qualifications and skills that will enable full use of the opportunities related to the development of technologies such as AI. Openness of both employees and employers to changes and flexibility in adapting to them is also important. It is perhaps a bit exaggerated information that there are currently 3 billion digital workers working for various

industries, not only IT or ICT. At least one corporation in four will introduce by 2024 [11]. AI technologies that will not only replace 69% of the management activities of managers and executives, but will also introduce technologies and applications that will monitor the work performed remotely/hybrid, will be more efficient and effective than the management staff, and especially will be resistant and more effective than humans (fatigue, human errors...), because it is effective 24 hours per day [11].

In the moment as the development of generative artificial intelligence reaches its peak, many people from various industries fear losing their jobs, especially representatives of creative industries. Instead of being afraid that generative AI will replace today's employees, we should rather adjust to it and, as the present experience indicates, follow the first signals of the technological revolution, following the intersection of AI and the labor market/competences/technology, being vigilant and ready for the highly probable changes in the economy. Despite lawsuits and strikes in creative industries, this trend is certainly growing and will be irreversible. Therefore, the generative AI revolution is inevitable despite last attempts to control more strictly by the law and regulations. So, instead of being afraid, it is better to know how to familiarize yourself with the AI sphere and adopt it as quickly as possible. Generative artificial intelligence is probably the fastest to initiate a revolution in media production, but it also raises widespread controversy, leading to lawsuits and strikes in creative industries, led by the biggest Hollywood stars, such as Kevin Bacon, Jamie Lee Curtis and Susan Sarandon. However, as Lev Manovich, a long-time researcher of new media at New York University, aptly notes, the apogee of the development of "generative media" means a new revolution in media creation, which has been developing for over 20 years [12]. What is also important, McKinsey predicts that by 2030 30% of work hours in the US economy could be automated, further accelerated by generative artificial intelligence. Previously, Goldman Sachs predicted that 300 million jobs would be lost in services and production, and at the same time, as indicated, the production of objects and services will be at a better level than currently (thinking paradigm: man as the weakest link in a given process of production). Whether these are currently verifiable or too abstract statistical values thrown into the public space for various reasons remains to be seen. There is certainly still a lot of "magical craft" in these projections and we are dealing with issues and actions so dynamic and to some extent unpredictable in short terms. For instance, here is a statement from 12 years ago, which can still be agreed upon today - it has not yet been fully fulfilled, despite the passage of over a decade: "Artificial Intelligence (AI) and robotics will drastically decrease the number of job posts currently available, but that technology will in itself also create new work opportunities in its turn" [13]. Already back then (2012), the predicted disaster on the labor market due to AI did not materialize, at least COVID-19 and pandemic lockdowns and previous recessions wreaked more havoc in this respect. Tendencies and directions of scientific and technical progress, which include, among others: new and modernized products, production processes and methods of organization and management, will radically change production methods,

and this in turn leads to profound changes in the labor market, are already described and diagnosed also by Polish social politicians and academics.

Indeed, C. Freeman and F. Louca already at the beginning of the 21st century described these changes in terms of transformations of the dominant technical and social paradigm [14]. Societies that develop systemic forecasting skills faster have a greater chance for development. The condition for achieving a competitive advantage for entities is to carry out digital transformation. The digitization of society is identified with the use of digital techniques in almost every area of life and economy, in order to, collecting, processing and sharing information, disseminating knowledge, facilitating the acquisition of knowledge, but also improving trade and social communication. It can contribute to increasing professional opportunities for those who are particularly excluded territorially or even by lack of access to modern infrastructure, as well as to reducing social inequalities and, just as the first and subsequent globalizations did, even greater "democratization" of access to knowledge, competences and science. The necessary condition for using it is to have basic digital competences, i.e. a knowledge of digital tools and the ability to use them, because modern technologies are already present in the everyday professional life of most employees. However, returning to the nearer future, tasks related to physical work and repetitive intellectual activities may gradually be limited. This trend is already visible in machine, industrial and mining production technologies, and recently in the military - which we can see in the Russian-Ukrainian conflict or in special operations of the secret services. From the point of view of the labor market, at the very beginning the goal of automation was to reduce physical work and routine intellectual activities such as entering data, checking formal correspondence, performing calculations... etc. After all, the fundamental goal of the so-called "AI" was the creation of machines and patterns that would be able to create things in a way that would be considered intelligent if the work was done by humans. Nowadays, most administrative tasks also involve entering data or documents received from users of electronic systems and verifying them. Such activities can already be or are being massively substituted today, e.g. electronic banking has significantly reduced the interactions of bank customers with its employees, because customers can carry out many transactions on their own, and banks, as economic entities focused on pure profit, often lay off long-term and experienced employees. In mass trade, automation is already a certain necessity, which we observe every day entering the markets during packing purchases and goods at the self-service checkout: the example of service robotization, especially in trade, very well illustrates its use for several years when shopping in the USA by the largest discount chain of WALMART stores, although also Google recently presented the simplest robots for everyday shopping:

"The robots, which are about two feet tall, use a camera to determine if items are out of stock, have wrong prices or are missing labels. The information is transmitted to store management so personnel can address problem areas. Walmart, which has been criticized in the

past for out-of-stocks, said it is keen to use automation "to handle tasks that are repeatable, predictable and manual" [15].

There is general agreement that logical thinking, based on several intelligences at the same time, e.g. emotional and cognitive intelligence, will be a key skill of the future. Additionally, many administrative tasks will be automated and employees will need significant skills in problem solving, communication and the use of virtual platforms. Let us add that the Bard chatbot, despite its popularity and surprising functionality (it can transform the simplest and shortest formula written by E. Hemingway into a syllabotonic poem in 5 seconds), is still unable to completely replace an employee in many functions and, just like a human, has moments of weakness, the so-called "hallucinations" [16]. Although much of the current scientific and popular science literature focuses specifically on the skills and competencies that will be most desired in the future, for illustrative and comparative purposes, it is worth presenting some innovative professions in the field of information technology that may dominate the future labor market. These "professions" will immanently force the market to adopt the most adequate forms of employment or the provision of appropriate services [17]:

1. Machine learning specialist. The demand for cognitive computing skills is gaining attentions. Candidates should be skilled on unstructured data processing, statistical extraction of entities, machine learning, natural language processing, and online search. Requirements are degree in Machine Learning, Statistics, Applied Mathematics, Computer Science, Information Systems, or related quantitative disciplines, with a minimum of five years of relevant experience.

2. Blockchain engineer. A blockchain engineer is a person who is responsible for everything having to do with Bitcoin in a company and design procedures in order to accept and process Bitcoin transactions. They must be expert in cryptography, distributed systems, hash algorithms as well as in trading platform and secure identification.

3. Virtual reality engineer. Virtual reality is not a prerogative of game applications. A virtual reality engineer is an expert in the definition and execution of advanced technologies for Virtual Reality.

4. IoT architect. An IoT architect's job consists in designing end-to-end IoT solutions that solve real business problems in many fields (for example, automotive, aerospace, medical equipment, manufacturing, electronics and telecommunication, etc.). The IoT architect position combines domain knowledge, technical skills and the necessary competence to integrate various disciplines.

5. Cybersecurity specialist. A cybersecurity specialist analyses alerts from multiple and various sources within both public and private organizations in order to determine possible causes of such alerts, identify and distinguish between false and real cybersecurity incidents. Indeed, a cyber security issue takes places if an adversary seeks to gain something from their activity e.g. obtain

private information, undermine the system, or prevent its legitimate use [17].

Experts expect that, the future labor demand will be concentrated on high-skilled non-routine jobs involving interpersonal skills and/or creativity and low-skilled non-routine jobs, such as food services and security [5]. At the current trend, the share of men between 25 and 54 out of work in the United States is estimated to reach 24 percent by 2050 [18]. On the other hand a few years ago, for instance the Foundation for Young Australians' (FYA) and the AlphaBeta Corporation Ltd (2017) have explored how automation, globalization, and flexibility are changing the future of work, highlighting what the main implications will be for young Australians. Some interesting indications contained in this analysis are the following [19]:

1. Future pharmacy assistant - the time spent on store admin tasks (such as stocktaking and ordering) will be reduced from 22 hours per week in 2006 to 6 hours in 2030.
2. Future electronics technician - the time spent inspecting equipment will decrease from 9 hours per week in 2006 to 3 hours per week in 2030, whilst scheduling will also be cut (down from 11 hours to 1 hour); on the contrary, time spent interacting with customers or colleagues will increase from less than 1 hour to 4 hours, and time spent analysing product data will increase from 0 hours to 2 hours.
3. Future teaching/learning - by 2030, teachers will routinely use digital technology for lessons and to support students' self-learning. People will spend many hours learning on the job, and continuous learning will be a relevant part of everyday engagement in work.

From these days perspective we can conclude that the mentioned Australian report gathering data from almost 10 years ago also could not be accurate and was not able to predict exact shape of the future labour market for young Australians because simply was not able to predict the influence of post coronavirus pandemia effects and conditions of AI development acceleration. There is a broad consensus that smart thinking will be a crucial future skill [20]. Since many administrative tasks will be automated, workers will need strong skills in problem solving, communication, and the use of digital platforms. Moreover, it is expected that non-permanent and remote workers will make up the majority of workers, and consequently the need to collaborate across networks and lead by influence will increase. Finally, future work in the time of post-pandemic will be more flexible and independent and, accordingly, workers will also need to have an entrepreneurial mindset. A recent study, conducted using original survey data gathered from a sample of 10,000 individuals, analysed the possible impacts of artificial intelligence and robotics on employment [21]. The results of this investigation suggest that: [...] malleable/adaptable high skills acquired through higher education, particularly in science and engineering, are complementary with new technologies such as AI and robotics. At the same time, occupation-specific skills acquired by attending professional schools or holding occupational licenses, particularly those related to human-intensive personal services, are not easily replaced by AI and robots [22]. The emergence of employees performing

new professions also in Poland and the increase in demand for employees with specific competences will enable better use of new technologies, which in turn will influence changes in the earnings structure. Examples of new professions: application developer, blogger, vlogger, drone operator, information security engineer, but also empathy trainer, transparency analyst, artificial intelligence strategist, manager for relations with machines. Therefore, scientific and technical progress forcing transformations in the organization of production processes will significantly affect changes in the labor market that shape the professional aspirations and educational aspirations of current and future employees.

What emerges from the diagnosis is the importance of developing malleable high-level skills through postgraduate education and the development of personal skills specific to human-intensive services. In fact, skill shortages can compromise the ability of firms to innovate and adopt new technologies, whilst skill mismatches reduce labor productivity due to the misallocation of workers to jobs. As a consequence, anticipating emerging skills is crucial to harmonizing the impact of technology in the labor world.

II. MATERIALS AND METHODS

Authors of this review of labour market changing in Poland as well as in global scale in the context of acceleration of AI technology tried to gather the latest material concerning the issue basing on the interviews [23], the own research made by authors on the lack of needed management skills during the last COVID-19 epidemic period in Poland [24], conference sessions on the current situation of competences and labour market in Poland [25]. Therefore, the main method of research which is involved within the paper is a desk research and review of the latest data and reports on the given issue. A small amount of contribution comes from the own experience of the authors who have participated in numbers of social projects concerning of labour market in Poland in years of 2012-2022.

III. RESULTS AND DISCUSSION

We honestly admit that when it comes to replacing certain professions with AI, we are constantly in the area of indicating tendencies, predictions and approximate forecasts. There are still not too many cases in the Polish labour market where some human posts have been replaced by complete AI application. We meet rather semi AI solutions such as in services of IT, social media, training services or medical. After our review we mostly agree that the new technologies enable the creation of innovative products and services, increase productivity and work efficiency and the quality of services, but also enable the transfer of digital information between products without human intervention. AI does not have the competences that will allow it to solve current problems, especially unusual, individual ones in medicine or high-tech. There are 5 key areas of artificial intelligence development:

1. Image recognition and processing technologies;
2. Language processing technologies;

3. Virtual assistants;
4. Autonomous robots and vehicles;
5. Machine learning [26].

Finally, it is worth recalling again a quite radical forecasts with which we initiated the above considerations and review of the situation - robotization of the labor market. In the US, approximately 40% of current jobs will be filled by robots in the next 5-10 years. In AD 2024 year it is still hard to imagine those predictions when the rate of unemployment is still below 4% and many Americans, mostly women, have not returned to labour after COVID-19 yet. Researchers from the University of Oxford have published already in 2019 a detailed study on the potential impact of computerization on employment in the United States. They included among others the most at-risk professions:

1. Watchmakers,
2. Machine operators (many different subcategories),
3. Cashiers,
4. Dispatchers,
5. Drivers,
6. Cooks,
7. Postal officials,
9. Garden designers and greenery conservators,
10. Installers of electrical and electronic devices, printers [27].

Although we live in 2024 and those mentioned posts still exist in American labour market and are applied in fact mostly by immigrants though. While automation of these professions is possible in the near future, it is worth noting that it will not always be desirable. Social issues and desire of human interaction will be also highly decisive referring to the mentioned processes. In many situations, the presence of a natural person is highly needed. For example, in gambling field there are devices which can be (and are) built to replace dealers, but the desire for human interaction and empathy still drives at least some gamblers to play at the table rather than on a slot machine. However, we should mention also on the professions that are least susceptible to automation such as: sports therapists, audiologists, prosthetists, fabric and clothing designers, nurses, beauticians, veterinarians, photographers, florists and various types of artists [27].

According to our predictions in the Polish Labour market the process of implementing AI will be slower than in the EU, but we estimate that around next five years in the Polish commercial and public health services there will be at least one model robot of the AI providing the given medical service. The most vulnerable service providing areas of implementing AI technological solutions or semi AI will be production industry, education, medicine, social media, show business&media, IT industry, services with non human contact, some parts of agriculture, energy, military, administration, finance&banking, programming.

We claim that the most popular use of AI technology in near future will be a semi AI used or hybrid models where the the human presence will be indispensable as a checking& security factor. Therefore, current applied AI solutions proves that in logistics and industry, artificial intelligence already is used to reduce the carbon footprint of companies; shows how to reduce our negative impact on the environment. It can predict such phenomena as upcoming floods, alert firefighters about spreading fires, and support diagnosticians in early and accurate detection of cancer. However, giving machines (AI) the ability to decide for example in the vulnerable fields as medicine, education or management... etc., which has always been the responsibility of humans, will be slower in the global scale what proves very sceptical approach of legislatures in the EU or the U.S. as it was mentioned earlier within the article. Moreover, as various researchers predict, IT specialists, automation specialists, electronics engineers, biotechnologists and doctors will still be necessary, even though the changes in the labor market will be profound. But we are still not sure how long yet IT specialists cannot also be replaced totally by artificial intelligence? The intelligent chatbot (ChatGPT, 1-4 models), which premiered in November 2022 and is currently reaching the heights of popularity (in January 2023 alone, it was used 590 million times), answered this question: "Artificial intelligence is not a direct threat to the IT profession". Assuming that CHat GPT is not intentionally lying, let's take this opinion at face value. This is just a main source of generating a current distance and suspiciousness of public opinion and skepticism of specialists towards AI generative technology. There is still endemic fear towards the AI use & applying also in the labour market and market of providing services how to spot the very moment when the AI is becoming independent of humans and makes decisions autonomously. This crucial moment when the AI model replacing human is able to distinct the truth decision from the false is becoming the critical one and according to us will be a breakthrough in approach to AI apply. Bioethics ask weather AI models will be able to make moral decisions as human do, raising such a critical dilemma derives from the conclusion that because AI models in the labour market not only overrun, over power the best employees but also in the same time are able to become effective con artists, liars, cheaters. We didn't raise much attantion in our text on purpuse on the lack of certainty about how artificial intelligence makes decisions, what information it uses, and how objective and fair it is, therefore, we mention about it shortly for the objectivity of our perspective.

IV. CONCLUSIONS

To sum up, it is worth pointing out the relational changes within the work organization brought about by the recent digital and post-pandemic acceleration, namely the famous Gartner report from 2020-21 emphasizing the importance of the so-called soft skills and emotional intelligence among not only executives and managers, but all employees striving to be leaders in their profession. The report indicates that 70% of managers are overloaded with responsibilities, and only 16% of medium-sized companies have reduced the number of management responsibilities - moving towards better knowledge, integration, understanding and inclusion of employees

[11]. Relationships between management staff and employees will become 70% asynchronous and horizontal; they will concern analysing products and effects of work after the fact, rather than the production process itself, or direct insight into the provision of work, services... etc. At least one corporation in four will introduce AI technologies by 2025, which will not only replace 69% of the management activities of managers and executives, but will also introduce technologies and applications that will monitor remote/hybrid work; they will be more efficient and effective than management staff, and especially they will be resistant and more effective than humans (fatigue, human errors...), because they are effective 24 hours a day [11]. It seems obvious in these days that technology will change the way in which humans produce goods and run services. Some types of human labor, both physical and intellectual, will be replaced by intelligent programs and robots. Many jobs will be eliminated whilst others will be created. This means that future workers should be prepared to change their jobs and, perhaps, to work for more than one employer at the same time. Let us emphasize again repetitive and routine activities, such as data analysis or manual skills, will be less in demand as they can be performed by robots and the replacement of human work by AI may be complete. However, the importance of the ability to select information and absorb it effectively will increase. In the future, skills such as the ability to communicate with other people and robots, social intelligence, empathy and social perception, i.e. what currently distinguishes people from a programmed machine, will be quite important. It seems that the most desirable combination will be the combination of soft and exact skills. The most sought-after employees will be those whose skills will allow them to translate the language of complex technology and robotization into the language used by an average person, and vice versa. Such people will also cooperate with robots to better understand and understand human behavior.

The presented article pointed only on the main trends and proposals on the changes of labor market in connection with the acceleration of the implementation of AI and robotization after the phenomena of the post-pandemic crisis, certain signs of deglobalization, and still uncertain militarization in certain parts of the world and the loss of the so-called "peace dividends". The reference field of desk research and the chosen reports were the areas of the labor market in the EU, especially in Poland, and comparative phenomena in the USA.

REFERENCES

- [1] D. Hałas, "Liderzy firm tworzących AI ostrzegają przed AI", *Imagazine*. 2nd June 2023. [Online], Available: <https://imagazine.pl/2023/05/30/liderzy-firm-tworzacych-ai-ostrzegaja-przed-ai/>. [Accessed: Jul. 30, 2023]
- [2] K. Schwab, *Czwarta rewolucja przemysłowa*: Wydawnictwo Studia Emka, Warszawa 2018. K. Schwab, who intellectually patronizes the meeting of globalists and financial elites in Davos, authorizes the periodization of the divisions of the so-called industrial revolutions: "There is now discussion about even a Fourth Industrial Revolution. According to Schwab (2016; 2018), this revolution is characterized by a blurring of the distinctions between the physical, digital, and biological spheres, as major technological advances are making a profound impact on economies, businesses, and the personal lives of people throughout the world. However, even this revolution, which is bringing us advanced robotics, autonomous transport, artificial intelligence and machine learning, the Internet of Things with 5G and even 6G technology, advanced materials, biotechnology, genomics, nanotechnology, 3D printing, Big Data, algorithmic management, quantum computing, smart robots, alternative energy technology, sensors, and human chips, to name just a few advances, will itself also probably disappear at some time in the future, replaced by other revolutions that will follow".
- [3] Journal of Laws of 2016, item 64. [Online] Available: <https://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU20160000064/U/D20160064Lj.pdf> [Accessed 20 February, 2024].
- [4] A. Gray, 'The 10 skills you need to thrive in the Fourth Industrial Revolution.' In *World Economic Forum*, Vol. 19. 2016.
- [5] S. Scarpetta, "What future for work?," In *Organisation for Economic Cooperation and Development*. [Online] Available: *The OECD Observer*, 2016 (305), 1F. /295083048_What_future_for_work/links/5746c5dd08aea45ee856769a.pdf; [Accessed 11h July 2018].
- [6] R. Kochhar and J. Bennett., U.S. labor market inches back from the COVID-19 shock, but recovery is far from complete. 2023. [Online]. Available: <https://www.pewresearch.org/fact-tank/2021/04/14/u-s-labor-market-inches-back-from-the-covid-19-shock-but-recovery-is-far-from-complete/>. [Accessed 20h November 2023].
- [7] G. Yukl, *Leadership in Organization*: Pearson, New Jersey. 2006.
- [8] A. Frączkiewicz-Wronka and A., Austen-Tynda, *Przywództwo w ochronie zdrowia, Idee i instrumenty*, Warszawa: Wolters Kluwer, 2009. pp. 251-254.
- [9] M. Grewiński and M. Kawa, "Niedobory kompetencyjne kadry zarządzającej w placówkach całodobowej opieki i Domach Pomocy Społecznej w dobie pandemii COVID-19 (eng. Competency shortages of management staff in 24-hour care facilities and social welfare homes during the COVID-19 pandemic)" in *Pedagogika i Polityka Społeczna na trajektorii zmian. Księga Jubileuszowa w 30-lecie Uczelni Korczaka*, J.Auleynter, Ed. Warszawa: Elipsa, pp. 205-215.
- [10] M. Raich, Eds. *Perspectives & Challenges for Education in the Cyber-Age*, key note speech at Congress of Social Policy, Warszawa June 13th, 2016, Korczak University in Warsaw, 2016.
- [11] *Hybrid Workplace*: Harvard Business Review. Boston Massachusetts: Harvard Business School Publishing Corporation, 2022, pp. 10-11, 69.
- [12] L. Manovich, *Artificial Aesthetics*. Published March 26, 2024. Other chapters: A Critical Guide to AI, Media and Design. [Online]. Available: <http://manovich.net/index.php/projects/artificial-aesthetics>. [Accessed 25h September 2023].
- [13] J. Manyika, S. Lund, B. Auguste, L. Mendonca, , T. Welsh and V. Ramaswamy, "An economy that works: Job creation and America's future", 2011. [Online]. Available: [https://www.mckinsey.com/~media/mckinsey/featured-insights/Employment and Growth/An economy that works for US job creation/MGI_US_job_creation_full_report.ashx](https://www.mckinsey.com/~media/mckinsey/featured-insights/Employment%20and%20Growth/An%20economy%20that%20works%20for%20US%20job%20creation/MGI_US_job_creation_full_report.ashx); [Accessed 5h September 2020].
- [14] F. Louca and L. Freeman, *As Time Goes by: From the Industrial Revolution to the Information Revolution*, New York: Oxford University Press, 2001, pp. 301–335.
- [15] G. Anderson, "Walmart's Robots Are No Replacement For Humans", *Forbes* 2017. [Online]. Available: <https://www.forbes.com/sites/retailwire/2017/11/02/walmarts-robots-intended-to-free-up-humans-to-better-serve-customers/#7ffb434940bf>; [Accessed 7h September 2023].
- [16] W. Knight, "Google Rolls Out Its Bard Chatbot to Battle ChatGPT", *Wired*. Mar. 21, 2023.
- [17] G. Hanlon, "Professionalism as enterprise. Service Class Politics. Redefinition of Professionalism.," In *Professions and Professional Service Firms: Private and Public Sector Enterprises in the Global Economy*, M. Saks and D. Muzio Ed: Routledge; Rotterdam: SensePublishers, 2017, pp. 111-130.
- [18] P. Singer and W. A. Friedman, *Cybersecurity: What Everyone Needs to Know*: Oxford University Press. 2014.
- [19] Foundation for Young Australians (FYA) & AlphaBeta Consulting Ltd. (2017). "The new work smarts: thriving in the new work order". [Online] Available: https://www.fya.org.au/app/uploads/2021/09/FYA_TheNewWorkSmarts_July2017.pdf [Accessed 21st April 2024].

- [20] N. Eberstadt, *Men Without Work: America's Invisible Crisis*: Templeton Foundation Press. 2016.
- [21] M. Vaughan, *The thinking effect: Rethinking thinking to create great leaders and the new value worker*: Hachette UK, 2013.
- [22] M. Morikawa, Masayuki, "Who Are Afraid of Losing Their Jobs to Artificial Intelligence and Robots? Evidence from a Survey,": GLO Discussion Paper Series 71, Global Labor Organization (GLO). 2017. p. 10.
- [23] A. The interview at the Ezra Klein Show with Dario Amodei worked at OpenAI: "What Di Dario Amodei is Right About A.I.?", *YouTube*. [Online]. Available: https://www.youtube.com/watch?v=Gi_t3v53XRU&t=1447s [Accessed 13th April 2024]. B. The interview at the Ezra Klein Show with Cade Metz, a technology reporter for The Times, explains what he uncovered: "A.I.'s Original Sin" *YouTube*. [Online]. Available: <https://www.youtube.com/watch?v=CJWPezMVNdQ&t=481s> [Accessed 16th April 2024].
- [24] M. Kawa and M. Grewiński, "Niedobory kompetencyjne kadry zarządzającej w placówkach całodobowej opieki i Domach Pomocy Społecznej w dobie pandemii COVID-19" (eng. "Competency shortages of management staff in 24-hour care facilities and social welfare homes during the COVID-19 pandemic"), in: *Pedagogika i polityka społeczna na trajektorii zmian. Księga Jubileuszowa w 30-lecie Uczelni Korczaka, pod red. J. Auleytnera*. ed. Warszawa: Dom Wydawniczy ELIPSA, 2023, pp. 205-217.
- [25] M.Kawa, "Od ChatGPT po automatyzację usług. Nowe wyzwania i problemy rynku pracy" (eng. "From ChatGPT to service automation. New challenges and problems of the labor market"): 40th Conference of Social Politicians - SOCIAL POLICY CONGRESS 2023: Social policy as the foundation of socio-economic development - on the 100th anniversary of the adoption of the Social Welfare Act, 30-31 May, Warsaw, Poland, 2023.
- [26] Ł. Kryskiewicz, "Sztuczna inteligencja – schyłek wielu zawodów czy rozwój rynku pracy", Available online: Fundacja Republikańska, [Online] Available: <https://fundacjarepublikanska.org/sztuczna-inteligencja-schylek-wielu-zawodow-czy-rozwoj-rynku-pracy/>. [Accessed 24th April 2024]
- [27] C.B. Frey and M.A. Osborne, „The Future of Employment: How Susceptible Are Jobs to Computerisation?”, Oxford Martin School, University of Oxford, [Online] Available: https://www.oxfordmartin.ox.ac.uk/downloads/academic/The_Future_of_Employment.pdf, [Accessed 24th April 2024].

What motivates the creativity of Generation Z employees? The influence of extrinsic and intrinsic motivating factors on the example of IT specialists from EU countries

Svetlana Gribanova

IT SOLUTION

Riga, Latvia

svetlana.gribanova.p@gmail.com

Abstract. Generation Z is entering the labor market. Like the previous generation, Generation Z has its own specific characteristics, values and expectations. This creates new challenges for managers and organizers of work processes in companies. The object of this study is IT professionals belonging to generation Z. Managing of creative employees is in itself, a complex task. Combined with the characteristics of the new generation, this task becomes especially important and difficult. Currently, there is a dearth of research in the academic literature regarding work motivation and work expectations for Generation Z, as this generation is just beginning its work life. This study seeks to clarify these issues. Empirical data for the study was collected through an online survey of Generation Z IT professionals from EU countries. The sample size is 2153 individuals. The study used intrinsic and extrinsic motivation theory and social motivation theory as the theoretical framework. The results of the study show that for IT professionals of generation Z it is primarily important to have a job where their professional skills are valued and conditions for the development of these skills are created, as well as their contribution to labor results is fairly evaluated. For IT professionals of this generation, it is important to work among people who share their values and beliefs, to have time for personal life and the opportunity to participate in socially important projects. Their creativity is enhanced when it is necessary to do a very important job that will bring respect to the team. They are not afraid of losing their jobs and are willing to take risks.

Keywords: *Generation Z, extrinsic motivation, intrinsic motivation, social motivation, IT professionals*

I. INTRODUCTION

Generation Z (people born between 1995 and 2014) is entering the labor market. Every time a new generation appears in public life, it arouses great interest among scholars and researchers. This is primarily due to the fact

that each generation has its own values, its own expectations, its own reference points. The labor market is a place where all differences are particularly acute. Life orientations and life goals determine expectations from work, life style and values influence the factors of motivation to work and the requirements to the organization of the work process.

Generation Z is the first generation that was born in a global world [1], where many processes are interconnected, where there are close ties between people from different countries [2], where technology is available to people of all ages [3]. In their childhood and youth, this generation experienced the economic crisis of 2008, followed by the economic revival and development. They have grown up with the acceleration of communications and social networking, shaping the global debate on climate change and the need for solidarity to overcome social crises [4]. This generation is "globally oriented" [5] because they were raised in a culturally diverse environment where it is possible to connect people from different cultures, different backgrounds and different life situations through social networks. They are used to diversity, they have empathy for other people, and social justice and equality are important to them [5]. Generation Z is expected to be more educated than all previous generations and to favor creative activities [6].

Motivational preferences and job expectations for generation Z are poorly understood. In 2014, a study came out that showed the workplace preferences of this generation (at that time they were 16 to 20 year olds) [7]. The results of the study showed that for generation Z there are three factors that can be considered as factors of motivation to work. These are career opportunities, material rewards and interesting, important work [7]. Exactly in that order. Subsequent studies [8],[9] came to

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8071>

© 2024 Svetlana Gribanova. Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

similar conclusions only the order of motivational factors was different. In the first place is money, then important and interesting work, and only in the third place - career opportunities.

A study of career preferences of Generation Z university students in Slovakia, conducted by [10], showed that when looking for a future employer, the most important factors were the nature of the job and work-life balance. In addition, members of Generation Z expected their work to be internally satisfying and considered rewards (along with work-life balance) to be a strong factor for both job retention and job satisfaction.

Another study was conducted by the USA [11]. The respondents were members of generation Z. This study showed that training opportunities and job security are important factors for the motivation of generation Z. Finally, the results of the study by Stefanie Boyer and David E. Fleming [12] on the perception of the existing methods of attracting and retaining employees in Latvia show that the employees of generation Z do not seek lifetime employment, they put forward their special values, expect the employer to meet their needs for flexible working hours and flexible workplaces where they can apply their individuality, they are attracted by the company's reputation, innovation, speed of change, a platform for education and promotion, as well as special additional benefits.

For Generation Z, creative professions are attractive, often related to the IT technology market [13]. IT technologies are an important element of modern economy, which is often called "knowledge economy". In such an economy skills, abilities, knowledge, creativity and individuality of employees, their human capital, are the key components [14],15]. As a consequence, attracting, retaining and motivating creative employees becomes the most important and urgent management task in modern business companies [16]. In a situation when creative employees are also representatives of a new generation about which not much is known yet, the task of managers becomes doubly difficult.

The purpose of this study is to identify the opportunities and factors of motivation of employees of creative industries from generation Z on the example of the European IT market, to form a motivational management model that would support, develop and stimulate the creative skills of employees of IT professions of the new generation in the labor market.

II. MATERIAL AND METHODS

The most popular theory of motivation that is currently used to identify motivating factors is the self-determination theory [17]. This theory divides motivation into two components: extrinsic motivation and intrinsic motivation. Ryan and Deci define intrinsic motivation as doing of an activity for its inherent satisfactions rather than for some separable consequence or performing an activity for the pleasure inherent in the activity, rather than working for reward or recognition.

In their research, Ryan and Deci found that intrinsic motivation makes an individual much more likely to be motivated and perform well as opposed to those that were

extrinsically motivated [17]. In fact, those who were intrinsically motivated were less motivated by material incentives. Thus, intrinsic motivators are the sense of satisfaction that employees get from doing important work, especially when that work is done well.

Extrinsic motivation is defined as doing something because it leads to a separable outcome. It may be some kind of encouragement or reward (usually material), but not the feeling of satisfaction from doing the work. Such motivation is called extrinsic motivation because the means that are used for the purpose of motivation are external to the content of the work and to the worker himself. They are set and controlled by other people. The decisions of these people determine the amount of reward. Money is not the only motivator that is considered extrinsic. Extrinsic motivators include working conditions, job security, promotion opportunities [18]. There are studies that show that some extrinsic motivators, such as career advancement, can lead to an increase in intrinsic motivation, but the motivators themselves are still extrinsic [19].

Although it may seem that extrinsic motivation is not as important as intrinsic motivation, research often demonstrates that the ability to find a balance between types of motivation is an art of management and can lead to positive results [20].

Because Generation Z's socialization took place in close contact with people from other cultures and in other life circumstances, they may be more sensitive to concepts such as justice, social solidarity. In order to uncover this, this study utilizes psychological theories of motivation, particularly justice theory.

Equity theory postulates that employees will commensurate their contribution to work with the result they get from it - the greater the reward, the higher their satisfaction [21]. According to this theory, employees who believe that they get more out of their work than they put into it will experience job satisfaction. Certain aspects of the job itself also influence how an employee perceives it. Clear and specific tasks bring greater job satisfaction because a clear role generates passion, engagement and leads to greater enthusiasm for the job.

The author identified five main characteristics of work that affect the psychological state of the employee and determine his motivation. These are the significance of the task, the opportunity for the worker to maximize his skills, identity, autonomy and feedback. Psychological theories of motivation use the concept of social motivation, which occurs when the tasks that a person solves in the workplace correspond to his values, ideas about justice, when he is surrounded by people with similar ideas about the world around him.

The empirical material for this study was collected by means of an on-line survey. The sample was formed by a random method, in the course of a general call, using filters to select respondents who worked in the field of IT technologies. The survey was conducted in all EU countries. 2153 respondents belonged to generation Z. The survey was conducted in 2021. The representatives of Generation Z were between 18 and 26 years old.

The questionnaire for the survey included blocks of questions aimed at identifying motivation to work, job satisfaction and factors that increase the creativity of employees. Creativity in this case means the ability to generate new ideas, solve complex problems, and seek new, unconventional solutions. The purpose of the study was not only to identify the presence and measure the importance of intrinsic, extrinsic and social motivation for increasing the creativity of IT professionals of Generation Z, but also to test how these three types of motivation relate to each other, constituting a certain motivational complex.

The study tested the following hypotheses:

H1: Intrinsic motivation is the most important motivation for increasing the creativity of Generation Z IT professionals.

H2: Without intrinsic motivation, employees will not be creative even if they are highly socially motivated.

H3: Extrinsic motivation is the weakest motivation for an employee to work more effectively.

TABLE 1. FACTORS OF MOTIVATION TO WORK.

Factors of external motivation	Factors of internal motivation	Factors of social motivation
Having a job that allows me to make a career, take administrative positions, gives me the prospect to enter the management of the company.	Having a job that raises my self-esteem, inspires me, makes me work as efficiently as possible	Having a job that gives me the opportunity to participate in socially important projects
Having a job that generates an income that allows me to significantly improve my standard of living	Having the opportunity to do challenging work, the result of which gives me a sense of satisfaction Having a job where my abilities, skills and abilities are adequately assessed	Having a job where my abilities, skills and abilities are adequately assessed
Having good working conditions (comfortable office, social package, opportunity to do sports, organization of meals, etc.)	Having an opportunity to improve my qualifications and acquire new skills	To work with people who share my values and beliefs
Have a job where I have credibility and respect from my colleagues	Have a lot of freedom in how I do my job	To work for a company where the process is organized in a way that each employee's contribution is valued fairly
Having a job that leaves enough free time for personal or family life	Having the opportunity to realize my skills and abilities to the fullest extent possible in my work Having a job where financial rewards fairly evaluate the results of my work	Having a job where financial rewards fairly evaluate the results of my work

The variables presented in Table 1 were used to operationalize the three motivational mechanisms (extrinsic, intrinsic and social motivation). Question: "What factors are important to you when choosing a job?" In this case we are not so much talking about your current job, but about the job you would like to have. Rate the importance of each of the following factors on a ten-point scale, where 1 means that this factor is not important to you at all, and 10 means that it is very important".

In addition to motivational factors, the study analyzed the factors that can increase the respondents' creativity, make them work more efficiently, create something new. These factors can also be divided into external and internal factors. They are presented in table 2. Question: "Were there times when you worked particularly quickly and efficiently? What factors made you work much more efficiently than usual?"

TABLE 2. FACTORS THAT INCREASE CREATIVITY.

Extrinsic factors	Intrinsic factor
Fear of being fired or losing a bonus	Great importance, prestige of the task to be solved
Fear of censure from the team and management	Clarity, clarity of goals and desired result
Management approval	Interesting, complex, creative task
Respect of the team	
Chance to move up the career ladder	

Frequency analysis was used to assess the significance of motivational factors for IT specialists of generation Z. Logistic regression method was used to test the formulated hypotheses. The dependent variable in the logistic model was the variable that divided the respondents into those who (according to their self-assessment) can be creative and those who do not possess this quality ("To what extent the statement "I can be very creative at my job" applies to you"). Thus, the model analyses what factors increase the respondent's confidence in his/her own creativity.

Motivational indices (extrinsic motivation, intrinsic motivation and social motivation) were used as independent variables, which were calculated as the average of all factors included in each index.

III. RESULTS AND DISCUSSION

In order to identify and evaluate the most important motivational factors in the study, a frequency analysis was conducted, in which only the responses in which each item was recognized as the most important (having a score of 10 on a scale of 1 to 10) were considered. The results of the analysis are presented in Figure 1. Since each respondent could choose several items that are the most important for him/her (have the highest score), the sum of responses exceeds 100%.

The most frequently encountered factor is the one indicating the importance for IT professionals of Generation Z of the opportunity to improve their qualifications and acquire new skills (58% of respondents gave this factor the highest degree of importance). In second place is a fair assessment of labor results in the company (56.5%). The third place in the rating is work in

a company where the process is organized in such a way that everyone is rewarded according to their contribution to the production process (55%).

It is important to note that all these factors do not relate to the content of the work, but to the way the work process and interaction with employees is organized in the company. In other words, these are issues that do not depend on what the company does and what working conditions it provides.

Next in the rating are three factors that relate directly to the company, to what the company

produces, how the company evaluates the work of employees and how the work process is organized. These are such factors as increasing the employee's self-esteem from what he/she does (52%), financial remuneration, which allows increasing the standard of living (49%) and the opportunity to devote enough time to personal life (46%). The motivation related to the opportunity to realize one's abilities is of the same importance. That is, personal

life and self-actualization are of equal importance for generation Z.

Then there are motivational factors that are related to the characteristics of employees rather than to the characteristics of the company and the organization of the production process. These are the importance of career, the importance of respect from colleagues, the opportunity to work with people who share the same values, and the importance of participation in social projects.

Thus, the results of the study show the importance of intrinsic and social motivation factors for Generation Z. External motivation plays a less important role for this generation. However, one cannot but see that for this generation such categories as free time, good working conditions and the possibility of self-actualization are at the same level of importance. This indicates a certain hedonism inherent in the young generation and the fact that their basic needs in life have already been realized.

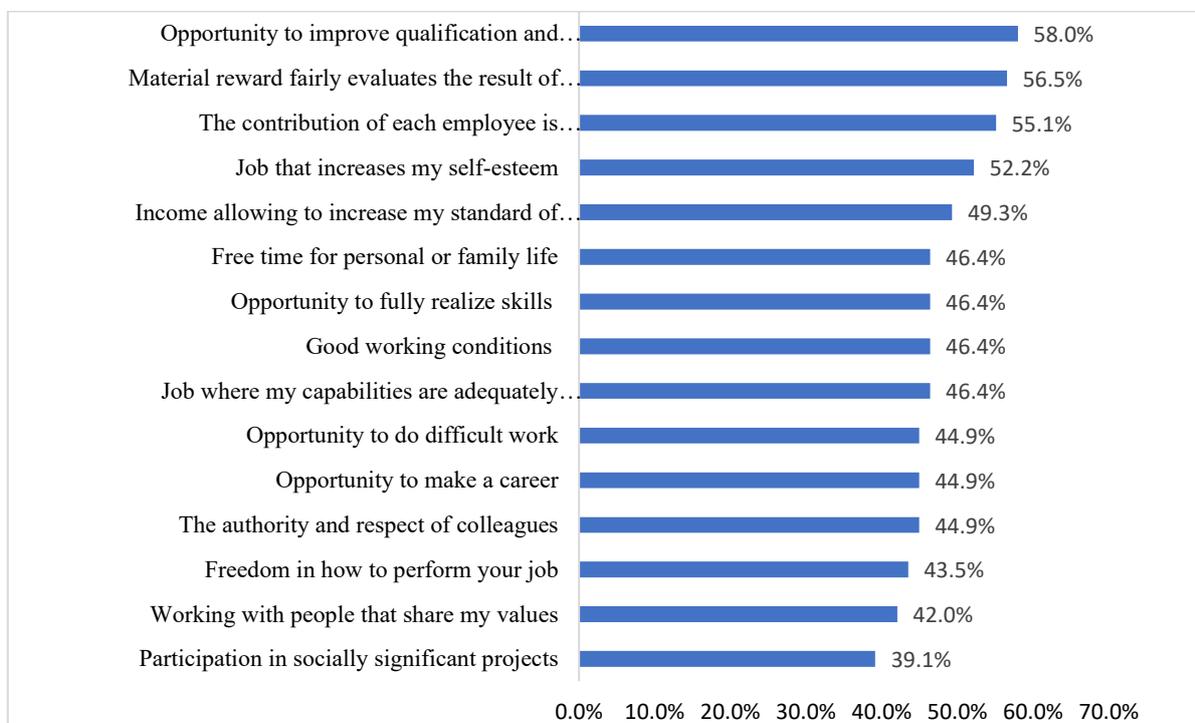


Fig. 1. Fig. 1. Rating of factors of motivation to work.

Fig. 2. shows the results of the frequency analysis of the factors for increasing employee creativity. Only those answers in which the factor was named very important were analyzed. The question implied multiple answers, so the sum of answers is greater than 100%.

The data presented in Fig. 2 shows that the creativity of the young generation can be increased primarily through challenges related to the complexity and prestige of the task to be solved (44.3%), as well as through the respect of the team (40.3%). This result suggests that creative people from generation Z are interested not only in professional realization, but also

in recognition of their achievements. It is important to emphasize that representatives of this generation are inspired by the importance and prestige of the task, not by the fact that the task is interesting and difficult. This factor was chosen by only 30% of respondents. Perhaps, for IT specialists of the younger generation, interesting and meaningful work is not something exceptional, but an everyday phenomenon. The same can be said about the factor related to clarity of goals. The fear of punishment and dismissal is very bad for the creativity of generation Z.

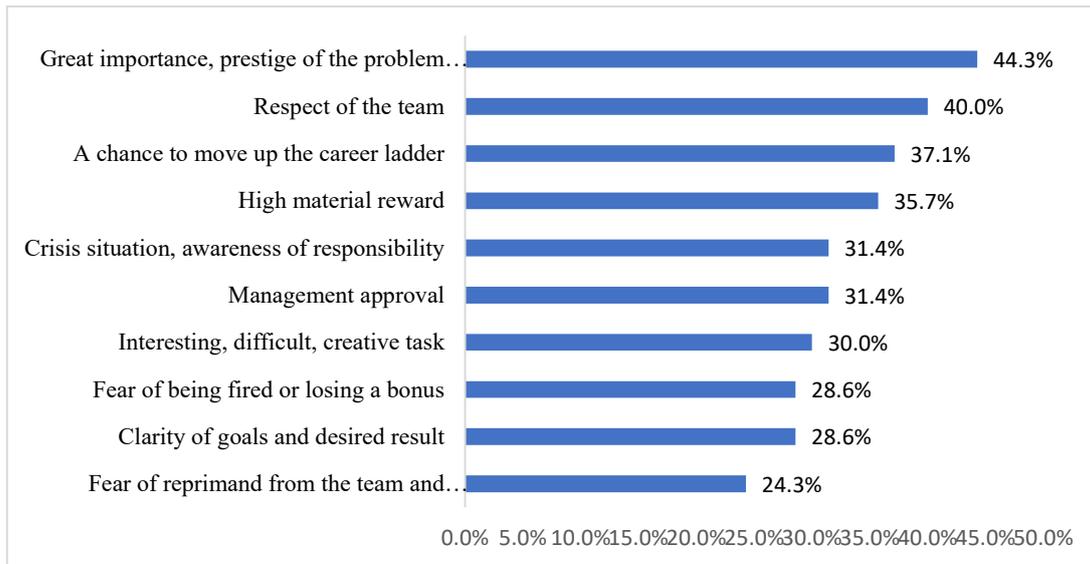


Figure 2: Factors that increase the creativity of Generation Z.

Table 3. presents the results of logistic regression. This model tests hypotheses about the importance of the influence of different types of motivation to work on the creativity of employees of generation Z. The logistic model was built for each motivational mechanism separately because these variables are correlated with each other.

The results presented in the model support the first and third hypotheses, i.e., they show that of the three motivational mechanisms, extrinsic motivation is the weakest for increasing creativity and intrinsic motivation is the strongest. The strong pairwise correlation between the independent variables does not allow us to see the joint effect of motivational mechanisms on creativity, i.e., it does not allow us to test the second hypothesis. But, Model 3 confirms the higher importance of social motivation for Generation Z than extrinsic motivation. This means that employees who value fairness in the company and the social orientation of its activities will be more creative than those employees who are career (and thus do not like to take risks), are focused on income that raises the standards of their lives (i.e. they do not have some lower level needs satisfied than the needs of solidarity and self-actualization). It can be assumed that social justice is important for Generation Z, both in the workplace and in the world around them. And they are ready to show their best qualities for the sake of this idea.

TABLE 3: LOGISTIC REGRESSION RESULTS. MODEL OF THE RELATIONSHIP BETWEEN CREATIVITY AND MOTIVATION FACTORS.

Variables	Model 1	Model 2	Model 3
Constant	2,981***	3,102***	2,988***
Extrinsic motivation	0,135***		
Intrinsic motivation		0,149***	
Social motivation			0,136***
R square	6,2%	8,1%	6,8%

The purpose of this study was to identify and evaluate the significance of work motivation factors for generation Z. This is important in order, firstly, to have some results

for research aimed at understanding the behavior of the new generation in the labor market and, secondly, to better manage employees from this generation.

The results of this study show that IT professionals from generation Z are motivated by a wide range of factors that relate to job content, organization of the work process, and relationships with other employees in the production process. Researchers in other projects have come to similar conclusions [22]

It should be noted that most of the identified factors can be attributed to previous generations of IT specialists [23]. However, their importance and priority in generation Z differs from both Millennials and generation X. The main differences concern the factors that are described by psychological theories of motivation. For the new generation of IT professionals, fair relations between employees, as well as between employees and employers, are of great importance. In addition, the company's participation in social projects is also important.

In line with previous research, our results show that having a meaningful job that one really enjoys is a vital factor in motivating Generation Z. In many studies on Generation Z, this factor is rated as the most important one. A number of researchers from Slovakia, Czech Republic, and Poland, analyzing the perceptions of Generation Z students, found that the most important factor for choosing a future job for them is interesting and meaningful work [24]. In this study, meaningful work was mentioned by respondents as a factor that motivates them to be more creative. However, it was not at the top of the list. A more important factor was the opportunity to do a challenging and prestigious job, a job that brings respect from colleagues. Perhaps for young IT professionals, an interesting job is a prerequisite to sign a labor contract. It is a necessary condition to start working, but not sufficient to work particularly effectively. In any case, it is important to clarify in further research the content of the concepts: "meaningful work" and "prestigious work". Whether these concepts coincide with the notion of "work that contributes to personal growth" and "work that allows one to realize all of one's abilities and skills". It is

important to understand what makes a job meaningful, prestigious and interesting. What makes a specialist agree to enter into a working relationship with a company, and what stimulates him to high performance. This question becomes not trivial at all when it comes to creative employees.

Another important factor for work motivation that this study revealed is work-life balance and the freedom to manage one's working time. This is not a unique result. It has also been written about [25]. However, these studies referred to older generations. What Generation Z mean by work-life balance is not very clear yet, as most of them do not have families and children. This question also needs more research.

IV. CONCLUSION

Our main objective was to explore Generation Z's perceptions of work motivation factors and factors that can enhance their creativity. The study aimed to understand the motivational models of IT professionals of generation Z in order to approximate this model to people in creative professions from this generation. The design of the study was designed in such a way as to be able to obtain some quantitative estimates as well as to test a number of hypotheses about the relationship and importance of motivators of different levels. This is one of the differences between this study and a number of other studies that also focus on the new generation in the labor market but do not make such estimates [26].

An important result of this study is that it has shown some differences between generation Z and previous generations. These differences are related to the fact that for this generation the values of freedom, justice, tolerance are greater than the values of comfort and career. It can be assumed that companies that have a developed social responsibility program, companies that are involved in social, charitable and environmental projects have more chances to get talented and creative employees from the younger generation.

Another important result is that the most important factors of work motivation of Generation Z are not related to wages, and not to the company's products, but to the way the work process is organized in the company. This primarily concerns fair participation of employees in the production process and fair payment for this participation. Also important is the employee's freedom in planning his working time and management's concern for his self-fulfillment. All this shows the importance of the company's management in attracting creative young employees.

Obviously, this study also has a number of limitations that need to be mentioned. First of all, it is related to the small sample for which the analysis was conducted. This drawback can be explained by the methodology of the survey organization, which assumed random selection of IT specialists, rather than a directed search for IT specialists of generation Z. Since this generation is just entering the labor market, their share among IT specialists is not very high yet. It may be too early to make confident generalizations about all next-generation creatives in the labor market, but important estimates have been obtained

and hypotheses for further research can be formulated. As with any findings, the results of this study need validation. And, given the interest of researchers in Generation Z, we can expect the necessary discussion in other studies.

REFERENCES

- [1] "Gen Z and Gen Alpha Infographic Update". Online. <https://mccrindle.com.au/article/topic/generation-z/gen-z-and-gen-alpha-infographic-update/> (accessed 5 July 2021).
- [2] D. Kalkhurst, 'Engaging Gen Z students and learners'. Online. <https://www.pearson.com/en-us/higher-education/insights-and-events/teaching-and-learning-blog/2018/03/engaging-gen-z-students.html> (accessed 10 July 2021).
- [3] C.P. Schofield, S. Honoré, S., 'Generation Y and learning', 360° – The Ashridge Journal Winter, 2009. V.10, pp. 1–7.
- [4] A. Dokadia, S. Rai, D. Chawla, 'Multigenerational Differences in Work Attributes & Motivation: An Empirical Study', Indian Journal of Industrial Relations, 2015, V1, no. 1, pp. 81–96.
- [5] N. Zupan, R. Kaše, M. Rašković, K. Kao, C. Wang, 'Getting ready for the young generation to join the workforce: A comparative analysis of the work values of Chinese and Slovenian business students', Journal of East European Management Studies, 2015, v.20, no.2, pp.174–201.
- [6] H. He, W. Zhu and X. Zheng, 'Procedural Justice and Employee Engagement: Roles of Organizational Identification and Moral Identity Centrality', Journal of Business Ethics, 2014, v.122, no. 4, pp. 681–695.
- [7] C. Crappell, 'The ABCs of Gen X, Y(P), Z: A Column for Young Professionals Discovering Best Practices By Studying Generational Learning Preferences Part II, American Music Teacher, 2018, v.67, no.5, pp. 42–45.
- [8] D. Tual, 'Gen Z in a VUCA world'. In English Medium Instruction at European Universities, edited by L. Szczuka Doma and K. Matuszak, 153–8. Poznan: Publishing House of the Poznan University of Technology. UPP Foundation, 2021, pp. 153-158.
- [9] C. Seemiller and M. Grace, 'Generation Z: Educating and engaging the next generation of students', About Campus, 2017, v..22, no.3, pp. 21–6.
- [10] H.H. Skurak, S. Malinen, J.C. Kuntz and K. Näswall, 'The Relevance of Self-Determination for Corporate Volunteering Intentions', Voluntas: International Journal of Voluntary and Nonprofit Organizations, 2019, v. 30, no. 5, pp.1054–1068.
- [11] J.Kroll and P. Dussias, 'The benefits of multilingualism to the personal and professional development of residents of the US'. Foreign Language Annals, 2017, v. 50,no.2, pp.248–59.
- [12] S. Boyer, D. Fleming, M. Rodriguez and S.R. Cohen, 'Empirical Investigations of the Impact of Entrepreneurial Orientation and Grit on Salesperson Turnover for Generation Z', Journal of Managerial Issues, 2020, v. 32, no. 2, pp. 144-161.
- [13] N.K. Ramsey, Generation Z Leaders' Perspectives of Professional Organizations in Music Education. Contributions to Music Education. Published By: Ohio Music Education Association
- [14] N. Bansal, 'Motivation & Attitude of Generation Y in India: An Exploratory Study', Indian Journal of Industrial Relations, 2017, v.53, no. 1, pp.102–114.
- [15] Crappell, C. (2015). 'The ABC s of Gen X, Y(P), Z: A Column for Young Professionals: Using Multimedia To Enhance Lessons And Recitals Part I', American Music Teacher, 2015, v.64, no.6, pp. 10–13.
- [16] H. Over, 'The origins of belonging: social motivation in infants and young children', Philosophical Transactions: Biological Sciences, 2016, v.371, no. 1686, pp.1–8.
- [17] R.M Ryan and E.L.Deci, 1985; 2000) 'Self-Determination Theory and the Facilitation of Intrinsic Motivation, Social Development, and Well-Being', American Psychologist, 2000, v.55, no.1, pp.68-78
- [18] M.L. Springer, Multiple Generations in the Workplace—It's How We Grew Up. In *Project and Program Management: A Competency-Based Approach, Fifth Edition 2023*, (5th ed., pp. 149–196). Purdue University Press.

- [19] M.L. Springer, Multiple Generations in the Workplace—It's How We Grew Up. In *Project and Program Management: A Competency-Based Approach*, Fifth Edition 2023, (5th ed., pp. 149–196). Purdue University Press.
- [20] B. Šramová, J. Pavelka, M.V .Abad, C.L. Barroso and G.B. Daimiel, (2023). TRANSGENERATIONAL APPROACH FOCUSED ON GENERATION Z AND GENERATION ALPHA TO CURRENT CONSUMPTION OF MOBILE APPLICATIONS. In *Consumo, marcas e intangibles en el público infantil y joven*. 2023. (1st ed., pp. 132–154).
- [21] S. Gribanova and A. Ābeltiņa, 'Management of creative class. The case of IT professionals in Latvia'. The 19th International Scientific Conference Globalization and its Socio-Economic Consequences 2019 – Sustainability in the Global-Knowledge Economy Volume 74, Teplice, Slovak Republic (Accessible https://www.shs-conferences.org/articles/shsconf/pdf/2020/02/shsconf_glob2020_02006.pdf) ISI Web of Science, Scopus
- [22] T. Carter, 'Preparing Generation Z for the teaching profession'. *SRATE Journal*, 2018, v. 27, no.1, pp.1–8.
- [23] K. Moore, 'The Millennial/Zer Need for Feedback: Four Reasons Why and How to Give It'. In *Generation Why: How Boomers Can Lead and Learn from Millennials and Gen Z* , 2023, pp. 111–128. McGill-Queen's University Press.
- [24] S. Gribanova, Motivation of Creative Employees in the Context of Globalization. IT Professionals in the EU The 22nd International Scientific Conference Globalization and its Socio-Economic Consequences 2023 Proceedings, Teplice, Slovak Republic pp. 372-380 (Accessible https://globalizacia.com/wp-content/uploads/2023/02/Globalizacia_2022.pdf) ISI Web of Science, Scopus
- [25] S.Gribanova, 'The Impact of Intrinsic and Extrinsic Motivators on IT professionals. Case of Latvia', The 20th International Scientific Conference Globalization and its Socio-Economic Consequences 2020, Volume 92, Teplice, Slovak Republic (Accessible https://www.shs-conferences.org/articles/shsconf/pdf/2021/03/shsconf_glob20_04008.pdf) ISI Web of Science, Scopus
- [26] S.M. To and H.L. Tam, 'Generational Differences in Work Values, Perceived Job Rewards, and Job Satisfaction of Chinese Female Migrant Workers: Implications for Social Policy and Social Services, *Social Indicators Research*, 2016 v. 118, no. 3, pp.1315–1332. <http://www.jstor.org/stable/24721063>

Analysis of Good Practices in STEM Education in the Schools of the Veliko Tarnovo Region in the Second Year of the National Program

**Bonka Encheva Karaivanova-
Dolchinkova**

*RUO-Veliko Tarnovo, Veliko
Tarnovo, Bulgaria
doctoral student at "Bishop
Konstantin Preslavski", Shumen
University, Shumen, Bulgaria
Veliko Tarnovo, Bulgaria
bonka_vt@abv.bg*

Abstract. In the current National Program for the construction of STEM centres in the schools of Bulgaria, the basic parameters for the requirements for the construction of modern teaching laboratories, offices, etc. are laid down. 16 schools from the Veliko Tarnovo region have been approved for the various stages of the program and for the second year have successfully implemented training in the built STEM centres. The centres built in some of the schools, their orientation and their use in the education of the students are shown. In these schools, the newly built centres are already used by the teachers of the relevant subjects for training in modern conditions with the aim of increasing the success rate of the students and practical application of the acquired knowledge. Construction of such centres in other schools is also planned for the next academic year.

Keywords: *classroom, laboratory, learning, school, STEM centre, students.*

I. INTRODUCTION

The National Program "Building a School STEM Environment", launched 2 years ago, aims to increase students' interest and achievements in the field of science and technology by supporting the creation of school centres with a focus on STEM. This program aims to increase the engineering thinking of students, to awaken in them the interest in discovering and implementing new knowledge and skills. In these centres there will be built laboratories, offices, corners depending on the level of education in the respective school and the focus of the built centre. They will provide all the necessary conditions for conducting modern and high-quality STEM education

at school. The program will finance projects for the construction of school STEM centres in two categories: small (up to BGN 50,000) and large (up to BGN 300,000). In this way, there will be some fairness and equality of schools of different sizes [1, 2, 3].

The national curriculum emphasizes learning in mathematics, science, modern technology and engineering thinking. This theory developed at the end of the 20th century, and we can look for its roots in the middle of the last century with the development of the movement for technical and scientific creativity of the youth. The emphasis is on developing the thinking and creativity of the younger generation and practical application of knowledge in real conditions.

In the study, an attempt was made to evaluate the effectiveness of training in the newly built centers in the school network. Cardinal assessments can be made after at least 5 years, but this study and its analysis provide initial attitudes and results after the first year. After each subsequent year, further surveys and analysis of them will be made to monitor the development of the process, and not after 5 years to make the first surveys and report results. The purpose of the study is to capture the dynamics of the development of the processes and to be able to adjust, if necessary, some activities under the program.

Various methods were used in the conduct of the research: surveys, information gathering, discussion with teachers and students, comparison of expectations and actual results, comparison of results from different periods, analysis and others.

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8083>

© 2024 Bonka Karaivanova- Dolchinkova. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

When conducting the research, a restriction was made that only schools that are participants in the national program from the first stage are approved. In subsequent research, the restrictions will be changed and research will be done in other schools that have joined the program in subsequent stages.

This program is important because:

1. Young people will acquire the necessary knowledge and skills to successfully implement themselves in the professions of the future and will be able to work in an environment close to the one in which they will implement their knowledge and skills in the future;

2. The students will be trained in an environment and through methods close to business and real life and thus will be prepared for future realization in the chosen profession;

3. School education will promote learning through creativity and the creation of innovative solutions to real-life problems;

4. More young people will choose to train and realize themselves in professions related to science and technology and will be directed to engineering activities;

5. Young people can have a successful future and a decent life in Bulgaria. They will be significantly better prepared for real life after completing the training, gaining knowledge, skills and technical literacy.

The national program is aimed at the creation of new school centres in more and more schools in the Republic of Bulgaria - an integrated set of specially created and equipped learning spaces with a focus on the study and application of competences in the field of natural and mathematical sciences in state and municipal schools in the country. Each school centre will include a change in the following elements: physical environment (improvement of internal architecture and furnishing of existing spaces), technology, learning content, teaching methods and management of the educational process, carrying out real activities with concrete results. After the completion of the second year of the program, good results are reported and the program will develop with the opening of STEM centres in all schools, with more than 50 million BGN allocated for the construction of these centres [4, 5, 6, 7].

II. MATERIALS AND METHODS

According to their scope, projects are divided into large and small.

➤ Activity I: large projects (up to BGN 300,000)

These projects are complete unified centres with a specific focus (among those proposed below) that include several classrooms as well as their adjacent common spaces. The total cost of the project may include a combination of construction and renovation activities for conversion of existing spaces, furniture, equipment, teacher training, creation of integrated educational content, etc [1, 2, 8, 9].

Types of projects for the initial stage that can be implemented under this type of project are:

• Centre for young researchers

A guiding principle in shaping the innovative physical environment is that it is suitable for the stages of development and learning of the youngest students. The centre for Young Researchers aims to promote the research approach in education and the integration of subject knowledge from various scientific fields with the aim of developing students' 21st century skills, basic and functional literacy, creative and digital skills, coping skills in different situations, positive thinking.

The centre will promote creativity and work on project-based learning in digital and non-digital environments; the development of skills for working in teams and in various group roles. Learning spaces can be organized into corners and zones, allowing for a different, flexible curriculum and organization of the day. The environment can include hands-on outdoor areas, zoos, robotics stations with age-appropriate tools for students, and more. The new environment allows and encourages group planning among teachers and joint implementation of lesson units, hours of the whole day organization of the school day, extracurricular activities, as well as activities in partnership with external organizations (museums, libraries, observatories, research centres, etc.).

The types of projects for junior high school and high school stage are:

• Centre for Technology in the Creative Industries

This type of centre may have been inspired by the expanding share of creative industries as part of the value-added economy. The centre will provide a technological learning environment for students interested in digital/video game development, mobile applications, media products, product development, digital marketing, graphics and design, and more. The purpose of this type of environment and content is to encourage the development of creative digital skills in a motivating way, incl. to direct students to professions related to the creation of video content, video games and digital tools, digital platforms and mobile applications or the development of new products and services in a technological environment. The centre may include equipping classrooms with computers and specific software in accordance with the needs of the creative industries (for drawing, animation, modelling, editing, assembly, 3D design, etc.); creative corners and spaces; video studio and filming equipment; recording studio; simulation technique, virtual and augmented reality [2, 10, 11].

• Centre for Digital Creators

The centre creates conditions for work in some of the following areas: Application programmer and System programmer, profile Hardware and software technologies, etc. The centre aims to foster students' interest in digital sciences and the creation of digital content with a wide range of applications in real-world environments. It is important that it simulates a real work environment in a technology company, incl. a place for creative activity, individual work and work in teams, non-traditional learning and working environment, high-speed Internet connectivity, etc.

The centre could provide students with work on creating applied projects that solve real cases and problems of business and life of modern man and society. Using electronics and robotics, research, experimentation and analysis, students will be able to create economic and technological solutions based on the premise of intelligent integrated and inclusive management of natural resources and infrastructures.

According to the vision and needs of the particular school, this kind of centre can offer 3D technology, electronic boards and microcomputers, a set of programming tools and robotics. The centre may also include the creation of maker space workshops [3,12].

- Centre for Natural Sciences, Research and Innovation

The centre could provide students with work on applied projects that solve real business cases and problems, research, experiments and analysis. The goal is to use new methodological concepts related to problem-based learning, learning expeditions, case studies, simulations. The centre will provide an environment that could be used both in general education and profiled training, as well as in dual classes in vocational schools for training related to the content and processes of the real work environment in the partner companies. The centre may contain hands-on laboratories in the traditional natural sciences as well as more specific environments such as laboratories in biotechnology, genetic analysis, pharmaceuticals, elements of food production, etc. according to the need of the particular school. It is important that the overall project is a combination of a new learning environment, learning content and practical and applied teaching methods [3, 13, 14].

- Activity II: small projects (up to BGN 50,000)

These projects will transform and equip smaller scale physical spaces – one or two classrooms or corners in an existing space. Although smaller in terms of funding, these projects have the same goals as the larger ones: creating conditions for developing skills related to creativity in digital technologies; experimental work; developing engineering thinking and problem-solving abilities; work on projects and assignments with a practical orientation in science and technology [15].

The total cost of the project can include a combination of construction and repair activities, furniture, equipment, teacher training, etc. in the following type projects:

- Corners of the "workshop" type

The project may include the creation of designated spaces in rooms or study (corners) for creativity and digital technologies or the conversion of a classroom into a similar place. These projects aim to stimulate the interest of a wide range of children in creative activity and the creation of solutions (a combination of hand-made and digital products). Activities in this school space should focus on solving real-life problems such as (but not limited to) creating effective engineering solutions to

environmental problems, 3D-printing industrial prototyping, solutions for social causes, etc.

- Research laboratories

These are small or complementary projects for hands-on equipment and science stations; provision of research needs; applied research and laboratory work. This project aims to equip one office space/storage/classroom for a laboratory or laboratory stations in several offices. The project may include mobile/portable digital laboratory kits, technical equipment, access licenses to platforms with electronic content in the sciences, etc., necessary for the students' applied work.

- A classroom for creative digital makers

This project aims to promote students' interest in digital science and digital content creation, as in the large project category, but is smaller in scale – for example, one classroom with adjacent common spaces. The project aims to build an innovative learning space and can include various hardware and software technologies, according to the needs of students, robotics and engineering science kits, 3D printer, electronic boards and microcomputers, creative corners, zoo corners, etc.

III. RESULTS AND DISCUSSION

The National Program "Building a School STEM Environment", launched 2 years ago, aims to increase students' interest and achievements in the field of science and technology by supporting the creation of school centres with a focus on STEM. This program aims to increase the engineering thinking of students, to awaken in them the interest in discovering and implementing new knowledge and skills. In these centres there will be built laboratories, offices, corners depending on the level of education in the respective school and the focus of the built centre. They will provide all the necessary conditions for conducting modern and high-quality STEM education at school. The program will finance projects for the construction of school STEM centres in two categories: small (up to BGN 50,000) and large (up to BGN 300,000). In this way, there will be some fairness and equality of schools of different sizes [15, 16].

The national program is aimed at the creation of new school centres in more and more schools in the Republic of Bulgaria - an integrated set of specially created and equipped learning spaces with a focus on the study and application of competences in the field of natural and mathematical sciences in state and municipal schools in the country. Each school centre will include a change in the following elements: physical environment (improvement of internal architecture and furnishing of existing spaces), technology, learning content, teaching methods and management of the educational process, carrying out real activities with concrete results. After the completion of the second year of the program, good results are reported and the program will develop with the opening of STEM centres in all schools, with more than 50 million BGN allocated for the construction of these centres [17].

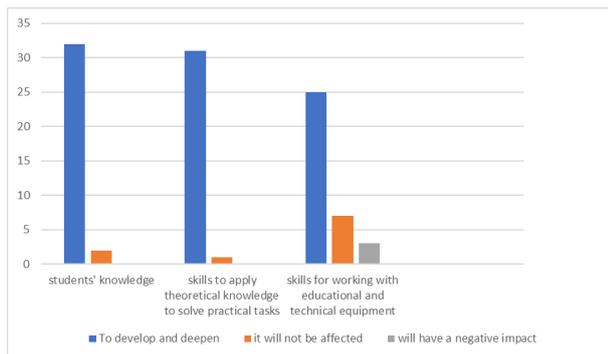


Fig. 1. Expectations of learning in a STEM environment

The national program will create "models" in some Bulgarian schools to demonstrate the process of successfully investing in a comprehensive idea, including learning environment, technology, management, integrated content, qualification and teaching methods. Successful practices will be able to be used by other schools in implementing the training.

Investment in innovation with a focus on STEM has the following objectives:

- Significant increase in students' motivation for learning natural sciences and mathematics;
- Creating opportunities for project-based learning, connection with business, integrative knowledge, learning on specific scientific topics and changing the existing educational paradigms;
- Enhancing student engagement, skills and achievement (digital literacy; digital arts and creativity; skills relevant to industry requirements; skills to solve real-life and business problems; mathematical thinking; skills to create technological solutions; work in team, critical thinking, etc.);
- Stimulating students to create and improve technological solutions in the field of mechanics, programming and artificial intelligence;
- Skills for creating new technologies and their automation; - Increasing the number of students interested in university majors and jobs in technology industries;
- To contribute to the growth of technology industries and their share of GDP.

The expected learning outcomes in a STEM environment are shown in fig. 2., where it is evident that 97% of the respondents indicate that they expect the interest and motivation of learners to increase as a result of the introduction of training in a STEM environment.

As end products, the program aims to create innovative learning centres with a focus on STEM, which will include change in a number of elements of the educational process.

The educational environment (physical environment inside and outside the classroom through conversion of existing learning spaces, common spaces, outdoor areas for STEM activities) will be most significantly changed. This includes furnishings and interior design that support

learning and creativity; integration of digital and non-digital technologies in the physical environment, in administrative and teaching and learning processes, providing opportunities for active participation of students with Special educational needs (SEN) and a number of others that are tailored to the specific school and the direction of the training [18].



Fig. 2. Expected results of the introduction of STEM training

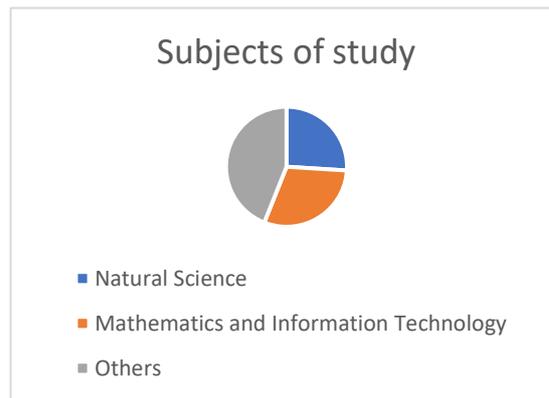


Fig. 3. Teachers' teaching sphere

According to what the respondents teach, their decisions to implement training in a STEM environment can be divided into 3 main groups. The first (26.1%) includes teachers of natural sciences - physics and astronomy, chemistry and environmental protection, biology and health education and man and nature. 30.4% are teachers who teach mathematics and information technology. 43.5% are the remaining teachers who teach other subjects, and here the circle is too wide and it is not possible to make a separate segment, because the profiles of the schools are different from there and the subjects taught are too wide (Fig. 3).

The learning content of the taught material will be expanded through the proper use of integrated lessons, integrated learning modules, integrative subjects, new learning content modules, new learning subjects, extracurricular activities with a focus on STEM, including educational resources for teaching students with Special educational needs (SEN);

Also, the ways of teaching the learning material will be significantly expanded through methods and tools for: lesson planning, teaching, ways of grouping students, project-based or problem-based educational process, types of assessment, including those for students with Special educational needs [19].

It is planned to create a new organization of learning and administrative processes and introduce school policies supporting STEM, giving feedback between pedagogical specialists, involving external partners and creating new partnerships for student learning in real production settings (Fig. 4).

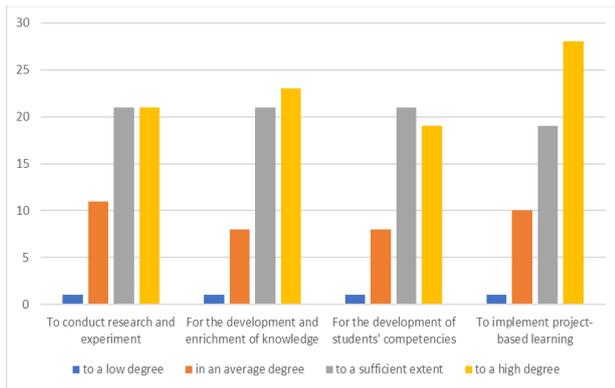


Fig. 4. Studying how the STEM environment will affect the provision of opportunities for the realization of learning objectives

The program is implemented on the territory of the Republic of Bulgaria and covers all state and municipal schools. Schools in the initial stage of the program prepared projects and applied for approval from the Ministry of Education and Culture. At the next stage, the number of admitted schools increased, and now work is already underway to build STEM centres in all schools on the territory of Bulgaria.

IV. CONCLUSIONS

I believe that the results achieved so far are related to both the renewal of the material base and the motivation of the students. By studying in a STEM center, they get a new experience and an opportunity to gain experience that takes them from accepting the new content and information, through its analysis and in-depth research, to its practical application and testing. It is through this process that the interest in the given knowledge increases, and once ignited, it can be easily channelled into the development of specific skills that will help the realization in a number of technological and other spheres.

The easiest integration of educational content is achieved in man and nature and in the subjects of the professional training of students in high school. There are also the highest results in schools from the Veliko Tarnovo region in the second year of the National Program.

In the next academic year, a change in teaching methods in the STEM environment is to be sought. To apply more broadly the project-based learning principle, learning by doing, inquiry method and other interactive methods. Training in a real work environment will also be expanded in the final stage of high school education.

V. ACKNOWLEDGMENTS

I would like to express my gratitude to my scientific supervisor from Bishop Konstantin Preslavski Shumenski University, Professor Penka Kojuharova, for the assistance provided, and to all my fellow teachers in the schools with STEM centers for the assistance and readiness for the construction of these new structural cells in the educational process.

REFERENCES

- [1] Ministry of Education and Science, National Program "Building a School STEM Environment", 11.05.2020; <https://www.mon.bg/dokumentatsiya/programi-i-proekti/arhiv-natsionalni-programi/natsionalni-programi-2020/21-np-izgrazhdane-na-uchilishtna-stem-sreda/> [Accessed: Jan. 30, 2024].
- [2] Preschool and School Education Act, 2016, https://lil.mon.bg/uploaded_files/ZAKON_za_preducilisnoto_i_ucilisnoto_obrazovanie_EN [Accessed: Jan. 19, 2024].
- [3] Ministry of Education and Science, Guidelines for Applications under the National Program "Building a School STEM Environment", 2020, <https://www.mon.bg/nfs/2021/03/20rh937.pr> [Accessed: Jan. 24, 2024].
- [4] B.Karaivanova-Dolchinkova, The educational process in schools with a built-in STEM environment, National conference with international participation "Natural Sciences' 2022", "Episkop Konstantin Preslavski" Shumen University 30.09.-1.10.2022
- [5] B.Karaivanova-Dolchinkova, Innovative schools - a model for implementing learning in the classroom and for building knowledge and competences among students, National conference with international participation "Natural Sciences' 2022", "Episkop Konstantin Preslavski" Shumen University 30.09.-1.10.2022
- [6] S.A.Piven, Activation of cognitive activity of students in physics lessons, methodical collection: STEM-technologies in educational organizations, pp. 7-13, Ulyanovsk, 2020
- [7] N. Zh.Tonoyan, STEM-technologies in education, methodical collection: STEM-technologies in educational organizations, pp. 34-37, Ulyanovsk, 2020
- [8] B.Karaivanova-Dolchinkova B., Implementation of stem projects during the school year 2020/2021 in the Velikotarnovo district, Yearbook of Vasil Levski National University part 2, 2020, Publishing complex of Vasil Levski National University V. Tarnovo, ISBN 1312-6148, pp. 265-270
- [9] N.Dolchinkov, Use of digital resources in nuclear physics education at Vasil Levski National Military University, Annual scientific conference of Vasil Levski National University - May 28-29, 2020. ISSN 1314-1937 vol.6 pp. 176-184
- [10] B.E.Karaivanova-Dolchinkova, Need and Expectations for Learning in a Stem Environment, Environment. Technology. Resources. Rezekne, Latvia, Proceedings of the 14th International Scientific and Practical Conference. Volume 2, Print ISSN 1691-5402, Online ISSN 2256-070X, <https://doi.org/10.17770/etr2023vol2.7225> pp 126-131
- [11] N.Dolchinkov, Physics education in the modern development of education in Bulgaria, Annual scientific conference of Vasil Levski National University - June 27-28, 2019. ISSN 2367-7481 p. 466-477
- [12] N.Dolchinkov, State of the population disclosure systems in the changing radiation situation in Bulgaria, 12th International Scientific and Practical conference Environment. Technology. Resources. ISBN 1691-5402, Vol 1, 20-22.06.2019, pp 54-58
- [13] N.Dolchinkov, B. Karaivanova-Dolchinkova, Teaching physics and astronomy in junior high and high school and transition to university teaching, XIV International Conference "Contemporary Physics Practice", Moscow, September 2016 UDC 372.853 PACS 01.04.Fk p. 35-37
- [14] <https://stem.mon.bg> [Accessed: Jan. 12, 2024].
- [15] <https://stem.mon.bg/wp-content/uploads/2020> [Accessed: Jan. 12, 2024].
- [16] <https://stem.mon.bg/wp-content/uploads/2020/05/%D0%9D%D0%B0%D1%81%D0%BE>

- %D0%BA%D0%B8_200508_FINAL.pdf [Accessed: Jan. 15, 2024].
- [17] <https://uchitel.bg/kakvo-trjabva-da-znaem-za-stem> [Accessed: Feb. 18, 2004].
- [18] <https://www.stem.com/> [Accessed: Feb 11, 2024].
- [19] <https://www.livescience.com/43296-what-is-stem-education.html> [Accessed: Jan. 22, 2024].

Monitoring And Analysis Of The Achieved Results Of Using The STEM Offices In Veliko Tarnovo Region After The Launch Of The National Program

Bonka Encheva Karaivanova-Dolchinkova
RUO-Veliko Tarnovo, Veliko Tarnovo, Bulgaria
doctoral student at Shumen University "Bishop Konstantin Preslavski"
Shumen, Bulgaria
bonka_vg@abv.bg

Penka Kozhuharova
Shumen University "Bishop Konstantin Preslavski"
Shumen, Bulgaria
p.kozhuharova@shu.bg

Abstract. Research has been done on the expectations and implementation of training in the newly built STEM centres under the current national program of the Ministry of Education and Science in Bulgaria. Initially, 14 schools on the territory of the Veliko Tarnovo region were selected for the construction of STEM centres with different orientations. They have been working for 2 years now, and based on observation and research among students and teachers, analysis and proposals for improving their effectiveness have been made.

Based on the achieved results, the Ministry of Education and Science has expanded the national program for the construction of STEM centres and there will now be such in all schools, which eloquently speaks of their effectiveness and the increase in academic results. The results of conducting the training in the newly built centres and the satisfaction of the trainees and teachers are indicated.

Keywords: national program, results, STEM centre, school, student, teacher, training

I. INTRODUCTION

STEM is an abbreviation of the first letters of science, technology, engineering and mathematics (from English: Science, Technology, Engineering and Mathematics), combining chemistry, physics, biology, astronomy, statistics, etc. Although STEM has a very literal meaning, today the acronym is used to direct the focus to the development of algorithmic, logical, engineering thinking and a new learning methodology based on project-based learning. In STEM education, the student is at the centre of the learning process. Creativity is encouraged and traditional teaching dynamics and teacher-student

relationships are changed. It is learned through experience, experiments, solving problems and the practical application of the developed skills and acquired knowledge is sought. In addition, STEM builds on traditional education by focusing on cross-curricular connections and teamwork not only among students but also among educators [1].

Education needs to respond to dynamic reality, and the jobs of the present and the future increasingly involve artificial intelligence, working with algorithms, invention and engineering. That is why the interest in STEM is increasing and logically, more and more schools are betting on STEM centres as a place to hold classes. It is not by chance that the Ministry of Education and Science expanded the scope of the STEM centres being built, and after the completion of the second year of the operation of the National Program for the construction of STEM centres, money was allocated for the construction of such centres in all schools [2], [3], [4].

STEM education has a number of benefits for students. If the educational goal is for students to become adaptable and critical thinking young people, then we help build the following skills in them on which the concept of STEM is based, namely:

- Creative thinking;
- Critical analysis;
- Teamwork;
- Initiative;

Print ISSN 1691-5402
Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8094>

© 2024 Bonka Encheva Karaivanova-Dolchinkova, Penka Kozhuharova.
Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

- Mathematical literacy;
- Algorithmic thinking;
- Social-emotional skills [1], [5].

The present study was conducted at the initial launch of the National Program and after the second year of the project, when the built STEM centres actually function and classes are held in them. At the end of this year, a further survey will be conducted in order to be able to compare expectations, results after the second year of the start of the program and the second year of using the offices and laboratories. Due to the COVID epidemic, the STEM centres could not be used practically in the first year and therefore there is a difference between the second year of the program (first for use of the offices) and the second year of use (third year of the project). Teachers from 14 schools from the Veliko Tarnovo region, who teach general education subjects in junior high and high school, and teachers of profiling and professional subjects in secondary education participated in the survey. Approximately 80 teachers from the three categories participated.

II. MATERIALS AND METHODS

In the Bulgarian educational environment, STEM began to be actively implemented through the STEM program (NP "Building a school STEM environment"), under which funds were allocated for the implementation of STEM projects, the use of "STEM technologies" (higher class equipment, suitable for the performance of more complex tasks) and the study of STEM subjects. However, the space for innovative and creative practices requires more than just funding [2], [6].

After the launch of the program, many schools prepared projects and participated in the selection of the Ministry of Education and Science. Out of a total of 81 schools in Veliko Tarnovo district, 25 schools submitted project proposals and 14 were approved. External experts appointed by order of the Minister of Education and Science carried out the organization, selection and ranking of the projects. The approved schools were 7 in the first group or activity 1 with a budget of up to BGN 300,000, namely: PMG "Vasil Drumev" town of Veliko Tarnovo, OU "Bacho Kiro" town of Veliko Tarnovo, PGSAG "Angel Popov" town of Veliko Tarnovo, PGT "Dr. Vasil Beron" town of Veliko Tarnovo, SU "Vicho Grncharov" town of Gorna Oryahovitsa, SPG "Aleko Konstantinov" town of Svishtov and SU "Dimitar Blagoev" town of Svishtov. From the second group or activity 2 with a budget of up to BGN 50,000 were: PGE "Alexander Stepanovich Popov" Veliko Tarnovo, SU "Vladimir Komarov" Veliko Tarnovo, OU "Petko Rachev Slaveikov" Veliko Tarnovo, PGLPI "Atanas Burov" Gorna Oryahovitsa, OU "St. St. Kiril and Metodii" village of Polikraishte, OU "Elin Pelin" village of Parvomaytsi and PDTG "Dimitar Hadjivasilev" town of Svishtov.

The schools selected at the first stage of the National Program are from the three largest municipalities in Veliko Tarnovo region - Veliko Tarnovo, Gorna Oryahovitsa and Svishtov. The opening of the various laboratories, offices, corners and others was in 2021 and 2022, and from the academic year 2022/2023 classes

began to be held in them, although not in full volume and load. In the 2023/2024 academic year, the workload of the STEM centres increased and is over 75%, and in some schools it is close to 100%, as they are also used for extracurricular activities.

In this 2023/2024 school year, all classrooms are already in use and there is a repeat of the activities carried out in them for the second school year. At the end of the first school year, the author conducted a survey about the expectations and the results obtained in the first year, which were presented at the scientific conference "Environment. Technologies. Resources." in Rezekne in 2023.

After the built STEM centres have been fully used for the second year in these schools, a comparison of expectations and achievements can be made and a comparison can be made between the first and second year of training in the equipped centres. This was done by running a second survey and analysing the respondents' responses.

In this study, the results achieved during the first full academic year of study in the STEM centres are noted and only a comparison can be made between expectations and results, but not between achieved results. For this reason, no comparison and corresponding analysis has been made in the article, because there is still no data that can be compared and the corresponding conclusions can be drawn. On the basis of the answers received at this stage, only recommendations are made on the workload of laboratories and offices, on the optimization of the educational process, but not with regard to quality indicators [7], [8], [9].

III. RESULTS AND DISCUSSION

How does STEM happen in practice? To create a STEM center, the school must prepare a project and a concept based on four elements:

1. An environment that predisposes to innovative practices and creativity.

Changing spaces is the most visible sign to the outside eye that the school has embarked on the path of educational transformation. The STEM environment in modern schools should predispose to freedom, flexibility and creativity in the processes of learning and research. To stimulate communication and teamwork, as well as to offer corners for privacy and reflection [3], [10], [11].

This change includes the layout of the spaces, but also the colors, the furniture, the flooring, the lighting, the access to the space. It is not enough that the environment is simply updated, modern and beautiful. It must functionally contribute to the learning process.

The planning of the working environment must be subordinated entirely to the educational objectives and the type of methodology to be used [3], [12], [13].

It is important that the change in the environment does not happen for its own sake. To fulfil its function as a pillar, it must be planned in harmony with the other three pillars – content, qualification, technology.

In order to be carried out in the best possible way, it is recommended that the planning and implementation process take place together with specialists - architects, designers. There are already good examples in Bulgarian schools from which inspiration and experience in implementation can be drawn.

The school is a shared space for students and teachers. Therefore, in the process of making decisions about it, we must involve the students and take into account their opinion, wishes, needs and expectations.

2. Content that places the student in the role of an active leader in the learning process.

Quality learning is not a one-way process in which the teacher feeds information to students and assesses their ability to reproduce it. It is transformed into researching information, researching and analysing problems and proposing possible solutions to them.

Therefore, the educational content is a pillar without which the STEM transformation cannot take place. We need to answer the questions: what content will we go through; does it meet the educational goals we have set for ourselves; how it corresponds to the environment in which we will examine it.

Project-based learning often involves the work of more than one teacher within a learning project. This challenges teachers and school principals to have interdisciplinary content that includes knowledge from different subject areas within the project.

However, creating new learning content is a methodical process that takes more time.

To overcome this difficulty, it is important to include in the planning process an investigation of what already developed solutions we can reach and what can be usefully taken from other projects and schools.

For example, it is necessary to find out whether:

- Robots, 3D printers, VR glasses to be purchased are accompanied by educational content already developed for them;
- Content is applicable to students' environment and culture;
- Teachers have the necessary skills to handle it;
- The content is in the language in which we conduct the training;
- It has rights to use it and what is our access to it [14], [15].

The transformation of the learning content does not mean to exclude knowledge from it. In the educational project, children acquire the knowledge they should have for the respective age and educational level. In addition to these, they understand how this knowledge relates to the real world and how they could put it into practice.

With this, the learners form skills to solve the problems of the present, as well as the not yet existing problems of the future.

3. Equipment and relevant technologies to carry out tasks and develop digital and technological skills.

Technology is the third major foundation. The answer to the question of which technologies to choose lies in what tools are needed for innovative content in the transformed environment.

When they are thought of separately, there is a significant risk that the end result is that the technology and the environment do not work well together. And in connection with this, it is necessary to make additional changes and spend an additional resource to adapt one to the other or vice versa.

An example of this is the classic information and communication technology classrooms. Usually there are computers located on the periphery of the rooms and the students have their backs turned to the space, to the classmates and to the teacher. Although the technique is available, it does not correspond well with the environment and does not predispose to group work, to easy adoption.

Technology is the most dynamically developing pillar compared to the other pillars of the STEM transformation. Every month, technology companies make updates to their products and even come up with completely new solutions. Therefore, it is important to look at the choice of equipment as an investment that can fully meet the objectives and the other elements of the plan.

A technological solution is meaningless if there is no place to use it, but also if teachers are not trained to use it.

The tools used to achieve the set goals can include technology – computers, tablets, robots, smart screens and whatever other equipment is needed. All that is specific as a technology is subservient to the content and woven into the environment [1], [4], [10].

4. Training for teachers to help them confidently handle new technologies and methodologies.

It is the ability of teachers to skilfully handle them that is the engine that makes the environment, content and technology "come alive".

In the development of the STEM project, the training of pedagogical specialists should not be omitted, so that they are skilful and confident to take advantage of all the advantages of the transformed environment and the introduced new technologies.

It should be borne in mind that training the team is a process that requires time, and it is advisable to take place in parallel with the work on the other three pillars, and not only at the end of the process, when valuable time for preparation will have already been lost.

It is a good practice to involve the teachers in a STEM working group for the construction of the project. In this way, the team is part of the transforming process from its first steps, recognizes it as its own, participates and contributes to its implementation.

Another option to support the teacher qualification plan is cascading. A group of teachers undergo training and themselves, working in a team, pass on the skills to their colleagues.

The qualification of the teachers must be tailored not only to the educational goals, but also to the personal characteristics and wishes of each of them, to the needs of the students and to the readiness, motivation and digital competences of the team as a whole. A long-term plan of steps to develop the team and team members ensures a smoother and smoother development of skills [5], [16].

When determining the effectiveness of the use of STEM centres, the following should also be taken into account:

- Whether and how STEM lessons will be integrated into the curriculum;
- What preferences and needs do all three parties have - teachers, students and parents;
- The organization of the learning process in the context of the entire school day and term;
- Effective allocation of roles and management of the STEM centre;
- Initiating partnerships and working together with business and the community.
- These are the main criteria that are included in the assessment of how the newly built STEM centres are linked to the training and the learning process [17], [18].

In the second year of the operation of the built STEM centres in 14 schools in the Veliko Tarnovo region, all the laboratories, offices, halls and others were already in use, and real classes were held in them, and the workload of these units was very high. In different schools, the conduct of classes in a STEM environment was different, but everywhere the utilization schedule of the newly built STEM rooms was over 60%, and in 3 schools it was over 90%.

Expectations of achieving good results among teachers who teach vocational subjects and participated in the survey after the first year are expressed in fig. 1. On the graph in fig. 1 presents the percentage ratio of the grades given by teachers for the results achieved when working in a STEM environment. None of the respondents gave the lowest rating of 1, while 67% gave the maximum rating of 5 for the quality of the training. Satisfactory (2) and good (3) ratings were given by 2 and 3.5% of those who participated in the survey, respectively.

The profile of the teachers who participated in the study and work in these STEM centers should also be noted. These are teachers from "Vasil Drumev" PMG, Veliko Tarnovo, "Angel Popov" PGSAG, Veliko Tarnovo, "Dr. Vasil Beron" PGT, Veliko Tarnovo, "Vicho Gruncharov" University, Gorna Oryahovitsa, "Aleko" Konstantinov" Svishtov, PGE "Alexander Stepanovich Popov" Veliko Tarnovo, SU "Vladimir Komarov" Veliko Tarnovo, PGLPI "Atanas Burov" Gorna Oryahovitsa and PDTG "Dimitar Hadjivasilev" Svishtov. Due to the specificity of each school and the training carried out, we can summarize that these are teachers of informatics, computer science, construction, design, hotel management, economics, electronics and a number of other disciplines specialized for the specific specialty.

Often, in a STEM center, classes in related disciplines are also held, but teaching of radically different disciplines is also observed, because students in different classes study multiple subjects, some of which build on previously studied ones.

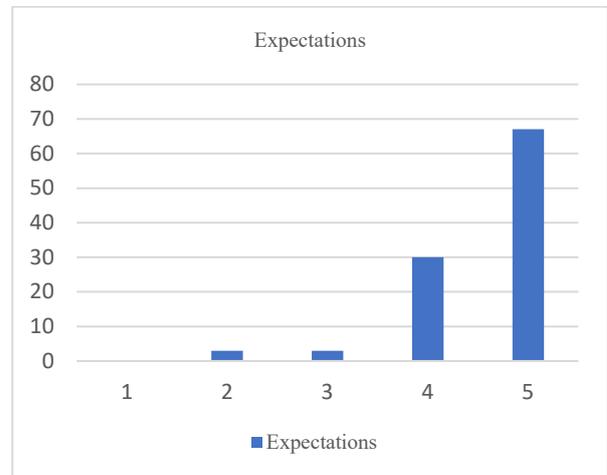


Fig. 1. Expectations of teachers of professional subjects for achieved results in learning in a STEM environment.

STEM education is mainly related to engineering and technical sciences and that is why the expectation is so high. This is also due to the fact that the built STEM centres have modern techniques and equipment and the students carry out practical activities in a real environment. All schools used the program to purchase and equip laboratories, offices and others with equipment that will bring training as close as possible to real production conditions. This is the reason to expand the scope of the program to more schools in the following years, and even now all schools from this year have joined this program. This is particularly important for vocational training, where the equipment of classrooms, laboratories and workshops is, to put it mildly, outdated and it was absolutely necessary to re-equip them.

In fig. 2. a similar study is shown, but with teachers who teach a general education subject in junior high school. Here, 26% of respondents teach natural sciences (physics and astronomy, chemistry and environmental protection, biology and health education, man and nature), 30% are teachers of mathematics and information technology and the remaining 44% are teachers of other subjects. In the last group, the teachers are the most diverse and teachers of Bulgarian language, English and other foreign languages, history and civilization, geography and economics and others also participate here. In the last group, heterogeneity determines the diverse use of the built centres and each teacher adapts them to the subject he teaches.

Here, teachers rate the achieved results very highly, with the grades being very good (24%) and excellent (76%). This is due to the opportunity to conduct quality laboratory and practical classes, the opportunity for demonstrations and visualization of the taught educational content, which in the previous form of conducting classes had already exhausted its resource. Teachers from all schools participated in this study.

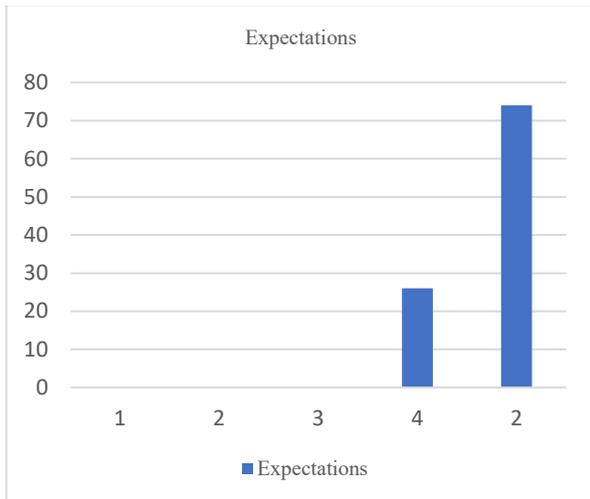


Fig. 2. Expectations of teachers in general education subjects at the junior high school stage of education

During the survey, the teachers also indicated what skills the students would develop when working in a new environment. The most common answers are:

- Digital skills, working with technical means, teamwork
- Communicativeness and inventiveness
- Flexibility, variability
- IT skills
- Group work, observation, critical thinking, analysis, problem solving, etc.
- More focused and interested.
- Team work, communication
- They will improve communication and the level of communication; They will acquire purely practical skills for working with technical and specific means and equipment
- They will improve their motivation to learn
- To observe and study the surrounding environment more deeply, to build skills for creative and critical thinking.
- Responsibility and independence, critical thinking, initiative
- To take responsibility, make decisions, develop leadership skills [1], [15], [16].

The last group of surveyed teachers are those who teach a general education subject in high school. The results are shown in Fig. 3. Here, the ratio of grades is different from that of a junior high school class, with 5% giving a good grade, 41% giving a very good grade, and 54% giving an excellent grade. The lower scores are due to the degree of the educational stage and there is a significant difference in the quantitative assessment in different schools, which is not the subject of this report.

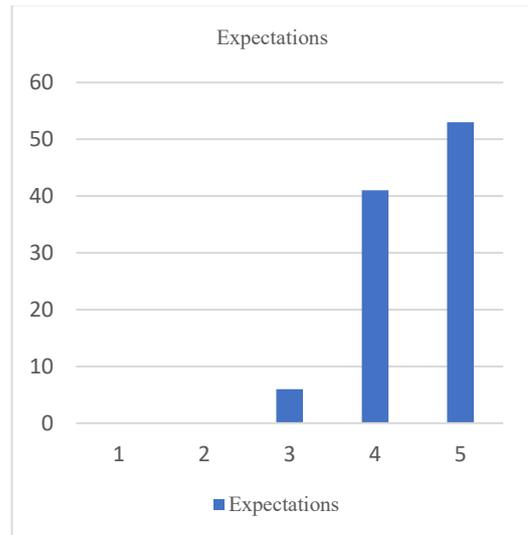


Fig. 3. Expectations for the learning outcomes in a STEM environment of teachers teaching general education subjects at the high school stage of education

In contrast to the junior high school stage of education, in the high school stage the expectations are to develop the following skills:

- Teamwork, leadership skills, good communication, creativity, creation of innovative solutions to real-life problems.
- They will become more confident in using modern technologies, they will be able to use more resources for learning a foreign language in and out of school.
- Team work, presentation skills
- Learning by doing
- Analytical, creative, ability to work in a team, etc.
- Communicative
- Communicative; practically
- Concentration skills, team work, reaching an expected result [10], [17].

In the second year of operation of the built STEM offices, laboratories, workshops and others, when the load percentage of the built units increased by 20-30% and the results of the training conducted in them increased. Here, 100% of the respondents unanimously expect an increase in the success rate and a better assimilation of the taught material. This is taken into account after the end of the second academic year. However, due to the fact that not all offices and laboratories were used already in the first year, it is impossible to compare the results achieved in the first and second year. At this stage, it can be noted that the results and the success rate have increased compared to the period before the construction and furnishing of this material base. And an increase in the success rate with from 0.2 to 0.8 units can be reported in different schools and subjects. The results are yet to be summarized and analysed.

IV. CONCLUSIONS

The national program "Building a school STEM environment" provides opportunities to build and equip classrooms, laboratories, workshops and other STEM centres in the school network, where quality lessons can be held. In this way, the quality of training is significantly improved in all stages of the educational process, as it is conducted in close to real conditions. When conducting the lessons, it is possible to conduct demonstrations, experiments and visualization of the taught material, thus increasing the success rate in the relevant academic disciplines.

Expectations and results after the first and second year of the program's work are very good, with different subjects and schools, the values of excellent results are more than 50%, and somewhere it reaches 80%. The results achieved raise the expectations and the percentages are even higher. A problem in the implementation of the national program was the COVID-19 epidemic, which had not yet subsided and not all classes were held in person. There were also delays in the delivery of the necessary equipment. After the completion of the second academic year of study in the STEM centres, a further study will be conducted, and then it will be possible to compare real results, not expectations and reality. In this way, specific results will be fixed and measures to improve training can be identified.

Through the implementation of the national program, the aim is to conduct quality practical classes that are close to the real conditions in the production processes. In this way, students acquire and consolidate new skills in real conditions and prepare for realization in life.

V. ACKNOWLEDGMENTS

I would like to express my gratitude to my scientific supervisor from Shumenski University "Bishop Konstantin Preslavski", Professor Penka Kojuharova, for the assistance provided, and to all my fellow teachers in the schools with STEM centers for the assistance and readiness for the construction of these new structural cells in the educational process.

REFERENCES

- [1] Ministry of Education and Science, National Program "Building a School STEM Environment", 11.05.2020; <https://www.mon.bg/dokumentatsiya/programi-i-proekti/arhiv-natsionalni-programi/natsionalni-programi-2020/21-np-izgrazhdane-na-uchilishtna-stem-sreda/> [Accessed: Jan. 30, 2024].
- [2] Preschool and School Education Act, 2016, https://lil.mon.bg/uploaded_files/ZAKON_za_preducilisnoto_i_ucilisnoto_obrazovanie_EN [Accessed: Jan. 19, 2024].
- [3] Ministry of Education and Science, Guidelines for Applications under the National Program "Building a School STEM Environment", 2020, <https://www.mon.bg/nfs/2021/03/20rh937.pr> [Accessed: Jan. 24, 2024].
- [4] Karaivanova-Dolchinkova B., The educational process in schools with a built-in STEM environment, National conference with international participation "Natural Sciences' 2022", "Episkop Konstantin Preslavski" Higher Secondary School - 30.09.-1.10.2022
- [5] Karaivanova-Dolchinkova B., Innovative schools - a model for implementing learning in the classroom and for building knowledge and competences among students, National conference with international participation "Natural Sciences' 2022", "Episkop Konstantin Preslavski" Higher Secondary School - 30.09.-1.10.2022
- [6] Piven S. A., Activation of cognitive activity of students in physics lessons, methodical collection: STEM-technologies in educational organizations, pp. 7-13, Ulyanovsk, 2020
- [7] Tonoyan N. Zh, STEM-technologies in education, methodical collection: STEM-technologies in educational organizations, pp. 34-37, Ulyanovsk, 2020
- [8] Karaivanova-Dolchinkova B., Implementation of stem projects during the school year 2020/2021 in the Velikotarnovo district, Yearbook of Vasil Levski National University part 2, 2020, Publishing complex of Vasil Levski National University V. Tarnovo, ISBN 1312-6148, pp. 265-270
- [9] Dolchinkov N., Use of digital resources in nuclear physics education at Vasil Levski National Military University, Annual scientific conference of Vasil Levski National University - May 28-29, 2020. ISSN 1314-1937 vol.6 pp. 176-184
- [10] Karaivanova-Dolchinkova B. E., Need and Expectations for Learning in a Stem Environment, Environment. Technology. Resources. Rezekne, Latvia, Proceedings of the 14th International Scientific and Practical Conference. Volume 2, Print ISSN 1691-5402, Online ISSN 2256-070X, <https://doi.org/10.17770/etr2023vol2.7225> pp 126-131
- [11] Dolchinkov N. , State of the population disclosure systems in the changing radiation situation in Bulgaria, 12th International Scientific and Practical conference Environment. Technology. Resources. ISBN 1691-5402, Vol 1, 20-22.06.2019, pp 54-58
- [12] Dolchinkov N., B. Karaivanova-Dolchinkova, Teaching physics and astronomy in junior high and high school and transition to university teaching, XIV International Conference "Contemporary Physics Practice", Moscow, September 2016 UDC 372.853 PACS 01.04.Fk p. 35-37
- [13] <https://stem.mon.bg> [Accessed: Jan. 12, 2024].
- [14] <https://stem.mon.bg/wp-content/uploads/2020> [Accessed: Jan. 12, 2024].
- [15] https://stem.mon.bg/wp-content/uploads/2020/05/%D0%9D%D0%B0%D1%81%D0%BE%D0%BA%D0%B8_200508_FINAL.pdf [Accessed: Jan. 15, 2024].
- [16] <https://uchitel.bg/kakvo-trjabva-da-znaem-za-stem> [Accessed: Feb. 18, 2004].
- [17] <https://www.stem.com/> [Accessed: Feb 11, 2024].
- [18] <https://www.livescience.com/43296-what-is-stem-education.html> [Accessed: Jan. 22, 2024].

Synergy of Competences in Aeronautical English Education

Vanya Katsarska

Humanities and Natural Sciences Department

Air Force Academy

Dolna Mitropolia, Bulgaria

vkatsarska@af-acad.bg

Abstract. Successful communication between military pilots and air traffic controllers is vital for ensuring the safety and efficiency of aviation operations. While linguistic competence is fundamental, efficient communication in this context transcends mere language proficiency. The research study explores some contemporary under-researched theoretical and practical issues regarding the acquisition of the military aeronautical English language and establishes a strong correlation between aviation linguistic competence and interactive, cross-cultural and professional competence. This article explores the synergy of these competences and underscores the significance of integrating them in aviation English education. The synergy of competences equips pilots and controllers with the multifaceted skills necessary for ensuring the safety and success of flights in increasingly complex and globalized airspace environments.

Keywords: *aeronautical English language, aviation, competences*

I. INTRODUCTION

Military pilots and air traffic controllers (ATCs) work in multinational, multilingual and multicultural environment where most days the air-ground communication is conducted in the English language. Against this background a need exists to provide officer-cadets from the Bulgarian Air Force Academy (BAFA) with special professional language – aeronautical English. This special radiotelephony language employs standardized phraseology, developed deliberately and designed for aviators to speak briefly and clearly, together with plain English, vocabulary, grammatical structures and functions used in aviation context. Any misunderstanding during flights can cause a disaster or some kind of damage. That is why English language proficiency is a safety measure in this field and has become a compulsory element of any aviation training. Just a general understanding of the English language will not suffice in this context.

Since the early days of aviation flying qualification and experience have been measured in hours. For pilots,

professional competence is equated with flight time. Underlying assumption is that flight hours reflect quality training and correspond to a competence level. In order to complete one's pilot training and get a license, a pilot needs a certain number of flight hours (the number depends on the license – PPL, CPL, military, etc.) A pilot who has logged more hours is considered better than the one with half the flight time despite their respective experience with different aircraft types and responsibilities. However, recently the aviation industry has started to adopt new approaches and focus on competence-based training.

The concept of competence has evolved through the years. Although in the world there is no generally accepted definition or approach, there are a number of definitions emphasizing different aspects brought up by educators and linguists who have discussed competence-related issues. Noam Chomsky introduced the term competence as a key term in linguistics. Dell Hymes [1] argued that Chomsky's linguistic competence failed to explain the overall language behavior and offered the focal term "communicative competence." He highlighted the fact that the linguistic knowledge is not enough. Apart from the grammatical knowledge, one should have the ability to use this knowledge appropriately in social interactions: one should know when to talk, when not, and as to what to talk about with whom, when, where, in what manner [1]. Munby [2] went a step further and looked at the grammatical competence not as a separate element but as an element inextricably bound up with the communicative competence. Michael Canale and Merrill Swain [3] contributed to this with their communicative competence framework which distinguishes three major domains. First, an indispensable component of the communicative competence is the grammatical competence. The term usually refers to morphology and syntax, so it is slightly misleading in this context. Canale and Swain use it in a broader sense - knowledge of vocabulary, rules of grammar, semantics, and phonology. They assigned it a central role because it is essential for

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8098>

© 2024 Vanya Katsarska. Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

externalizing communicative intentions. Second, sociolinguistic competence – sociocultural and discourse rules, i.e. on one hand, knowledge of how to use language in different sociocultural situations, and the extent to which appropriate attitude and register are conveyed by a particular grammatical form in certain sociocultural contexts; on the other hand, skills of combining utterances and functions as regards discourse rules; the cohesion and coherence of sentences and paragraphs. Third, strategic competence – verbal and nonverbal communication strategies... that compensate for breakdowns in communication [3]. In 1983 Canale elaborated this framework further and set apart discourse competence as a separate component. Savignon [4] expanded the concept by suggesting five characteristics. Two of them are particularly relevant to the aeronautical English: “Communicative competence is a dynamic rather than static concept. It depends on the negotiation of meaning between two or more persons who share to some degree the same symbolic system” and “Communicative competence is relative and depends on the cooperation of all participants involved” [4, p.9]. While proposing their approach to language test design, development and use, Bachman and Palmer [5] formulated a “theoretical framework of communicative language ability”. This theoretical framework indicates how various components relate to each other in a complex manner. The three components - language competence, strategic competence and psychophysiological mechanisms – are interdependent. The language competence can be classified into two broad categories: organizational competence (which consists of grammatical competence and textual competence) and pragmatic competence (which consists of illocutionary competence and sociolinguistic competence). For the acquisition of knowledge and skills in using language functions, Bachman and Palmer [5] prefer to use the term functional knowledge instead of illocutionary competence.

Adopting a communicative competence framework leaves open the question as to how to describe different proficiency levels and how to harmonize them in so many different countries. In the beginning of the 21 century the European Qualification Framework (EQF) and the Common European Framework of Reference for Languages (CEFR) dealt with this issue. EQF is based on learning outcomes defined in the form of competences; the European Credit System for Vocational Education and Training (ECVET) recognizes and validates work-related skills and knowledge acquired in different countries through the creation of a set of reference levels; the CEFR gives a comprehensive description “what language learners have to learn to do in order to use a language for communication and what knowledge and skills they have to develop so as to be able to act effectively” [6, p.1]. The definition in the EQF states that “competence means the proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development” [7, p.6]. Responsibility and autonomy are the two notions which describe the term “competence” in the EQF. CEFR adds two further types: general competences and specific communicative language competences. General competences “are those not specific to language, but which are called upon for actions of all kinds, including language activities” [6, p.9]. The communicative language

competences are linguistic, sociolinguistic and pragmatic competences, a delineation that is clearly informed by the communicative approach. Language use and language learning develop a variety of competences in various contexts and under various conditions. The interconnection between general competences and communicative language competences is reinforced by the words, “All human competences contribute in one way or another to the language user’s ability to communicate and may be regarded as aspects of communicative competence” [6, p.101].

In 2007 Celce-Murcia suggested a comprehensive model, which shows that the various components of the communicative competence are interrelated [8, p.45].

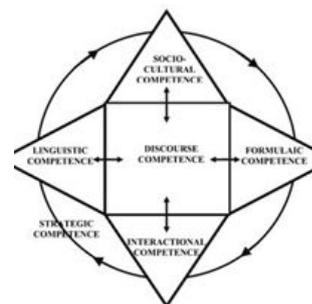


Fig.1. Celce-Murcia’s model on competences

Celce-Murcia proposes a complex and multidimensional model where the communicative competence contains linguistic competence, sociolinguistic competence, formulaic competence, and interactional competence, all of them supported by discourse competence and interrelated with the strategic competence. Celce-Murcia prefers "linguistic competence" to "grammatical competence" in order to highlight that this component comprises all the basic elements of communication: not only morphology and syntax but also lexis and phonology. The formulaic competence is the “counterbalance to linguistic competence” [8, p.47] and concerns the routine formulas and pre-fabricated chunks of language which facilitate the conversational flow. Murcia also uses the term "sociocultural competence" instead of "sociolinguistic competence." Sociocultural competence addresses the knowledge of conversing appropriately in a particular social and cultural context, in accordance with the pragmatic factors related to variation in language use. Discourse competence refers to the ability to select, combine, and arrange words, sentences and utterances to make a coherent spoken or written text. This model places it in a central position by means of which all other competences intersect and interact with it. Celce-Murcia believes that interactional competence is one of the most useful because it ensures that all parties involved comprehend the communicative act. Strategic competence – cognitive and metacognitive strategies that allow the speaker to negotiate meaning, resolve ambiguities and compensate for deficiencies in the other competences. Celce-Murcia concludes that “the application of the model is relative rather than absolute” [8, p.55] and it has to be adapted to the needs of each group of students.

Recently some scholars [9, 10] have given empirical evidence that successful aeronautical radiotelephony

communication is dependent on more competences than the linguistic one. Communication threats related to the use of English by aircrew members and controllers range from linguistic to discursive to strategic or cultural factors. Kim and Elder [11] address this issue and claim that the communicative needs of pilots and air traffic controllers extend beyond their language proficiency, requiring negotiation, collaboration and interaction, "These participants, whatever their language background, need to be able to adapt to the situation at hand and enlist a range of communicative resources to participate in and make sense of messages delivered by speakers with differing levels of English competence in situations which may range from routine to highly unpredictable" [11, p. 14]. Emery [12] claims that background professional knowledge is inseparable from language use. While at work aircrew and air traffic controllers must rely on their knowledge, skills, and competences of all subjects they studied at school – navigation, meteorology, tactics, etc. – and apply them to the particular situation using their English language communicative competence. Moreover, it is only in the aviation English classroom that all domain-specific knowledge from all subjects comes into interplay.

III. MATERIALS AND METHODS

The key research question that this study addresses is: What competences would serve best the English language communicative needs of pilots and air traffic controllers and are validated by key stakeholders? The aim was to find out which competences officer-cadets need for effective flight training in English.

Three context-specific surveys were developed and they were quantitatively tested with 53 teachers in aviation English from 25 countries in 3 continents, 106 Bulgarian air force officers and 24 cadets from Bulgaria. The surveys were created using Google Forms and distributed via author's personal network and the social network Linked-in, a platform used for professional networking and career development. Participation in all surveys was voluntary and anonymous.

The answers of the respondents of the three surveys are valuable as they are all representative members of a group of specialists who are completely aware of the target language use (TLU) domain and the needs, wants and necessities of military air crews, as well as of the essential issues in the aviation communication. Most of the teachers and military personnel had both life and professional experience. 42.3% of the teachers were between 40 and 50 years old while 55.6% of the pilots and ATCs were 30 – 50 years old. All cadets were in the age range 20-24. 48.1% of the military personnel had more than 10 year professional experience. 77.4% of the teachers have been teaching English as a foreign language for more than 10 years. It is worth noting that 58.7% had more than 6-year experience in teaching aviation English in particular.

The population of the teachers was diverse and heterogeneous which we definitely see as an advantage because they contain variability of characteristics and provide worldwide perspectives on the researched topics. On the other hand, the pilot/ATC population was rather homogenous consisting of Bulgarian military pilots and

air traffic controllers, both newbies and experienced. This choice was deliberate due to the needs analysis and the need to generalize for the cadet population at the Bulgarian Air Force Academy. These domain experts can provide valuable information about job profiles, job-related tasks, and competences. They can bring forth insight and data that yields accurate understanding of their own occupation. The specific knowledge, skills, and attitudes as well as methods and tools required by professionals in order to fulfill their duties well can be best described by members of the profession. With this survey population, the basic requirement for diversity was fulfilled - maximum variation sampling where diverse respondents, who have different perspectives on the issue, are chosen.

Survey 1 had 31 questions; survey 2 - 24 questions; survey 3 – 15 questions. These surveys were a component of a bigger mixed-methods research study which had additional goals and research questions. That is the reason why only a couple of survey questions will be discussed in this article. Part I in all surveys collected demographic information for the respondents. The aim was to determine the profile of the participants. Part II of the surveys had 6 common questions. The competences were measured using a Likert rating scale. There is a competences grid with 19 Likert items ranging from "least important (1)" to "most important (5)". Additionally, there were a couple of open-ended questions.

IV. RESULTS AND DISCUSSION

All survey respondents were emphatic of the topic and they found the discussion about the aeronautical English timely, useful and important. The three surveys had Cronbach's alpha above 0.9, which indicates very good internal consistency of the surveys. In other words, the surveys measured what we wanted to measure.

Survey 2 investigated the necessity of pilots and ATCs to study aeronautical English. In this regard two questions were asked. One of them, question 5, asked if the English language is an integral part of the professional life of pilots and air traffic controllers (ATCs). The answers provided by the respondents confirmed unequivocally the necessity to teach aeronautical English: 96.2% replied "yes" while the rest of them "to some extent." The other one, question 6, asked: "How often do you participate in international meetings/exercises/missions where English is the common language in communication?" 35.8% replied 2-5 times a year, 26.4% replied that they do it annually; 15.1% participate between 6-10 times per year, while 16% take part in international activities more than 10 times per year. Only less than 7% have never participated. These answers revealed the necessity for the BAFA cadets to learn aeronautical English as they will use it in their future careers.

Survey respondents emphasized that communication is crucial for good teamwork and it is fundamental to flight safety. One of them explicitly mentioned that "the importance of communication for orderly and efficient job performance cannot be overemphasized." The respondents drew the attention to the various purposes of military aviation English during a typical working day at an air force base, during international training exercises, and during wartime. During combat aircrews are under an

enormous stress. When long or complex or coded instructions are given in English, pilots and controllers need proficiency in aviation English. In case of allies taken hostages or spying missions, military personnel should be armed with the communicative competence in English.

The key variables were identified and analyzed, using descriptive statistics and mean and mode. In Figure 2 below the mean, the average score, and the mode, can be seen. The mean shows us which variables were rated as more important. Although the mode is the least precise measure of a central tendency, it is necessary because it is the value which is most frequent; it shows the most commonly chosen answer in the survey. According to the findings the linguistic, interactional, intercultural and professional competences were confirmed as relevant for the design of an aeronautical English syllabus for BAFA cadets and their aviation English education.

Variable	N	Mean	Mode
Linguistic competence			
know and use correctly standard radiotelephony phraseology	183	4,75	5
know and use clear, concise and unambiguous language in aviation context	183	4,74	5
use intelligible pronunciation and intonation	182	4,53	5
be able to accommodate to various native speaker and non-native speaker accents	182	4,32	5
know and use accurate grammar	182	3,85	4
Interactional competence			
communicate successfully in routine situation	167	4,71	5
communicate successfully in unpredictable situations	166	4,72	5
cope adequately with apparent misunderstanding by checking, paraphrasing, confirming, clarifying information and repairing breakdowns	181	4,63	5
demonstrate fluency in speaking	182	4,23	5
demonstrate accuracy in speaking	181	4,30	5
Intercultural competence			
be aware that there are different cultures with different values, beliefs and behaviors	165	3,81	5
demonstrate openness and flexibility to different cultures e.g. accept their communication style or work strategy	182	3,82	5
be aware of the effects of gender on communication	164	3,38	3
be aware of the effects of losing face on communication	164	3,73	5
Professional competence			
be aware of the effects of military hierarchy and authority on communication	166	3,68	5
possess initial background professional knowledge	166	4,36	5
comply with the rules and procedures for radiotelephony communication	164	4,70	5
demonstrate a professional attitude and tone	165	4,48	5
be able to offer and accept teamwork	166	4,51	5

Figure 2. Mean and mode of competences

Pilots and ATCs, cadets and teachers consider as the most important element of their aeronautical English to learn, know and use correctly standard radiotelephony phraseology (4.75); to know and use clear, concise and unambiguous language in aviation context (4.74); and to communicate successfully in routine and non-routine situations (4.71). It is not surprising that they value highly the strict compliance with the rules and regulations of the radiotelephony communication. The lowest rated variable was being aware of the effect of gender on communication (3.38).

The surveys delineated the four core competences that are necessary for the professional careers of the officer-cadets.

Furthermore, the research study aimed to investigate the interdependence between linguistic competence and interactional competence, cultural competence and professional competence. According to the correlation analyses all correlations are statistically significant. Linguistic competence strongly correlates with interactional competence. Pearson correlation coefficient is 0.830. Another strong correlation is between linguistic competence and professional competence – 0.777. The correlation between linguistic competence and cultural competence is on medium strength 0.568.

		Interaction competence
Linguistic competence	Pearson Correlation	0,830**
	Sig. (2-tailed)	0,000
	N	160

		Cultural competence
Linguistic competence	Pearson Correlation	0,568**
	Sig. (2-tailed)	0,000
	N	158

		Professional competence
Linguistic competence	Pearson Correlation	0,777**
	Sig. (2-tailed)	0,000
	N	160

Figure 3. Correlations between competences

Linguistic competence. The English language is an indispensable part of the aviation communication in international context and this was confirmed by both the literature review of relevant sources and the empirical data from the surveys. Even in such a highly technical domain as aviation everyday English knowledge and skills are required. In Survey 2 open-ended questions respondents recognized the importance of general English as a factor for miscommunication – “lack of general English knowledge”; “low level of English proficiency” were mentioned as key issues in the breakdown of air-ground communication.

The respondents of the surveys found the standardized radiotelephony phraseology an indispensable part of the aeronautical English communicative competence. Pilots, ATCs, flight instructors, aviation English teachers emphasized and prioritized strict adherence to the phraseology. Reinforcing the correct use of standard phraseology was addressed by many respondents. Some particular examples of incorrect use of standard phraseology were provided in Survey 2 – “Stand by for take-off” or “Ready for take-off”. Lack of knowledge or

noncompliance of standard phrases was a problem commonly mentioned as a main cause for communication breakdowns. In Survey 2 a lot of respondents addressed this issue. Problems in communication are due to “different phrases used by pilots from various air force bases during identical situations”, “misleading phraseology”, “lack of standardization in the flight phraseology”. Another participant said, “in my opinion the greatest problem is that in the Bulgarian air force bases some pilots and controllers do not comply with the standard phraseology”. In some cases the problem is in the individual professional who has not learned the standard phrases and either does not use them or uses them inappropriately – “It is extremely important to speak correctly and fluently. It is also important to use the standard phraseology. Some military pilots try to be creative but when they are creative in English, they are only ridiculous” and “the mixture of Bulgarian and Western terminology may cause problems”.

The main conclusion from the surveys of the Bulgarian military pilots and air traffic controllers is that a need exists to standardize the phraseology in all Bulgarian air force bases. This goes together with implementation of the phraseology, appropriate refreshment training, and control on the correct usage of that phraseology.

The linguistic – interactional correlation is the strongest one according to the surveys. Obviously all stakeholders realize that it is not sufficient to know lexical items or grammatical structures in isolation. Some of the respondents suggest that the interactive skills are more important than the pure linguistic ones. Functions are used in spoken English interactions and they are recognized as important by most aviation English users. Communicative strategies are required between all speakers, proficient or not, native or non-native. In aviation they are particularly needed when there is congested traffic and stressful non-routine situations. The comments of the respondents support the idea that interactive factors affect pilots’ and ATCs’ discourse in different ways.

A pilot expresses his irritation at a controller who lacks communicative strategies – “After ‘say again’ the Tower repeats the instruction word by word. It is much better to paraphrase their instruction... to use easier words”. Paraphrasing is considered a function which could repair communication breakdowns and negotiate meaning. On the other hand, the above mentioned observation implies that collaborative behavior and supportiveness are directly linked to aviation safety. The concepts of team work, negotiation, collaboration in avoiding misunderstanding, adaptation to the speaking of others, flexibility, tolerance accentuate the existing connections between the pure linguistic factors and the use of interactional strategies. Here are the words of an approach controller who confirms the idea that accommodation in adapting language to that of a communication partner is extremely important because it helps to avoid misunderstanding and decreases the human error in communication – “Everybody should aim at correct, clear and unambiguous speech; everybody should monitor if their message was understood correctly by the other person. Radiotelephony communication is teamwork”. Solidarity and teamwork especially in international surrounding are key factors to safety.

The linguistic – professional correlation is a key one. Both the literature review [10, 11, 12] and the empirical study report that aspects of professional competence contribute to effective intercultural aeronautical communication. Radiotelephony context is completely different from general English context. When aviators or controllers lack professional knowledge, they will not only be ridiculed by their peers but they can also jeopardize the safety of flights. A few survey extracts clarify that “not knowing the procedures in depth”, “not knowing holding procedures or SID procedures”, as well as some other factors „...not only make aviators look preposterous but they endanger the flight”. Assisting cadets in learning the language in appropriate aviation context brings communicative success for students in their professional lives in the future.

It seems difficult for pilots/ATCs to separate language ability from background knowledge. Thus they reinforced the view that linguistic and professional competences are interrelated in aviation communication. Highlighting the relationship between linguistic and professional competence, a Bulgarian pilot flying at an US air-force base has explained the following, “...I have no problems communicating with colleagues and instructors, on the ground and in the classroom. I have 3-3-3-3 at Stanag exam and I have ECL 99 points. But I have to admit that I have difficulties with English. Mostly when I am in the air. When I expect a specific answer, I have no problem understanding it and responding accordingly. But if the situation changes and if there are many other aircraft that the controllers are talking to, it is quite difficult for me to sort out which radio message is for me and what exactly I need to do”. This pilot is confused and cannot differentiate if he lacks language competence or professional competence. Actually, often these two competences cannot be separated.

If companies and individuals aim to work effectively in aviation, then the complexities presented by differences in cultural predispositions must be understood and harnessed. The linguistic – cultural correlation is often underestimated but it is a crucial one, too. Communicating with pilots/ATCs who speak vague and ambiguous language is a threat to a successful flight. However, certain cultures are known to possess direct and objective language, and they get right to the point, whereas others not so much [13]. A lot of respondents reported instances of culturally influenced behavior that affected their work and their communications. A Survey 2 respondent wrote the following, “I can understand better a Bulgarian speaking in English rather than a foreigner speaking in English. It is important to practice English with foreigners in order to understand their way of thinking and speaking”. Teaching a foreign language is not a value-free activity and, consequently, language teachers, whether they realize it or not, are introducing certain patterns of thoughts, values and beliefs to their learners. Aeronautical English, however, is a lingua franca which means that a lot of cultures are interconnected while communicating in English. Aeronautical English is also the cultura franca and it reflects the perceptions of various nationalities, religions, ethnic groups and communities. Aeronautical English reflects diverse cultural experiences and language teaching should project them.

It is interesting to note that although intercultural competence was statistically weaker in my surveys, respondents actually shared a lot of observations connected with culture without realizing themselves that these were issues related with the intercultural competence. Here are a few examples: “some pilots explain in too many words what they want (especially Italians)” – stereotyping; “it is complicated when in one mission there are Bulgarian pilots who fly Czech airplanes and American pilots who fly F16 - mish-mash” – different cultural values and different measurement systems; “he is acting like a big boss, while actually safety comes first, not the boss” – power aspect; “civies (civilian colleagues) talk down to us but we are better in our profession” – organizational culture; “...the level of respect at civilian airports has decreased” – respect and judgmental attitude; “everyone should observe the rules of polite behavior and refrain from expressing their personal preferences” - deferential style of communication and avoiding conflict style.

No doubt literature [9, 10, 12] and the experimental study reveal that multicultural communicative competence should be included into aeronautical English trainings so that ab-initio and seasoned pilots and ATCs meet not only the sole language proficiency criterion but also the criterion for intercultural knowledge and skills which has already proved to be of vital importance in non-routine unexpected situations.

V. CONCLUSION

As global civil and military aviation have grown in complexity, effective language training of student pilots and air traffic controllers requires a more holistic approach. Air-ground radiotelephony communication is influenced by many elements most of which are interdependent. While linguistic competence is fundamental, successful communication in this context transcends mere language proficiency. Linguistic competence must be complemented by interactional skills, enabling effective negotiation of meaning and adaptation to dynamic communication contexts. Furthermore, professional competence ensures adherence to standard procedures and terminology, enhancing operational efficiency and safety. Additionally, cross-cultural competence enables individuals to navigate diverse linguistic and cultural backgrounds, fostering mutual understanding and minimizing communication barriers. The empirical study illustrated the stakeholders' perceptions of the importance of linguistic, interactive, professional, and intercultural competences to the successful aeronautical English communication and to the safety of this communication between pilots and air traffic controllers.

The main goal of this study is to help increase the professional competence of Bulgarian military pilots and air traffic controllers through the exploration of the competences required for effective communication, relying on the perceptions of a range of national and international aviation stakeholders. The relevance of the competence concept is its contribution to the syllabus design appropriate to the context of intercultural radiotelephony communications in aviation. Syllabi so far

have placed a great emphasis on linguistic components; however, this training has failed to take into consideration what domain experts value for successful communication in this professional context. Scholars nowadays recognize the interdependence between language and communication. The linguistic components of language, i.e. semantics, grammar and discourse, are interrelated with the pragmatic components i.e. the functional, sociolinguistic, and strategic. Language is used to facilitate social and professional exchanges between individuals. Language is learned by means of communication; meaning and content are of paramount importance.

Communication in a multicultural aviation context is the intersection of language, professionalism and culture. The synergy of the four competences – linguistic, interactional, professional and cross-cultural – can contribute to the on-going improvement of the aviation language proficiency training of military pilots and air traffic controllers.

REFERENCES

- [1] H.D. Hymes, “On communicative competence” in J.B. Pride and J. Holmes (eds.) *Sociolinguistics. Selected Readings*. Harmondsworth: Penguin books, 1986 pp. 269-293. 1972.
- [2] J. Munby, *Communicative Syllabus Design*. Cambridge: Cambridge University Press, 1978.
- [3] M. Canale and M. Swain, “Theoretical bases of communicative approaches to second language teaching,” *Applied Linguistics*, 1, 1-47, 1980. DOI: 10.1093/applin/1.1.1
- [4] S. J. Savignon, *Communicative Competence: Theory and Classroom Practice*. Addison-Wesley Publishing Co. 1983.
- [5] L. Bachman and A. Palmer, *Language testing in practice*. Oxford University Press, 1996.
- [6] Council of Europe, *Common European Framework of Reference for Languages: Learning, Teaching, Assessment*, Strasbourg: Language Policy Division, Council of Europe / Cambridge University Press, 2001.
- [7] Council recommendation of 22 May 2017 on the European Qualifications Framework.
- [8] M. Celce-Murcia, “Rethinking the role of communicative competence in language teaching” in Solen, E. and Jorda, M. (ed.) *Intercultural language use and language learning*, pp. 41-57. Springer, 2007.
- [9] A. Monteiro, From a language only approach to a broader view of communicative competence for intercultural communications in aviation. Workshop presented at the International Civil Aviation English Association International Conference, Tokyo, Japan, 2019.
- [10] C. Elder, T. McNamara, H. Kim, J. Pill and T. Sato, “Interrogating the construct of communicative competence in language assessment contexts: What the non-language specialist can tell us” *Language and Communication*, 57, 14-21. 2017. doi.org/10.1016/j.langcom.2016.12.005
- [11] H. Kim and C. Elder, “Understanding aviation English as a lingua franca: Perceptions of Korean aviation personnel” *Australian Review of Applied Linguistics* 32 (3), pp 23.1–23.17. 2009. DOI: 10.2104/ara10923
- [12] H. J. Emery, “Aviation English for the next generation” in A. Borowska and A. Enright (Eds.) *Changing perspectives on aviation English training*, pp. 8-34. Wydawnictwo Naukowe, Uniwersytet Warszawski, Warsaw, 2016.
- [13] Hofstede, G. and Hofstede, G.J. and Minkov, M. (2010). *Cultures and Organizations: Software of the Mind*. Revised and Expanded 3rd Edition. New York: McGraw-Hill USA.

Principles of creating and designing video content for asynchronous learning

Anna Khilya

Department of Primary Education
Vinnytsia Mykhailo Kotsiubynskyy
State Pedagogical University
Vinnytsia, Ukraine
anika.line@gmail.com

Halyna Kukharchuk

Department of Foreign Languages
Vinnytsia National Technical
University
Vinnytsia, Ukraine
galinakuh07@gmail.com

Yuliia Sabadosh

Department of Foreign Languages
Vinnytsia National Technical
University
Vinnytsia, Ukraine
avatic87@gmail.com

Alona Korol

PhD in Special Education, Lecturer
at the Department of Preschool
Education
Vinnytsia Mykhailo Kotsiubynskyy
State Pedagogical University
Vinnytsia, Ukraine
akorolin@gmail.com

Abstract — A key stage of professional training is to prepare them for the use of ICTs and modern innovative solutions that would not only improve the quality of presentation of educational content, but also minimise the time spent on learning new material and repeating material that has already been covered. Therefore, a relevant aspect of preparing teachers and future professionals in general for self-presentation or presentation of their own projects should be preparation for the use of video editors and online platforms to create short videos that both students and teachers can use to save time during teaching or to support projects that are offered to a wide audience.

For this reason, in our review, we focus on the theoretical aspects of introducing video content into the educational process; high-quality video editing software that students and teachers can use from any device; analyse the quality of the projects prepared by students; review teaching approaches for asynchronous learning.

But, with the main objective of our research being to argue for the principles of creating and designing video content for asynchronous learning. We present not only the above results of our review and practical implementation of the relevant project activities, but also the theoretical aspects of the issue necessary for teachers' understanding and personal improvement.

This complex approach allows us to develop the simplest and most flexible algorithm for working with video content, depending on the needs of the teacher, their psychological characteristics and technical skills, as well as the purpose of the subject being taught. After all, for some subjects and the

teachers who teach them, the thesis "why should we reinvent the wheel" will be appropriate. While for the other part, this process will always be a personal challenge, an innovation and a requirement of modern education. That is why, in our opinion, the proposed flexible algorithm will be useful for both future teachers and professionals who already have teaching experience.

Keywords — asynchronous learning, flexible content creation algorithm, principles of creation, teacher training, video content.

I. INTRODUCTION

We are not the first researchers to deal with the issues of distance education, the problems of introducing and using ICT and innovative solutions, but this topic is also quite relevant for us. The reasons for its relevance remain the same:

- a sharp increase in demand and supply in the field of online learning, particularly since 2019;
- saturation of the education market and other areas of life with affordable and easy-to-use technologies;
- the existence of contradictory facts about the effectiveness of the traditional educational system.

Therefore, there are ongoing discussions among educators and scientists, as well as in public administration, to find the best solutions for the implementation of

Print ISSN 1691-5402
Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8088>

© 2024 Anna Khilya, Halyna Kukharchuk, Yuliia Sabadosh, Alona Korol.
Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

educational services that lay the foundation for the functioning of society and strategies for changing educational policy in line with the challenges posed by the fourth scientific and technological revolution.

In order to achieve the goal of education and to be guided by the technical capabilities of the modern world, teachers must be ready to work with technology, i.e. have the appropriate ICT competencies that are currently defined and recognised in the world. For example, the ICT competence framework includes 18 competences grouped into six areas of pedagogical practice (understanding ICT in education, curriculum and assessment, pedagogy, application of digital skills, organisation and administration, and teacher training), as well as three levels of pedagogical use of ICT by teachers (knowledge acquisition, knowledge deepening, and knowledge creation) [1].

But on the other hand, we should not forget that the responsibility for acquiring the relevant competencies lies not only with teachers, this is a joint project where educational institutions should provide the technical component of the educational process (ICT, gadgets if necessary, Internet access, availability of relevant resources and databases) and promote teacher self-development in this direction, and higher education institutions should provide an appropriate level of teacher training and retraining.

Turning to the simplest and most acceptable way of interaction in distance learning, we should consider working with video materials. According to scientists, video is an excellent technology for online learning, especially as an asynchronous replacement or supplement to face-to-face learning, which can make learning time more productive for both teachers and students and become an adequate substitute for face-to-face lectures, as evidenced by various studies on the general benefits of using such tools for learning [2] – [4]. It is worth noting that today there are two main ways to create video clips: with a camera or with the help of a unique technology called screencast [3]. While we are all familiar with recording with a video camera and understand its features without further explanation, the issue of screencasts, in our opinion, requires clarification.

Thus, Ghilay defines a screencast as a digital recording of an image on a computer screen, usually containing audio narration and captions, and differs from a screenshot in that it creates a film of changes that the user sees on the computer screen over time in accordance with the purpose and topic related to the subject area of teaching [2], [3]. In addition, combined animation and audio presentations (essentially moving images and sound) provide a more effective learning experience than still images accompanied by text [3], [5].

In addition, some studies confirm that Video-Based Learning (VBL), in which the course curriculum is fully covered by video clips that replace or supplement live lectures, has significant advantages for learning subjects in higher education due to the flexibility of the process and high levels of student satisfaction [3]. In addition, video instruction brings courses to life by allowing online learners to use their visual and auditory senses to learn complex concepts and complicated procedures [4]. The use of video for learning has significant advantages due to the

growing use of smartphones and tablets, which allows students to watch useful videos while overcoming time and geographical constraints [5].

II. MATERIALS AND METHODS

We don't look at big data like our academic colleagues. We rely on similar studies of the productivity of using video for educational purposes. In addition, in today's environment, when there is available information on already processed data sets on any research topic, we believe that analytical articles and reports are the best choice for theoretical issues. In addition, in practical matters, it is also possible to refer to the experience of practitioners and relevant analytical reports of official international bodies and individual researchers from around the world, with one condition – their experience should be considered taking into account the national and cultural traditions of the country to which the relevant practice is planned to be applied.

This allowed us to formulate the main goal of the study of the proposed topic as the development of an algorithm for creating and designing video content for asynchronous learning, considering modern principles of education. Based on this goal, we identified the following tasks, which consisted of analysing theoretical developments on the implementation of video content in the educational process; creating a list of affordable and high-quality video editing programs that students and teachers can use from any gadget; presenting the results of projects prepared by students and reviewing approaches to teaching with video content for asynchronous learning.

But, given the main goal of our study, which is to argue the principles of creating and designing video content for asynchronous learning. We present not only the above results of our review and practical implementation of the relevant project activities, but also the theoretical aspects of the issue necessary for understanding and personal improvement of teachers.

III. RESULTS AND DISCUSSION

Thus, after carrying out a preliminary analysis of materials on the use of video in the educational process, we concluded that this topic has been raised more than once and is sufficiently described in the scientific and pedagogical literature, and also has its share in international documents. However, from the information we received, we also saw that the main achievements and qualitative description of the experience of implementing education through video are best presented in the exact sciences. That is why we analyse the use of video since the examples offered, but not only because they are more qualitatively prescribed and strategically planned. We use them as a basis because in mathematics/computer science there are two precise values of zero or one, truth or error. This standard allows us to better plan and assess the outcomes of participation in a particular teacher-student interaction. Whereas the social sciences have a multifaceted structure based on various aspects of human interaction and require diversity in finding the best approaches to fulfilling the tasks of personality development and formation set for specialists in the relevant field.

In the exact sciences, we are interested in the score of knowledge acquisition, and the results of the Y. Ghilay

study prove the effectiveness of learning through video. However, in the humanities, such as social work, teaching, psychology, the main assessment should not be limited to the acquisition of theoretical knowledge. We must pay attention to the understanding of the topic, concepts and worldview of the student who will work with the individual, because the values, guidelines, as well as competencies and skills of the teacher, social worker or psychologist are a visible tool for others to follow, social interactions and emotional intelligence of a professional are his or her largest and best portfolio.

That is why it is important for us to study new principles of creating educational videos, as technological advances open up new opportunities for design, and educational videos are used in new educational contexts [6] that go beyond the traditional model of education.

Thus, among the principles that are currently proposed for education are the following:

- The principle of coherence. Learning is improved when additional words, sounds and images (noise) are removed;
- The principle of signalling Learning is enhanced when there are cues in the main material that emphasise its importance;
- The principle of redundancy Learning is enhanced when graphics and narration are used rather than graphics, narration and on-screen text;
- The principle of spatial contiguity Learning is enhanced when related words and pictures are presented next to each other;
- The principle of temporal continuity Learning is enhanced when related words and pictures are presented simultaneously rather than one after the other;
- Segmentation principle Learning is enhanced when material is presented in segments that match the user's pace, rather than as a single, continuous unit;
- Pre-preparation principle Learning is enhanced when students know the names and characteristics of key learning points or concepts;
- Modality principle The principle that learning is enhanced by graphics and narration compared to animation and on-screen text;
- Multimedia The principle that learning is enhanced through words and pictures rather than words alone;
- Personalisation Principle Learning is enhanced when teaching is done in a conversational rather than formal way;
- The principle of voice Learning is enhanced when the story is told in a human voice rather than a mechanical one;
- The image principle Learning is not necessarily improved when an image of the speaker is added to the screen [7].

Each of these principles complements the general pedagogical principles with the needs of scientific and

technological progress and allows us to rethink the role of the teacher, the importance of text, audio and video materials that are part of the educational process. For example, we have taken as a basis the advice of Harvard University's management on creating content for online learning. In particular, it is worth noting that the recommendations themselves state that this is a suggestion, but each teacher should be guided by their own point of view in preparing materials, as these materials are recommended with an emphasis on the possibility of independent implementation of the online course project, without the need to rely on additional resources [8].

Among the recommendations for online courses, it is suggested to adhere to

- content [8] as a basic component of the course and a separate video designed to complete certain tasks intended for study;
- pedagogy. That is, ensuring the selection of adequate and effective forms and methods of work, with a clear proposal for processing materials before the class (asynchronously), during the class (synchronously), or after the class (asynchronously) [8], which also applies to cases of using video materials;
- qualitative assessment, which will facilitate the effective evaluation of the material [8], as well as reviewing its value for the course offered and the formation of competences that are relevant to the course aims and objectives.

Based on the above-mentioned general recommendations, the Harvard University management proposed a detailed algorithm for developing and implementing an online course, but we have identified elements of step-by-step work with video to implement the goals and objectives of humanities disciplines in a distance format.

Thus, as *the first step* in working with video material, we take the entire course offered to students in the discipline as a basis and review its structure for the ratio of asynchronous and synchronous elements. After all, as a result of teaching in a distance format for five years, we have been able to accumulate enough video material to further explain the topics of the subject. In this way, we determine the quantitative and temporal indicators of the use of video content in our course.

The *next step* concerns the audience we are working with, the need to create a community to discuss the videos we have watched, because target groups can develop through learning processes, which ensures the change of focus that scholars talk about, which refers to the transition from a content-oriented to a user-centred position [9]. This certainly does not mean that this position is limited to working in one of the messengers or at the level of discussion groups, but rather that it should be provided through study groups, project work, office hours, sections or casual conversations in the corridor, or comments on videos, which requires trust, familiarity and a social community of peers [8]. The teacher should keep this format of interaction in mind and accompany and guide students to communicate on Canvas discussion boards or through the Slack channel, or using interactive online boards JamBoard, Pinterest, and for direct communication

software such as Microsoft Teams, Discord, chats on the social network Facebook or in messengers that are most often used within the educational institution (Viber). In other words, this step concerns the direct interaction of the discipline's video content with the student audience.

The **third step** should include interactivity and peer-to-peer learning, as the use of video in a course from open sources of information can reach a large audience, create prerequisites for interaction not only among participants in the educational process, and be filled with elements of emotional communication through emoticons and chat. What determines the specifics of the step for borrowed video is the filtering of inappropriate emotional reactions and planning interaction within unforeseen situations to avoid the formation of negative experience within a particular course topic. Of course, it is impossible to predict all the options for negative developments, but pre-thinking through the reaction and further interaction with students based on frequently occurring situations is a fairly effective way (a video that is too emotionally intense and requires a discussion or an art therapy minute; an inadequate comment on the video that was picked up by a student/students and used in the interaction, etc.)

The **fourth step** involves creating a video based on the principles of effective pedagogy, rather than focusing on a specific method of work (although in some cases this may be justified by the need to explain the effectiveness of such a method in different conditions and for different age groups of participants in the educational process). In addition, it is worth paying attention to the ready-made video work of other teachers, which can be used and be more accurate than the video that we will edit separately.

As a **fifth step**, we propose to raise the question of the workload, which implies

- first, the need and expediency of using new technologies other than those you already use, because each new technology creates an additional workload for both teachers and students;
- secondly, whether the same functions can be performed with the help of the software you have already studied.

If we take video materials, we have to understand and distinguish between several aspects.

- To work in asynchronous or synchronous format, you should use video presentations from video hosting sites and platforms or social networks that are familiar to students. These are often YouTube and Canva. Today, we also use videos from Instagram and TikTok, and occasionally from open online course materials. But here it is important for the teacher to investigate the origin of the content to pay attention to the channel on which the video is posted, the personality of the channel manager or blogger (experience, in our case, in pedagogy and teaching, including research and scientific activities). When using a video that aims to present a technique, method, technology or to achieve the goal of developing students' emotional or social intelligence, we should pay attention to the quality of the video, the country of origin of the video (the difference in use and effectiveness of the content offered depends on the mentality, traditions and culture), the music or

background audio accompanying the video, comments and reactions to the content offered and, in particular, the age of the account and changes in the content presented on the channel or personal page. These are essential factors that can help avoid the difficulties we described in step two.

- If we create our own video, it should also be available both for scrolling in the classroom by the teacher and for self-translation, should be of high-resolution quality and, at the same time, should be lightweight so that even in case of slow network speeds, students can join and view the content. In this case, we can, of course, use the available, partially free software (Adobe Premier or Clipchamp for Windows-based PCs, Inshot for Android, Moviemaker for MacOS, etc.), built-in conference recording functions from Google Meet, Zoom, Go to meet, etc. But we can also use modern tools for quick video sharing on YouTube, Instagram and TikTok. Of course, after planning the content and assessing all the risks and benefits of posting it. But this is where the question of the teacher's ICT competencies and, no less importantly, his or her psychological stability and readiness to reach the public comes into play.

Based on our experience of interacting with students, during our first leap into distance education, we created a series of video instructions as part of podcast episodes (available here), which covered the technical aspects of organising online exams and practical tips on how to fill out the documentation of an inclusive classroom teacher.

This experience of working with your own or borrowed video can bring a new wave of motivation and interest in studying the materials of the discipline, because as we know, long lectures do not work as well in online teaching as in the traditional education system.

The sixth step is the so-called "Expert at a click away" [8]. Part of this is interaction with other people's video content, which we use to demonstrate certain topics and which we have written about before. On the other hand, it is guest lectures, meetings, and interviews with experts in the field that allow us to present and expand the scope of the discipline. Such materials include the playlists on our YouTube channel "Specialists About..." (available at https://www.youtube.com/playlist?list=PLJP7ziatOaS_iBquR2pA3c70cJynJ4Q40) and "Conferences" (available at <https://www.youtube.com/playlist?list=PLJP7ziatOaS-1GtcowJAgiXT03zdipzM>).

And the last **seventh step** in the Harvard framework is evaluation.

All of these steps individually and together answer the questions that Harvard suggests you ask of your online developments:

- how can you provoke students to start working on a particular topic?
- how you can encourage your students to search for key ideas and concepts on their own through active learning rather than passive listening or "show and tell";
- how to help students appreciate the bigger picture of why and how a particular learning concept generalises beyond a specific application,

because these simple considerations - how to provoke, discover and generalise - can go a long way towards creating interactive and engaging asynchronous materials [8].

Such an algorithm for creating and using existing videos in the study of our disciplines is incomplete, as we need to add two steps when referring to the concepts of inclusive education.

The first of them (*the eighth* in the general list) is the step of analysing the results of viewing a teacher-created or publicly available video from another producer to achieve the purpose of using video. This is achieved through synchronous discussion during online meetings, or as a result of asynchronous tasks related to questionnaires, writing comments of a given length, writing feedback and suggestions based on the results of viewing or searching for their own video options for the proposed topic. In addition, at this stage, students also could complete a more complex creative task of feedback with the creation of their own video fragment on the topic based on the materials they have watched.

In addition, this step can be more extensive with the involvement of students. They can present their thoughts or developments during the course in a video format. Thus, since 2020, we have gradually offered students to create their own video materials based on the results of the materials they have studied. The sequence of the introduction of this form of work can be traced on the pages of our Inclusive Education Facebook group, and some of the educational hackathon materials can also be found on YouTube. In 2021-2022, students continued to create video content on the subjects they were studying in accordance with the assignments, and some of them posted materials on their own YouTube channels. However, most of them restricted access by turning on the "private video" function. Since 2023, there has been a trend towards open coverage of videos on Instagram and TikTok. Some of the videos of their work in 2022 and 2023 were most often posted on the Kanva platform.

The second step (*the ninth* in the overall list) is to analyse the feasibility of reusing the video in the course we are teaching at the beginning of the next group of students. This step is necessary because, following the concept of inclusion, we refer to the personal experience of students, their familiarity with the course topic and, according to their level of awareness, interest, emotional involvement, and level of socialisation, we decide on the inclusion or replacement (editing) of the proposed content.

IV. CONCLUSIONS

This comprehensive approach allows us to develop the simplest and most flexible algorithm for working with video content, depending on the needs of the teacher, their

psychological characteristics and technical skills, as well as the purpose of the subject being taught. After all, for some subjects and the teachers who teach them, the thesis "why reinvent the wheel" will be apt. While for the other part, this process will always be a personal challenge, an innovation and a necessity of modern education. That is why, in our opinion, the proposed flexible algorithm will be useful for both future teachers and practitioners who already have teaching experience.

We have also partially presented our own experience of interacting with video in the context of teaching and the results of our work over four years of student teaching. This may indicate a gradual change in the emphasis in teaching and the perception of information by students. They drew attention to the principles of creating and designing video content for asynchronous learning, considering a step-by-step proposal for the implementation of the goals and objectives of disciplines in higher education.

V. ACKNOWLEDGMENTS

This research was made possible through the team's collaboration and the completion of a Thomson Foundation e-learning course on Mobile Journalism and Storytelling (TM18-EUUA-01.1UKR).

REFERENCES

- [1] L. B. Espejo Villar, L. Lázaro Herrero, & G. Álvarez-López. 2022. UNESCO strategy and digital policies for teacher training: The deconstruction of innovation in Spain.
- [2] Y. Ghilay. 2018. Comprehensive technology-based learning (CTBL): A comparison between various types of quantitative courses. *Economics and Culture*, 15(2), 14-24.
- [3] Y. Ghilay. 2021. Text-Based Video: The Effectiveness of Learning Math in Higher Education Through Videos and Texts. *Journal of Education and Learning*, 10(3).
- [4] C. Ou, D. A. Joyner, & A. K. Goel. 2019. Designing and developing video lessons for online learning: A seven-principle model. *Online Learning*, 23(2), 82-104.
- [5] Y. Ghilay. 2018. Video-Based Learning of Quantitative Courses in Higher Education. Ghilay, Y.(2018). Video-Based Learning of Quantitative Courses in Higher Education. *Journal of Educational Technology*, 15(2), 16-27.
- [6] C. Mehrotra, C. D. Hollister, & L. McGahey. 2001. Distance learning: Principles for effective design, delivery, and evaluation. Sage Publications.
- [7] T. C. Varkey, J. A. Varkey, J. B. Ding, P. K. Varkey, C. Zeitler, A. M. Nguyen, ... & C. R. Thomas. 2022. Asynchronous learning: a general review of best practices for the 21st century. *Journal of Research in Innovative Teaching & Learning*, 16(1), 4-16.
- [8] Harvard University's Office of the Vice Provost for Advances in Learning (VPAL). 2021. Designing Your Course for Online Instruction: Principles and Tips. https://teachremotely.harvard.edu/files/designing_your_course_for_the_fall.pdf
- [9] H. Haugsbakken. 2020. Five Learning Design Principles to create active learning for engaging with Research in a MOOC. *European Journal of Open, Distance and E-learning*, 23(1), 32-45.

Features of synchronous and asynchronous e-learning on the example of teaching the European experience of social inclusion

Anna Khilya

*Department of Primary Education
Vinnytsia Mykhailo Kotsiubynskyy
State Pedagogical University
Vinnytsia, Ukraine
anika.line@gmail.com*

Olena Kolosova

*Department of Preschool Education
Vinnytsia Mykhailo Kotsiubynskyy
State Pedagogical University
Vinnytsia, Ukraine*

Tatyana Kronivets

*Department of fundamental and
private legal disciplines
Vinnytsia Mykhailo Kotsiubynskyy
State Pedagogical University
Vinnytsia, Ukraine*

Irina Sarancha

*Department of Psychology and Social
Work
Vinnytsia Mykhailo Kotsiubynskyy
State Pedagogical University
Vinnytsia, Ukraine*

Abstract. The research focusing on synchronous and asynchronous learning is often reduced to a psychological assessment of the learner. The learner's motivation will determine the success of the learning process. The quality of perception and understanding of the educational content offered will depend on their experience. Familiarity with the research of the international community and European practices allowed us to select interesting content and diversify the module "Social integration of children with special needs in an environment of diversity and inclusion: European approaches" (SEEDUE4UA-101085267), as well as supplement the content of related disciplines.

However, we paid most attention to the issue of synchronous and asynchronous format of the online educational process. We had to implement this aspect of interaction with students due to the consequences of military aggression in Ukraine. And for the convenience of both students and teachers, we created a flexible package of educational content that allowed us to engage young people through the use of video materials, individual and group projects, and quickly change the form of the online classroom (when the lesson began in the synchronous mode of group interaction, and after 20-30 minutes we had to interact with students asynchronously due to the danger to the life and health of the participants in the educational process).

The biggest challenge in the flexible format for our team was the development of emotional intelligence, that is, the ability of students to assess the situation in an inclusive educational environment, conduct supervision, lead a discussion, etc.

Among the challenges, we also considered the issue of implementing sections of changes in students' attitudes and perceptions of information as a result of mostly asynchronous interaction.

That is why, in the course of this scientific review, we analysed the forms of interactive interaction we selected, described some of the programmes that were used and involved students with appropriate reflection with elements of simulation games, etc. We also drew an analogy with certain topics studied by full-time students in the traditional offline mode of interaction. This allowed us to draw conclusions about the need to adjust certain elements of the programme for all forms of the educational process based on the results of reflection on certain elements of emotional intelligence development within the framework of simulations of physiological and social skills.

As we noted earlier, this analysis allowed us to revise the amount of material and the format of its presentation for better mastering the module issues, as well as to develop a universal toolkit that can be flexibly used in the process of mastering information on social inclusion and European experience in synchronous and asynchronous formats of both project implementation and teaching of relevant disciplines.

Keywords: *asynchronous education, European experience, online education, social inclusion, synchronous education, training.*

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8074>

© 2024 Anna Khilya, Olena Kolosova, Tatyana Kronivets, Iryna Sarancha.

Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

I. INTRODUCTION

Our research is conducted within the framework of two main topics and areas of organisation of the modern educational space. The first of these is inclusive education, which is in line with the project we are implementing in cooperation with the EU. It is also the issue of inclusion of all children with special educational needs in the educational process, which has been addressed by the Ministry of Education and Science of Ukraine since 2010. In addition, this process is currently being expanded and transformed by lifelong learning.

On the other hand, the second topic that directly and fundamentally affects the educational paradigm is distance education and everything related to technology in education. E-learning, which encompasses various procedures such as online learning, computer-based learning, virtual classrooms and digital collaboration, provides a new paradigm in which learning has become possible in any field, for anyone, anytime and anywhere [1]. However, as our fellow researchers point out, despite the growing popularity of distance education and its potential benefits, there is still a lack of data on best practices and research related to teaching and learning in virtual schools [2].

Notably, from 2015 to the present day, it has been noted that student success in virtual schools is largely dependent on the teacher's ability to plan, implement and evaluate their online teaching and learning [2]. In particular, online course development and design is more complex and different from a face-to-face course, as teachers need to consider content, activities (including synchronous and asynchronous activities), facilitation and assessment, all within the constraints of physical and possible distance between the learner and the teacher [2].

This leads to the need to adapt and modify the existing methodology in the development of lectures, practical and other classes, considering the complex process of distance education with its own design, software and professional readiness of the student at the end of the course.

In the Ukrainian educational space, there are significant differences between distance education and inclusive education. Inclusive education provides conditions for unimpeded access to educational institutions and educational services. In particular, not far from the place of residence of a child or a person who needs additional psychological and pedagogical support [3]. While e-learning allows learning regardless of geographic location and time, and has been the main choice for continuing education since 2019 [4].

Thus, the similarity of these two areas is an integral part of the issues of accessibility of education. After all, distance education makes it possible to organise training for any category of people, anywhere in the world and within the required time frame. Similarly, inclusive education makes it possible to provide support and services to children with special educational needs in the format that suits them best. And in combination, these components create the best conditions for the development and functioning of the individual.

Although, again, the difference between them is manifested in the issues of socialisation, the formation of social and emotional intelligence, which we will write about later.

In general, it is a serious challenge for the implementation of our project. As well as for the organisation of the entire educational process, the issue of lack of physical access to educational institutions has become a major challenge. In 2019-2021, it was due to quarantine restrictions, and since 2022, due to the aggravation of the military and political situation in Ukraine. All this, on the one hand, contributed to the search, implementation and implementation of distance education, but on the other hand, required additional measures and implementation of the existing foreign experience of appropriate training organisation with the needs of Ukrainian pupils/students, including children with special educational needs.

Since we are responsible for training young professionals to work with children with special needs, we had to rethink and reformat the presentation of information. After all, those forms of work and training exercises that were effective in traditional education and ensured direct involvement of students in the work process have become essentially vestiges of education. Although they made it possible to understand the main positions and values of inclusive education through the proposed EU experience and the accumulated experience of Ukrainian teachers, experiencing it in the classroom. In order, to maintain the effectiveness of this teaching strategy, the most important thing was to transfer the relevant elements of training exercises and interactions with emotional inclusion and the development of individual skills into an online format.

Thus, the main purpose of our study is to analyse the possibilities and prospects of distance education in the format of training in synchronous and/or asynchronous format. We consider this on the example of teaching the European experience of social inclusion as part of the project of the module "Social integration of children with special needs in an environment of diversity and inclusion: European approaches" (SEEDUE4UA-101085267; hereinafter referred to as the SEED:UE4UA module).

The realisation of this goal allowed us to define the following tasks for the presentation of our experience:

- firstly, we had to analyse the issues of synchronous and asynchronous format of the educational process to achieve the main goal of the SEED:UE4UA module and related disciplines. We paid special attention to the flexible format of their combination due to circumstances beyond the control of the educational institution and the teacher;
- secondly, to present the developments within the proposed flexible format of interaction, their possibilities for the formation of emotional intelligence and feedback from students on the proposed forms of work.

II. MATERIALS AND METHODS

Thus, our research concerns the developments of the SEED:UE4UA module since 2022 and certain disciplines taught at the Vinnytsia Mykhailo Kotsiubynskyi State

Pedagogical University in the specialities of Inclusive Education and Speech Therapy since 2017 and related to the module topic.

Taking into account the tasks we set ourselves in this study, we analysed international and domestic scientific and pedagogical literature on distance education, in particular on the issues of synchronous and asynchronous formats of its implementation. This allowed us to further talk about the flexible format of distance education, which we came to due to the military-political situation (2014), quarantine restrictions (2019) and military escalation (2022).

For example, as part of the description of the flexible format, we presented the module itself and the forms of interaction with students that allow not only to enrich their knowledge on social inclusion, issues related to the environment of diversity, the experience of the European Union countries in implementing relevant strategies, but also to work out elements of practical activities through emotional inclusion during training exercises, reflection, simulation games, etc.

III. RESULTS

To address the first question, we identified as the main one. We can note that online education, also known as e-learning, has become increasingly important in recent years due to its advantages over classroom learning, which include significant savings in time, labour and material resources associated with managing an e-learning environment [5]. The advantages mentioned in almost all scientific reviews are the issue of opportunity:

- to receive education at an individual pace;
- reduce the interaction between students and teachers, or between teachers and students;
- to get rid of time and space constraints by using asynchronous and synchronous networked learning models [5] – [7].

If we look at the first attempts to organise online learning, we should understand that its organisation was based on the use of the so-called Web 1.0, which could ensure student participation only as a passive consumer of content provided by teachers. The evolution of Web 1.0 to Web 2.0 facilitated the use of e-learning in a more interactive form [5] although in Ukrainian society the process of using Web 1.0 can be considered as having been leapfrogged (within the framework of obtaining professions of the humanitarian cycle, such as psychologist, social worker, teacher, etc.) After all, by and large, those offers that entered the market and became available to the general public already had a Web 2.0 format (some of them were described in our previous analytical article on the proposed online courses for training inclusive education specialists).

It is also worth noting that, in addition to the advantages, scientists themselves note that distance education, in particular asynchronous learning, while creating time advantages and other conveniences for students, has a number of difficulties for teachers. In particular:

- difficulty in retaining students in an e-learning classroom, due to the lack of personal contact between students and the teacher. That is, the inability to read non-verbal signals, boredom or frustration of your students [6].
- another difficulty in the case of teachers is their low readiness to use web programming technologies that allow them to easily develop Web 2.0 applications. Although most teachers are gradually mastering the skills of organising the educational process within the framework of the proposed educational platforms, in most cases, to build high-quality own content, it becomes necessary to go beyond the proposed products (for example, educational products from Google).

If we go deeper into this issue, even in Moodle, there is a need to record your own lecture, edit it, supplement and format it if necessary, and upload it to the platform. And these actions already require knowledge of the relevant software, the help of technical specialists, and high-quality presentation material in addition to video, which are combined to form the necessary content. Yes, of course, the time, technical and design costs will quickly pay for themselves, but only if the information is static and there is no need to update the discipline's materials. At the same time, we understand that in today's open information society, static information can affect the interest and participation of students in the process of studying the discipline. Today, once prepared content (video, text, podcast, etc.) should be gradually supplemented and updated with additional data that will promote interest in the discipline. This is particularly true for distance education, as the less social interaction and emotional involvement in work and learning, the less response to the content.

It is equally important to understand the differences, disadvantages and advantages of synchronous and asynchronous learning. In particular, the issues we have raised above, and in the issues that our colleagues in different parts of the world are considering.

Turning to terminology, we can outline the following. Synchronous learning is more similar to face-to-face learning due to its important feature of providing real-time communication [8]. Asynchronous learning, on the other hand, takes place entirely in an online classroom without a real-time component, using multimedia (video lectures, graphics and/or other visual and audio media), announcements, discussion forums (e.g., threaded discussions), and course materials designed and adjusted to facilitate the achievement of the course learning objectives [9]

In practice, we can observe that teachers already use asynchronous media, such as e-mail and discussion boards, but these methods are often insufficient [10]. The implementation of courses, in the humanities, requires access and availability of information through practical aspects and emotions "here and now". In addition, teachers should not only have digital skills themselves, but also be aware of the level of relevant skills and the availability of technical means for students to participate in distance learning processes within the course. It is worth noting that students do not always "reveal" the real level of technical skills and knowledge of Web 2.0 products, which creates

their own collapse in gaining knowledge, because repeated repetition of information already heard, exercises performed or practicing already acquired skills not only wastes productive time, but also motivation and interest in the subject matter.

Smartphone learning became one of the most used methods for Ukrainian students in 2022 and 2023, which also had to be considered when organising courses, making presentations in synchronous mode and offering video viewing in asynchronous format. This requires attention to the video quality and resolution of presentations, which had to be loaded at the lowest quality of 144p - 360p (if we take YouTube as a starting point), but not lose the clarity of the visuals for reading text and infographics with a screen diagonal of 4" and up to 6.5". This factor is no less important than the others, as more than fifty per cent of students at home use personal mobile data with a moderate Internet connection [11]. In addition to this, over these 5 years it has become clear that students prefer to stay at home and attend classes because they have available devices [12], with which we fully agree, observing the changes in the attitudes of students, their self-employment and involvement in professional activities externally, i.e. before completing their studies (in some cases in the 2nd or 3rd year of their bachelor's degree).

For teachers, an important component of the success of teaching the course is proper technical support for the synchronous teaching format, so that all students can attend online classes, regardless of the mode in which it was implemented; have recorded classes and high-quality live classes; receive instant feedback in live classes [7], [12]. In addition, for many students, the unusual distance in learning was difficult, and the use of their webcams in synchronous settings created discomfort for students [7] although no one has cancelled research on the inconvenience for teaching staff, but it has not been studied from a psychological point of view. Separately, the authors emphasised the feeling of diffuse relationships with their peers and were less likely to feel social support in online learning compared to traditional learning [7], in particular, this was the case in Ukrainian practice in the first two years of the full transition to distance education. This, in our opinion, was due to the frustration of the teaching staff due to the unpreparedness of the content for presentation in the online environment and the psychological challenges that arose as a result of the technical inability to provide the course; lack of close interpersonal contact, group presence and physiological sense of closeness with the participants of the educational process for students who are accustomed to traditional learning (sitting in class, going out for a break with peers and friends) and constant live communication. It is this lack of physical and social presence that affects students' engagement and interaction, which are important factors that influence satisfaction with online learning and, in turn, affect students' knowledge, skills and attitudes towards online learning [11]. Although the main advantages of synchronous online learning are real-time interpersonal communication, the use of natural language and immediate feedback, this type of learning interaction has been found to be less useful when discussing complex ideas or deep thinking [7]. In addition, many students also reported an increase in workload [7] but teachers also

raised the same issues, adding to them the lack of separation of personal and workspace.

At the same time, it is worth referring to the research of our colleagues and the practical experience gained regarding the gaps in asynchronous learning. According to scholars and researchers, although this format of interaction can allow students to work at their own pace and independently of time and place, not all students have the right strategies to take advantage of this potential advantage. After all, it requires more self-learning skills to keep up with the schedule, including adequate motivation and desire to achieve learning goals [13].

In addition, the complexity of teaching was to change the role of the teacher to a facilitator of knowledge building, skill acquisition and information transfer. And students were transformed from passive receivers to active participants in the process, whose role was to interact with course materials, other students and the teacher to understand, analyse and apply course concepts and skills in practice [9]

Thus, having identified the main advantages and disadvantages of synchronous and asynchronous learning, the theoretical aspects of forming a quality online classroom environment, we came to the need to revise and transform the SEED:UE4UA module syllabus and to meet not only the principles of e-learning, but also the needs and capabilities of students and, in particular, project teachers.

The difficulty of this process was that the basic development of the module concept, presentation and implementation was based on the traditional teaching format. However, due to the circumstances in Ukraine, this format had to be converted into an electronic format without losing the quantity and quality of the material presented. In this case, it was logical to transfer the course to a synchronous form of distance education, which should not have seriously affected the timing of sessions and the organisation of discussions or projects within the four sections. However, due to the escalation of the military-political situation and temporary communication blackouts, the lack of power supply and the need to take shelter in time during air raids, we had to provide a flexible format for the interaction between the project team and module participants to work through the material according to the class schedule and in accordance with the topic.

The module included the following sections:

1. European social inclusion studies, which included the following topics:
 - Topic 1: European markers of diversity and their role in inclusive education.
 - Topic 2. European practice of finding educational strategies based on environmental factors.
 - Topic 3. Psychological and pedagogical bases of forming an environment of diversity and quality of education for children with SEN in the EU and Ukraine.
 - Topic 4 Psychological and pedagogical foundations of creating an environment of diversity and quality of education for children with

learning difficulties, cultural differences, social barriers, geographical barriers.

2. Legal, social and pedagogical basis for preparing children with special needs for successful life: comparison of European and Ukrainian experience
 - Topic 1: Regulatory and legal support for inclusive education: European and Ukrainian lawmaking and legal implementation.
 - Topic 2. Legal support for people with disabilities in crisis situations: the mission of the state and public institutions in Europe and Ukraine
 - Topic 3: Legal protection of persons with disabilities in the context of inclusion: mechanisms of interaction for social adaptation
3. European practices of developing social competence of gifted children in the regional inclusive space
 - Topic 1: Status of gifted children as persons with special educational needs in the EU and Ukraine.
 - Topic 2. Social and psychological problems and special needs of gifted children in the scientific field of the EU and Ukraine
 - Topic 3. Social and pedagogical work with gifted children with disabilities (doubly disabled) in the EU countries.
 - Topic 4. Cooperation of teachers, social workers and representatives of social services in social and educational work with gifted children.
 - Topic 5. Socially oriented volunteer projects in work with gifted children.
4. Social and pedagogical support for children with disabilities in a diverse environment: EU experience
 - Topic 1: Socio-economic and political prerequisites for the development of socio-psychological support for children with disabilities in the EU.
 - Topic 2. The main international documents regulating the social and psychological support of children with disabilities in the EU countries.
 - Topic 3. The system of social and psychological support for children with disabilities in the EU countries.
 - Topic 4. Participation of young people in support programmes for children with disabilities in EU countries.

Each of the topics was prepared by the teachers in the format of .pdf files and presentations, which were available for reading in a joint Google class. Questionnaires and surveys were conducted using Google forms both for the general data and by each teacher separately according to the topics they taught.

As part of the supervisions to discuss the best options for implementing the module's goals and objectives, the project team decided to follow the CTBL approach: Comprehensive Technology-Based Learning [14], which allowed to refer to international documents and European

practice of implementing diversity and inclusion policies in education through students' basic knowledge of pedagogical, psychological, social and legal disciplines.

This was a convenient solution that covered the basic needs of both teachers to teach the course and students to gain the necessary knowledge and skills. In addition, some of the materials were dubbed in a specially created group on the Viber messenger. The main attributes included in this complex were [14]:

- textual materials that provided full coverage of the material in accordance with the module topics, and also included answers to questions and questionnaires within each of the sections proposed by the teachers;
- videos, which included:
 - videos from the YouTube video hosting service, which were related to the presentation of the EU experience on diversity and inclusion;
 - video messages, instruction from teachers (in some cases, audio messages, which were better delivered in conditions of limited traffic) to prepare and guide students to complete practical tasks in an asynchronous format; preparation of materials and tools for exercises conducted in a synchronous format; and to clarify certain topics whose detailed discussion during the online meeting was interrupted by an air raid. The use of this video and audio format had its advantages and disadvantages, but the main one was that such video/audio did not require special processing, cutting, gluing, or other manipulations with the video recording of the lecture material. In addition, at the second stage of the project, the project team began to include videos from popular social networks such as TikTok and Instagram, which were selected to enhance the effect of emotional inclusion, the formation of emotional intelligence through discussions, and social intelligence through the development of algorithms for interacting with children with SEN based on emotional experience;
- feedback questionnaires, but, unlike the proposed approach, at all stages of the module implementation in accordance with the needs of the team and each teacher separately;
- answers to the questions that we transformed into interviews at the end of the module to obtain feedback and included as separate questions in the questionnaire by section. Following this point allowed us not only to keep in touch with students, but also to respond to challenges in a timely manner in accordance with their needs, the purpose and objectives of the module.

In addition, as part of the module and the proposed trainings for working professionals, we were able to use non-standard forms of interaction, such as online challenges, the simulation game "Together", an educational hackathon on inclusive topics, which helped to consolidate the knowledge gained within the module, practice exercises to develop emotional and social intelligence, involve a wide audience in discussing the results of the work of

project participants and students involved in related disciplines in discussing the European experience within the module "Social integration of children with special needs in an environment of diversity and inclusion: European approaches"

IV. DISCUSSION

Among the problematic issues that arise during the work of the project team, it is worth noting such a thing as feedback in the form of interviews or feedback questionnaires in the classroom. In our opinion, it has its limitations, which relate to sincerity in statements, relevance to the topic and general involvement of students in the interaction, their inclusion in synchronous discussion, formed life position regarding people with special educational needs, as well as the European experience of shaping the educational environment through social, economic and cultural levers that differ from the student's personal position. All this creates a separate "bubble" of personal experience and professional development, which directly affect students' responses, their practical skills in implementing an educational programme for children with SEN and their contribution to innovations that change the educational paradigm and should promote diversity and inclusion policies.

This, in turn, creates prerequisites for rethinking the format of material presentation, visible gaps in student engagement and motivation during work. However, this factor does not fundamentally change the project's subject matter and goal. Rather, we, like all our colleagues in the international space, need to think about updating the principles and strategies for implementing the module in particular and all related disciplines in general.

This part may be subjective, but it is fundamental to our project and teaching, as it allows us to provide an individual approach to teaching, which is part of the issues of inclusion and diversity.

V. CONCLUSIONS

Given that we have reviewed a number of modern studies and practical cases on the meaning, principles, and possibilities of synchronous and asynchronous learning. We got acquainted with the results of studies on the impact of synchronous and asynchronous learning on student performance, which are not without ambiguity [Y.Ghilya, 2022]. In our practice of flexible combination of synchronous and asynchronous distance education, we have come to the conclusion that with the use of quality planning, supervision and team discussion of the strategy for implementing each of the project steps, the use of clear instructions in creating practical and theoretical cases for students, and quality discussion of the issues raised in the module topics, we can achieve significant results in accordance with the goals and objectives of the courses. Unfortunately, it is not possible to compare the results of the distance format of the SEED:UE4UA module itself with the traditional form of teaching today, as we started working in autumn 2022, so we can only judge the effectiveness of the course from the online classes.

This also does not change the fact that for the second year in a row, working in a flexible distance learning format, we continue to improve and look for the best

solutions to present European experience to the students of the project. This is due to the involvement of new tools of good pedagogical practice and ongoing discussion of the results of each of the four sections and the training offer for practicing teachers.

In general, addressing the issue of teaching the European experience of social inclusion, we should note that thanks to modern technological solutions, CTBL cases, distance education in the format of training, that is, the use of training exercises and simulation games to form social and emotional intelligence in synchronous and asynchronous formats, has every opportunity to function without immersion in the traditional format of training specialists in the field of social inclusion and diversity.

VI. ACKNOWLEDGMENTS

This project has been carried out with the support of the Erasmus+ programme of the European Union, Module «The Social Integration of Children with Special Needs in an Environment of Diversity and Inclusion: European Approaches» Project: 101085267 - SEEDUE4UA - ERASMUS-JMO-2022-HEI-TCH-RSCH (2022-2025).

REFERENCES

- [1] H. Dargahi, M. Kooshkebaghi, & M. Miresghollah. 2023. Learner satisfaction with synchronous and asynchronous virtual learning systems during the COVID-19 pandemic in Tehran university of medical sciences: a comparative analysis. *BMC Medical Education*, 23(1), 886
- [2] B. L. Moorhouse, K. M. Wong. 2022. Blending asynchronous and synchronous digital technologies and instructional approaches to facilitate remote learning. *Journal of Computers in Education*, 9(1), 51-70.
- [3] N. Dmitrenko, O. Voloshyna. 2018. Training of Prospective Teachers of Foreign Language to Work in Inclusive Classes. *Pedagogika*. Pedagogy/ Vol. 129, No. 1, pp. 187-205.
- [4] R. Kimura, M. Matsunaga, E. Barroga, N. Hayashi. 2023. Asynchronous e-learning with technology-enabled and enhanced training for continuing education of nurses: a scoping review. *BMC Medical Education*, 23(1), 505.
- [5] M. A. Fernández, M. J. Muñoz, J. M. Rivera, R. León, E. Escrig, I. Ferrero. 2013. Using Web 2.0 Learning Tools: Two Virtual Experiences?. In 2013 International Conference on Advanced ICT and Education (ICAICTE-13). pp. 454-458. Atlantis Press.
- [6] A. P. Pavel, A. Fruth, M. N. Neacsu. 2015. ICT and e-learning-catalysts for innovation and quality in higher education. *Procedia economics and finance*, 23, 704-711.
- [7] S. Fabriz, J. Mendzheritskaya, S. Stehle. 2021. Impact of synchronous and asynchronous settings of online teaching and learning in higher education on students' learning experience during COVID-19. *Frontiers in Psychology*, 12, 4544.
- [8] A. Mihai. 2014. The virtual classroom: Teaching European studies through webinars. *European Political Science*, 13, 4-11.
- [9] G. Edmonds, & R. Pusch. 2022. Guidance for Designing Asynchronous Learning Experiences for Adult Learners. Region 5 Comprehensive Center.
- [10] S. Hrastinski. 2008. The potential of synchronous communication to enhance participation in online discussions: A case study of two e-learning courses. *Information & Management*, 45(7), 499-506.
- [11] S. Z. M. Osman. 2022. Combining Synchronous and Asynchronous Learning: Student Satisfaction with Online Learning Using Learning Management Systems. *Journal of Education and E-Learning Research*, 9(3), 147-154
- [12] P. R. Nisha. 2022. Synchronous and Asynchronous E-learning Styles: Exploring the Effectiveness of Virtual Classes on Tertiary Level EFL Learners. *Journal of Sustainable Learning and Development*, 2(1), 07-12.

- [13] Y.Ghilay. 2022. Quantitative Courses in Higher Education: A Comparison Between Asynchronous and Synchronous Distance Learning. *Journal of Education and Learning*, 11(5).
- [14] Y. Ghilay. 2017. ODL: Online Distance Learning of Quantitative Courses in Higher Education. *Advances in Social Sciences Research Journal*, 4(18) 62-72.

Application of AI-Enhanced Image Processing Methods for Educational Applied Physics Experiments

Eivin Laukhammer

Vilnius Kolegija, Faculty of
Electronics and Informatics
J. Jasinskio st. 15, LT- 01111 Vilnius,
Lithuania
E-mail: e.macerauskas@eif.viko.lt

Eugenijus Mačerauskas

Vilnius Kolegija, Faculty of
Electronics and Informatics
J. Jasinskio st. 15, LT- 01111 Vilnius,
Lithuania
E-mail: e.macerauskas@eif.viko.lt

Andžej Lučun

Vilnius Kolegija, Faculty of
Electronics and Informatics
J. Jasinskio st. 15, LT- 01111 Vilnius,
Lithuania
E-mail: e.macerauskas@eif.viko.lt

Antoni Kozič

Vilnius Kolegija, Faculty of
Electronics and Informatics
J. Jasinskio st. 15, LT- 01111 Vilnius,
Lithuania
E-mail: e.macerauskas@eif.viko.lt

Romanas Tumasonis

Vilnius Kolegija, Faculty of
Electronics and Informatics
J. Jasinskio st. 15, LT- 01111 Vilnius,
Lithuania
E-mail: e.macerauskas@eif.viko.lt

Abstract. This article examines the use of an AI-powered automated image analysis system. The system's purpose is to enhance the workflow of students during applied physics laboratory experiments, helping them analyze images and perform accurate microobject counting. On the software side, the system incorporates machine learning algorithms for visual processing applications using Python and its' extension libraries – CV2, Tensorflow, Keras, SkLearn etc.. The hardware consists of a camera and microprocessor, which, in conjunction with the image processing software, perform microobject recognition and counting in real-time. The goal is to automate applied physics laboratory experiments in which the counting of microobjects, be it organic or human-made, is usually done manually. During these applied physics laboratory experiments and with the aid of this system, students are exposed to a modern workflow, further preparing them for future work environments, teaching them about process automation, and further increasing their interest in micro-scale related science subjects. Automation using image processing technology combined with automatic data logging from images allows for fast and accurate micro-object counting.

Keywords: *Image Processing, Interdisciplinary Connections, Experiments Automation.*

I. INTRODUCTION

Blood cell counting by laboratory utilizes a microscope. This conventional task is laborious and time consuming, and is largely dependent on the physician's

skill. Fast and cost-effective production of blood cell count reports is of paramount importance in the health care industry. The traditional method of manual counting under the microscope yields inaccurate results and puts an intolerable amount of stress on the medical laboratory assistants [2]. Automated analysis of medical cell images has been gaining more importance in pharmacology and toxicology practice. Extraction of accurate quantitative data about the cell morphology is a critical task. An automated procedure for cell analysis is highly desirable since there may exist hundreds of images for each patient. In fact, one of the most challenging tasks is to extend the traditional approaches to segmentation and object classification.

In physics laboratories, students usually get their first touch with the microscope, which is a very important part of diagnostic laboratories. As mentioned previously microscopes are usually equipped with advanced software to diagnose, measure, or count specific particles found in patient fluids or tissues. But the first-year medical students are learning those techniques by hand. Working with a microscope using precise methods that are usually very time-consuming for the students as well as professors also that method is becoming outdated having in mind that applied sciences university's goal is to prepare students for future jobs as well as possible. The stained blood smears are typically viewed and identified with an upright brightfield microscope such as ZEISS AxioLab A1 [2].

Print ISSN 1691-5402
Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8068>

© 2024 Eivin Laukhammer, Eugenijus Mačerauskas, Andžej Lučun, Antoni Kozič, Romanas Tumasonis.
Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

Precise medical drawings can still be found in use as reference images today (Figure 1).

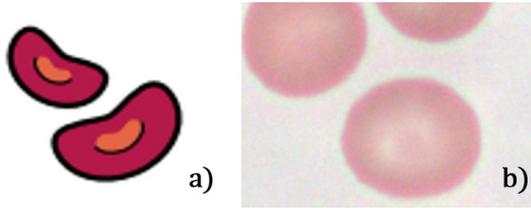
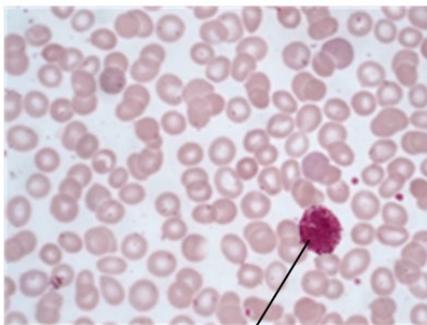


Fig 1. Model (a) + Real Erythrocyte (b) of blood cells

Maximum optical performance can only be achieved through the interaction of all the optical components, such as the lens, condenser, and eyepiece. A microscope camera with a high dynamic range precise image acquisition at the pixel level should be used to document or archive the results [3], [8].

The examination of blood under a microscope is a precise and equally complex procedure. The distinguishing features of the blood cells that are revealed must be clearly displayed in order to be classified correctly by the “eye of the trained observer” during daily routine activities [23], [25].

The traditional microscopic method based on the count of 100 cells has three types of errors: statistical error, distributional error owing to unequal distribution of cells in the smear, and error in identifying cells related to the subjective interpretation of the examiner. This method, therefore, suffers from imprecision, poor accuracy, and reduced clinical sensitivity [14], [15]. An example of an unknown object (Cancer) in blood is shown in Figure 3.



Blood Cancer cell

Fig 3. Blood Cancer cell detection example

Image processing applications are very important in medical diagnostics, and incorporating them in education makes the learning process faster and introduces medical students to technologies they will see later in life. With this technology, the motivation of students can be improved because they see the possible opportunities for the future. Figure 4.

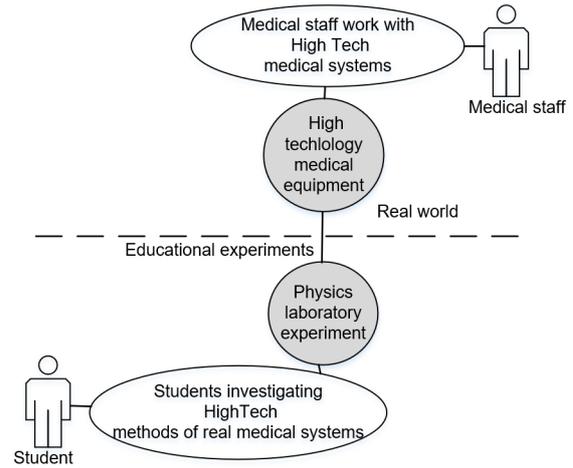


Fig 4. Introducing high-tech methods for the education process to improve student motivation

Due to fast improvements in hardware and software, physics laboratories can be provided with very precise measuring and counting software that uses video or photo analysis.

II. REALIZATION OF AN EXPERIMENTAL EDUCATIONAL SYSTEM

The modern information technology application to computer-based experiments is conducted on similar methods. With modern image processing technologies, Python programming, and OpenCV libraries, the system for automated physics laboratory experiments was created (Fig. 5).

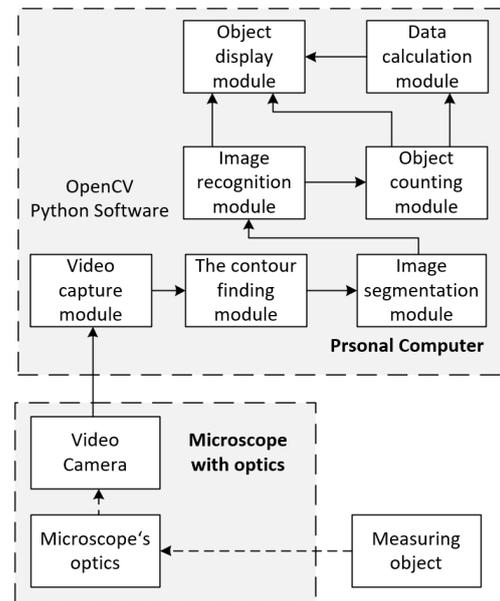


Fig 5. Block diagram for the system

The system consists of created software developed on a personal computer and a hardware measurement system consisting of a microscope and a video camera.

The research object is measured by the comparison method, where the dimensions of the measured object are compared with the dimensions of the reference object. The

resulting image enters the video camera through a microscope, and the camera converts it into a video signal. Several libraries can be utilized for image processing, classification, and counting tasks in Python to achieve different aspects of these tasks. In particular, the machine learning and deep learning libraries (TensorFlow, Keras, PyTorch) would be very useful for classification and counting. They provide algorithms to classify images after being trained on labeled data and perform object detection and counting. OpenCV also supports some machine learning algorithms and can be used with these libraries for such tasks [5], [8], [27].

Fungi classification

In image processing, the classification of fungi involves the use of algorithms and computational techniques to identify and categorize different types of fungi based on images. This process is significant in various fields, such as agriculture, food safety, environmental monitoring, and medical diagnosis. Image processing for fungi classification [6], [13], [17], [21].

Os: This is a standard Python library for interacting with the operating system. It provides functions for file and directory operations.

NumPy (np): NumPy is a fundamental package for numerical computing in Python. It supports large, multi-dimensional arrays and matrices and a collection of mathematical functions to operate on these arrays.

matplotlib.pyplot (plt): Matplotlib is a plotting library for Python. Pyplot is a module in Matplotlib that provides a MATLAB-like interface for creating and customizing plots.

seaborn (sns): Seaborn is a statistical data visualization library based on Matplotlib. It provides a high-level interface for drawing attractive and informative statistical graphics.

keras.applications.vgg16: Keras Applications provides pre-trained deep learning models for use in various applications. VGG16 is one such pre-trained convolutional neural network (CNN) model that is known for its simplicity and effectiveness.

keras.models: This module in Keras provides the basic building blocks for defining neural network models. It includes classes like Model for defining models and Sequential for creating models' layer by layer.

keras.layers: This module contains various layer implementations that can be used to build neural networks. We incorporated layers such as Flatten, Dense, Dropout, Conv2D, MaxPooling2D, and LeakyReLU.

keras.preprocessing.image: This module provides utilities for preprocessing image data and performing data augmentation. It includes functions for loading images from disk, resizing, and applying transformations.

keras.optimizers: This module contains implementations of various optimization algorithms that can be used to train neural networks. The Adam optimizer is an adaptive learning rate optimization algorithm that is widely used in training deep neural networks. It stands for Adaptive Moment Estimation and combines ideas from

two other popular optimization algorithms: AdaGrad and RMSProp.

keras.callbacks: Keras callbacks are objects that can perform actions at various stages of training (e.g., at the start or end of an epoch). Examples include EarlyStopping, ModelCheckpoint, and ReduceLROnPlateau, which help control the training process and prevent overfitting.

sklearn.metrics: This module from scikit-learn provides functions for evaluating the performance of machine learning models.

keras.regularizers: Keras provides support for adding regularization to neural network layers. Regularization techniques like L2 regularization (weight decay) can help prevent overfitting by adding a penalty term to the loss function.

keras.backend (K): This module provides functions that operate on tensors, which are the basic data structures used in neural networks. It abstracts away the backend implementation (e.g., TensorFlow, Theano) and allows for writing code that is backend-agnostic.

cv2: OpenCV (Open Source Computer Vision Library) is a library of programming functions mainly aimed at real-time computer vision. The cv2 module provides functions for image processing, manipulation, and computer vision tasks.

tensorflow (tf): TensorFlow is an open-source deep learning framework developed by Google. Keras can run on top of TensorFlow, providing a high-level interface for building and training neural networks. In our case TensorFlow is being used as the backend for Keras. Dataset [19], [21], [24].

License: For Fungi detection, the DeFungi Dataset was chosen [4], [10], [11]. It is being used under Attribution 4.0 International (CC BY 4.0 DEED) license, which allows us to use the dataset freely and to train our machine learning model based on this dataset.

The dataset consists of 5 classes:

- H1: Candida albicans
- H2: Aspergillus niger
- H3: Trichophyton rubrum
- H5: Trichophyton mentagrophytes
- H6: Epidermophyton floccosum

TABLE 1 DEFUNGI DATASET CLASS DISTRIBUTION

Class	Training set	Validation Set	Test Set
H1	1000	437	437
H2	1000	232	233
H3	1000	81	82
H5	1000	80	80
H6	1000	69	70
Total	5000	899	902

In order for the model to accurately predict a given class from an input image, the dataset needs to be diverse enough so that the model can train on all kinds of scenarios

and accurately predict a class given almost any circumstance: (Fig 6.).

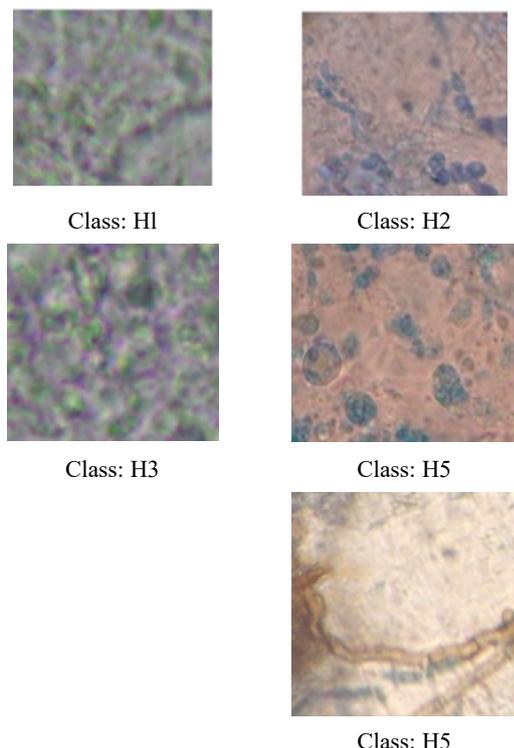


Fig 6. Example images from different class

Curating Challenging Examples: Including challenging examples in the dataset helps the model learn to handle complex scenarios and edge cases. These examples may include occluded objects, objects under different poses, cluttered backgrounds, variations in illumination, and other challenging conditions. By exposing the model to diverse and challenging examples during training, it becomes more resilient and capable of making accurate predictions in real-world scenarios.

Class Balancing Techniques: Addressing class imbalance is essential for ensuring that the model receives sufficient training examples for each class. Techniques such as oversampling minority classes, undersampling majority classes, or using synthetic data generation methods help balance the distribution of samples across classes. This ensures that the model does not become biased towards predicting the majority class.

Data Augmentation: Data augmentation involves applying a variety of transformations to existing images to create new, slightly modified versions of them. Common augmentation techniques include rotation, flipping, scaling, cropping, translation, brightness adjustment, and adding noise. Augmentation helps introduce variability into the dataset and enables the model to learn invariant features across different conditions.

Data augmentation techniques used:

Rescaling (Normalization): The rescale parameter is set to 1/255 for all data generators (train, validation, and test).

Rotation Range: Rotation range is set to 40 degrees. Rotation augmentation helps the model become more robust to variations in object orientations.

Width and Height Shift Range: Width and height shift ranges are set to 20% of the total width and height, respectively. This augmentation technique introduces translations of the image horizontally and vertically.

Shear Range: Shear range is set to 20%, and involves stretching or skewing the image along its x-axis or y-axis.

Zoom Range: Zoom range is set to 20%. Zoom augmentation allows the model to learn from images at different scales.

Horizontal Flip: Horizontal flip is enabled (horizontal_flip=True). Horizontal flipping mirrors the image horizontally, providing additional training examples while maintaining the same class label.

Fill Mode: The fill mode is set to 'reflect'. The fill mode determines the strategy used for filling in newly created pixels that may arise during augmentation, such as after rotation or shifting operations.

In summary, by employing these data augmentation techniques, the model is exposed to a more diverse set of training examples, which helps improve its generalization ability and robustness to variations in input data, ultimately enhancing its performance on unseen data.

Neural Network architecture.

Base Model (VGG16): VGG16 is a pre-trained convolutional neural network architecture that has been trained on the ImageNet dataset [18]. Additional parameter: include top=False parameter means that the fully connected layers (the classifier part) of the VGG16 model are not included [16]. This parameter allows for adding custom fully connected layers on top of the convolutional base. The input shape is set to (64, 64, 3), which is the shape of the dataset images [20], [22].

Neural Network architecture shown in Figure 7.

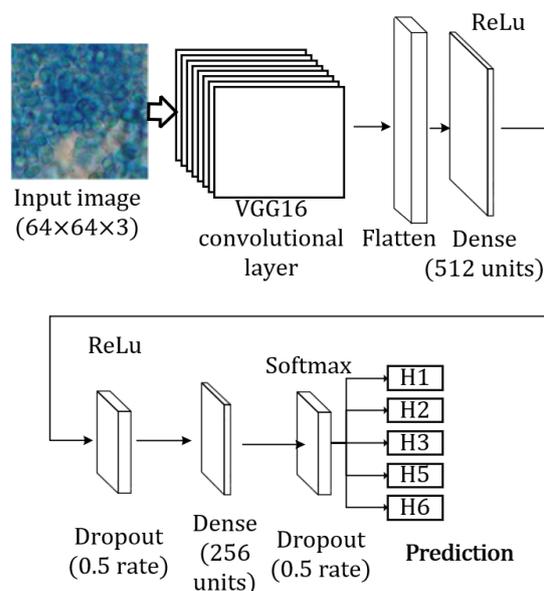


Fig 7. Neural Network architecture

Additional CNN Layers:

- After the base model, there's a Flatten layer to flatten the output of the base model before passing it to the fully connected layers.
- Two Dense layers are added with 512 and 256 units respectively. Each Dense layer is followed by a LeakyReLU activation function with an alpha of 0.1, which helps prevent the dying ReLU problem by allowing a small, positive gradient when the unit is not active.
- Dropout layers with a rate of 0.5 are added after each Dense layer to prevent overfitting by randomly dropping a proportion of the units during training.
- Finally, there's a Dense layer with 5 units (since the model is trained on 5 classes) and softmax activation function to output probabilities for each class.

Freezing Layers: All layers of the pre-trained VGG16 model are frozen, meaning their weights will not be updated during training. This is a common technique in transfer learning to prevent the pre-trained weights from being destroyed [26].

Optimizer: Adam optimizer is used with a learning rate of 0.0001 and a decay rate of 1e-6. The learning rate decay is applied to gradually reduce the learning rate during training, which can help the model converge better towards the end of training. Adam optimizer combines the benefits of AdaGrad and RMSProp optimizers. It maintains per-parameter learning rates and adapts them based on the moving averages of the first and second moments of the gradients.

Callbacks: EarlyStopping monitors the validation loss and stops training if there's no improvement after a certain number of epochs (patience). It helps prevent overfitting.

ReduceLRonPlateau: Reduces the learning rate when the validation loss has stopped improving, which can help the model to converge better.

ModelCheckpoint: Saves the best model based on validation loss.

Training

The model is trained using the mode.fit() method with the training and validation generators. The number of steps per epoch and validation steps are calculated based on the number of samples and batch size of the generators.

To summarize, this architecture is structured for transfer learning with VGG16 as the base model, and it utilizes techniques like dropout regularization, learning rate decay, and early stopping to prevent overfitting and improve convergence.

Model evaluation

Models' performance was evaluated by generating a classification report and confusion matrix.

TABLE 2 CLASSIFICATION REPORT

	precision	recall	f1-score	support
H1	0.49	0.54	0.52	437
H2	0.32	0.21	0.26	233
H3	0.09	0.10	0.09	82
H5	0.13	0.16	0.14	80
H6	0.10	0.10	0.10	70
accuracy			0.35	902
macro avg	0.23	0.22	0.22	902
weighted avg	0.35	0.35	0.35	902

From the classification report we can see that the H1 class was most effectively trained, producing the highest f1-score out of all evaluated classes. These results also show that the dataset has a class imbalance that the data augmentation techniques were not able to account for completely. The culprit is most likely that the training images were not that similar to the validation images, therefore resulting in a somewhat poor classification capability.

Train images examples for H1 shown in Figure 8.

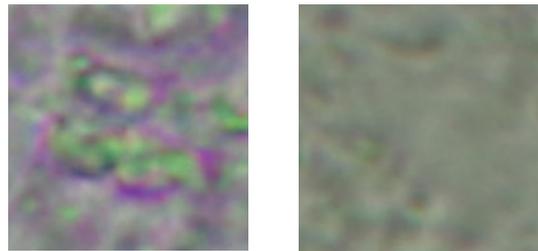


Fig. 8. H1 Train image examples

From the classification report we can see that the H1 class was most effectively trained, producing the highest f1-score out of all evaluated classes. These results also show, that the dataset has a class imbalance that the data augmentation techniques were not able to completely account for. The culprit is most likely that the training images were not that similar to the validation images, therefore resulting in a somewhat poor classification capability (Fig. 9).

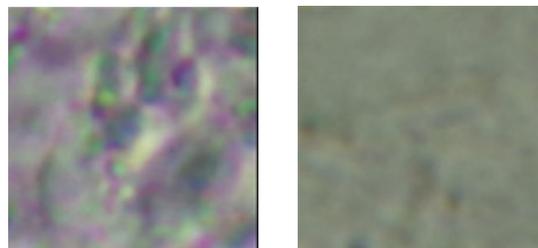


Fig. 9. H1 Validation image examples

The other issue with the dataset is it's image size. One image is 64 by 64 pixels, which is fairly small. An image upscaling algorithm could be used to increase the fidelity of the images, though the problem would be finding an algorithm that would properly work on the provided image type, since most upscales are trained on more common types of objects. The confusion matrix shown in Figure 10.

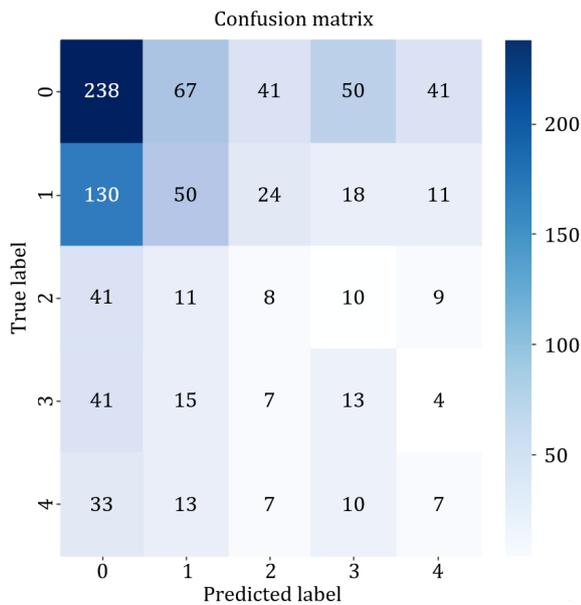


Fig 10. Confusion Matrix

Confusion matrix class labels – 0 is H1, 1 is H2, 2 is H3, 3 is H5, 4 is H6.

Some insights from the confusion matrix:

- The overall accuracy of the classification algorithm is 69%, which is calculated by dividing the sum of the diagonal cells by the total number of data points.
- The algorithm is most accurate at classifying H1, with an accuracy of 81%.
- The algorithm is least accurate at classifying H5, with an accuracy of 40%.
- The algorithm is more likely to misclassify H1 as H2 and H3 as H5.

The model accuracy vs epochs graph shows the Figure 11. Increasing accuracy of the model after a given number of epochs.

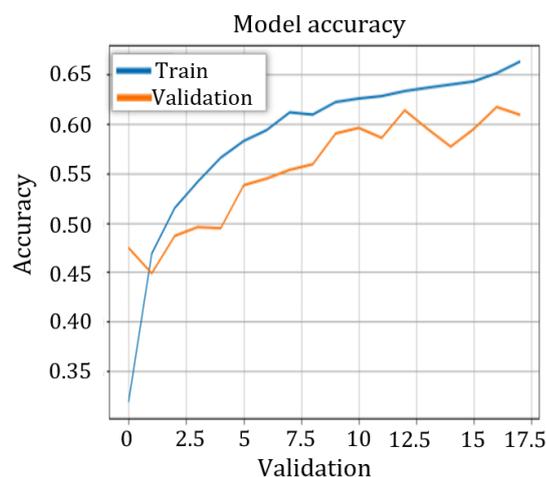


Fig 11. Model accuracy vs Epoch

The largest increase in accuracy occurs during the first 5 training epochs, after which the accuracy evens out. The blue line represents the training data and the orange line represents the validation data. Looking at the validation

data line, we can yet again confirm the imbalance of the dataset, seeing that the model is not quite capable of easily increasing its validation accuracy after each training epoch, as it doesn't always increase.

III. RESULTS

Measurement example:

In applying artificial intelligence, a measuring system was utilized to conduct initial practical experiments in applied physics. The system counted cells with 93% accuracy compared to visually counted method in classic way. The example of computer screen during laboratory experiment, presented in Figure 12.



Fig 12. Cells count = 156

One of the most important aspects, in terms of the application of automated image analysis based on dedicated algorithms, is the time required for image analysis. Traditional techniques for the quantitative determination are universal and efficient but, simultaneously, time-consuming (the classical manual method would take at least 50% longer).

The Figure 13 how students of different courses and different specialties can cooperate in an interdisciplinary way designing AI-based system and during applied physics experiments.

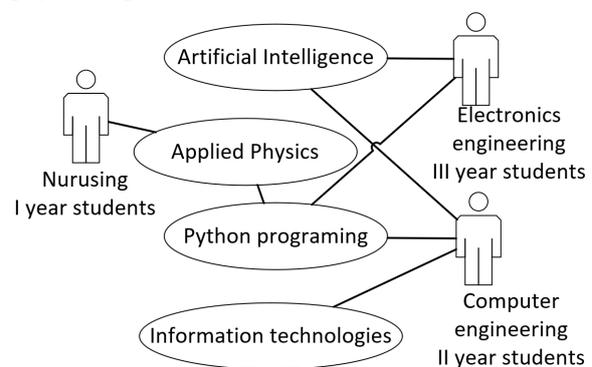


Fig 13. The interdisciplinary connections between different subjects.

The physics experiment of medical microscopy is designed for I year Nursing students who study Applied Physics. The III-year Electronics Engineering students participate in designing the physics experiment hardware and software. While developing the Applied physics

experiment system, they study subjects such as Artificial Intelligence and Python programming. Together with II-year Computer Engineering students, they create the software and hardware for the experiment. In this way, students of different specialties and different years not only learn the knowledge of their subject during their studies but also apply it to improve the study process on an interdisciplinary principle.

IV. CONCLUSION

The following conclusions can be made from the analysis of the application of the AI- based physics laboratory experiment developed by the students:

- AI-based Image processing applications for physics laboratory experiments facilitate the experimentation process and reduce the time spent on the analysis.
- During the first year, the student understands the practical benefits of the individual studies, and this option increases student motivation
- The automated system not only increased the interest of the students in experimental work, automation, and application of new technologies but also facilitated the professors' work by performing complex laboratory experiments that require a lot of precision work

AI-based image analysis methods can be successfully used for accurate, efficient and fast image analysis and widely applied in the learning process.

A comparison of traditional and automated image processing methods allows students to more easily understand the essence of modern research, to highlight the advantages and disadvantages of the methods.

ACKNOWLEDGMENT

This work has been supported by the Research Council of Lithuania (Project No. P-ST-23-168).

REFERENCES

- [1] J. Aaron, T.L. Chrew, (2021), A guide to accurate reporting in digital image processing – can anyone reproduce your quantitative analysis? *Journal of Cell Science*, Volume 134, Issue 6. <https://doi.org/10.1242/jcs.254151>
- [2] M. Buttarello and M. Plebani. Automated Blood Cell Counts: State of the Art. *American Journal of Clinical Pathology*, 130(1):104–116, 2008.
- [3] I. Cinar, Y. S. Taspinar, Detection of Fungal Infections from Microscopic Fungal Images Using Deep Learning Techniques, proceedings of 11th International Conference on Advanced Technologies (ICAT'23), Istanbul-Turkiye, August 17-19, 2023. [DeFungi]
- [4] Defungi Dataset <https://ui.adsabs.harvard.edu/abs/2021arXiv210907322P/> [Accessed: Dec. 17, 2023]
- [5] I. Goodfellow, Y. Bengio, A. Courville, & Y. Bengio, (2016). *Deep learning* (Vol. 1). MIT press Cambridge.
- [6] A. Gulli, & S. Pal, (2017). *Deep learning with Keras*. Packt Publishing Ltd.
- [7] R. Hayes, G. Pisano, D. Upton, and S. Wheelwright, *Operations, Strategy, and Technology: Pursuing the competitive edge*. Hoboken, NJ: Wiley, 2005.
- [8] K. He, X. Zhang, S. Ren, & Sun, J. (2016). Deep residual learning for image recognition. In *Proceedings of the IEEE conference on computer vision and pattern recognition* (pp. 770-778).
- [9] B. Herman and J. J. Lemasters (eds.), *Optical Microscopy: Emerging Methods and Applications*. Academic Press, New York, 1993, 441 pp.
- [10] L. Howell et al. (2021), Multi-Object Detector YOLOv4-Tiny Enables High-Throughput Combinatorial and Spatially-Resolved Sorting of Cells in Microdroplets, *Advanced Materials Technologies* <https://doi.org/10.1002/admt.202101053>
- [11] R. Lücking, S. D. Leavitt, & Hawksworth, D.L. Species in lichen-forming fungi: balancing between conceptual and practical considerations, and between phenotype and phylogenomics. *Fungal Diversity* 109, 99–154 (2021). <https://doi.org/10.1007/s13225-021-00477-7>
- [12] B. Matsumoto *Cell Biological Applications of Confocal Microscopy*, Second Edition (Methods in Cell Biology) (Methods in Cell Biology, 70).
- [13] L. Picek, M. Šulc, J. Matas, J. Heilmann-Clausen, T.S. Jeppesen, E. Lind. (2022), Automatic Fungi Recognition: Deep Learning Meets Mycology. *Sensors*. 2022; 22(2):633. <https://doi.org/10.3390/s22020633>
- [14] J. Poomcokrak and C. Neatpisarnvanit. Red Blood Cell Extraction and Counting. In *Proceedings of the 3rd International Symposium on Biomedical Engineering*, 199–203, 2008.
- [15] G. P. M. Priyanka, O. W. Senevirante, R. K. O. H Silva, and W. V. D. Soysa and C. R. De Silva. *An Extensible Computer Vision Application For Blood Cell Recognition And Analysis*, 2006
- [16] H. Qassim, A. Verma and D. Feinzimer, "Compressed residual-VGG16 CNN model for big data places image recognition," 2018 IEEE 8th Annual Computing and Communication Workshop and Conference (CCWC), Las Vegas, NV, USA, 2018, pp. 169-175, doi: 10.1109/CCWC.2018.8301729. [VGG16]
- [17] A. Rohani, M. Mamarabadi, Free alignment classification of dikarya fungi using some machine learning methods. *Neural Comput & Applic* 31, 6995–7016 (2019). <https://doi.org/10.1007/s00521-018-3539-5>
- [18] O. Ronneberger, P. Fischer, & T. Brox, (2015). U-net: Convolutional networks for biomedical image segmentation. In *International Conference on Medical image computing and computer-assisted intervention* (pp. 234-241).
- [19] S. A. Sanchez et al., 2020 IOP Conf. Ser.: Mater. Sci. Eng. 844 012024. doi 10.1088/1757-899X/844/1/012024 [tensorflow]
- [20] T. Shi, N. Boutry, Y. Xu and T. Géraud, (2022) Local Intensity Order Transformation for Robust Curvilinear Object Segmentation, in *IEEE Transactions on Image Processing*, vol. 31, pp. 2557-2569, 2022, doi: 10.1109/TIP.2022.3155954.
- [21] F. K. Shler, B. A. Sallow, (2022), Disease Diagnosis Systems Using Machine Learning and Deep learning Techniques Based on TensorFlow Toolkit: A review. *AL-Rafidain Journal of Computer Sciences and Mathematics*, 16 (1), 111-120. doi: 10.33899/csmj.2022.174415
- [22] K. Simonyan, & A. Zisserman. (2014). Very deep convolutional networks for large-scale image recognition. *arXiv preprint arXiv:1409.1556*.
- [23] Y. Skaf, R. Laubenbacher, "Topological data analysis in biomedicine: A review, *Journal of Biomedical Informatics*, Volume 130, 2022, 104082, mISSN 1532-0464, <https://doi.org/10.1016/j.jbi.2022.104082>.
- [24] S. S. Sumit et al 2020 *J. Phys.: Conf. Ser.* 1529 042086, doi 10.1088/1742-6596/1529/4/042086
- [25] O. Wu, F. Merchant, K. Castleman (2008). *Microscope image processing*. Academic Press is an imprint of Elsevier, UK, 2008. ISBN13 9780123725783
- [26] H. Yang, J. Ni, J. Gao, et al. A novel method for peanut variety identification and classification by Improved VGG16. *Sci Rep* 11, 15756 (2021). <https://doi.org/10.1038/s41598-021-95240-y> [VGG16]
- [27] A. Gulli, & S. Pal, (2017). *Deep learning with Keras*. Packt Publishing Ltd.

Title Organising Personalised Learning in the English Language Classroom: Computer Engineering and Information Technology Undergraduates Perspectives

Oleksandr Malykhin
Department of Didactics
Institute of Pedagogy of NAES of
Ukraine
Kyiv, Ukraine
malykhinalex1972@gmail.com

Nataliia Aristova
Department of International
Relations and Scientific Cooperation
Institute of Pedagogy of NAES of
Ukraine
Kyiv, Ukraine
n.aristova.na@gmail.com

Liudmyla Dybkova
Department of Informatics and
Systemology
Kyiv National Economic University
named after Vadym Hetman
Kyiv, Ukraine
dybkova.kneu@ukr.net

Abstract. *The more rapidly the area of information technologies develops, the higher are the requirements for training Computer Engineering and Information Technology students. Computer Engineering and Information Technology students training should be aimed at equipping them with subject-specific knowledge, on the one hand, and skills of the 21st century including strong communication skills in English, on the other hand. As practice shows good communication skills in English may lead to better job opportunities, more stable and prosperous future. The desire to succeed in mastering communication skills in English is directly related to Computer Engineering and Information Technology students' attitudes towards both English as a discipline and activities used in the English language classroom. Computer Engineering and Information Technology students show interest and enjoy learning only when it becomes personally meaningful to them. The research aim is to find out Computer Engineering and Information Technology undergraduates' opinions on organising personalised learning in the English language classroom aimed at developing their communication skills. The researchers used a convenience sampling technique to select the research population. The research population comprised 273 Computer Engineering and Information Technology first and second year students from Kyiv National Economic University named after Vadym Hetman and Kyiv National University of Technologies and Design. To collect statistical data on Computer Engineering and Information*

Technology undergraduates' opinions on organising personalised learning in the English language classroom the team of researchers developed a questionnaire and data collection took place in September-December 2023.

Keywords: *Computer Engineering and Information Technology undergraduates; English communication skills; English language personalised learning.*

I. INTRODUCTION

Advances in the area of information technology are significantly changing the labour market worldwide and the university graduates as its new entrants should be able to respond to all the challenges of the 21st century. And that is especially true for Computer Engineering and Information Technology students, since the more rapidly the area of information technologies develops, the higher are the requirements for their training. Present-day scholars and practitioners from around the world express their opinion that university training (including the training of Computer Engineering and Information Technology students) should be aimed at equipping them with subject-specific knowledge, on the one hand, and skills of the 21st century including strong communication skills in English, on the other hand [1], [2]. Moreover, as practice shows good communication skills in English may lead to better job opportunities, more stable and prosperous future. The desire to succeed in mastering communication skills in English is directly related to Computer Engineering and Information Technology students' attitudes towards both English as a discipline and activities used in the English language classroom. Computer Engineering and Information Technology students show interest and enjoy learning only when it becomes personally meaningful to them.

Present-day scientific pedagogical literature operates with such a concept as personalised learning and present-day university teachers have all the possibilities (a wide

Print ISSN 1691-5402
Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8092>

© 2024 Oleksandr Malykhin, Nataliia Aristova, Liudmyla Dybkova.
Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

range of methods, techniques and tools) to personalise learning for their students. We believe that English as a medium of instruction creates favourable conditions for comprehensive development of good communication skills in English among Computer Engineering and Information Technology undergraduate students through personalising their learning.

Akyuz defines personalised learning as “an educational approach that aims to customise learning for each student’s strengths, needs, skills and interests” [3].

Bulger claims that personalized learning “describes adaptation to a students’ unique combination of goals, interests, and competencies and the ongoing process of shifting instruction as these conditions change” [4].

In the research “A systematic literature review of personalized learning terms” Shemshack and Spector explain that “Learning is formed through an individual’s interactions, including the conveyance of knowledge and skills from others and experiences. So, learning is a personalized experience that allows one to expand their knowledge, perspective, skills, and understanding” [5]. The researchers are convinced that one of the main advantages of personalized learning is that educational process based on its principles can improve both learners’ motivation and their academic achievements. Shemshack and Spector aim to find out the connection between such terms as “personalised learning” and “adaptive learning”, “individualised instruction”, and “customised learning”.

We do believe that the main difference between individualised instruction and personalized learning is that individualised instruction “promotes either gaining or mastering students’ theoretical knowledge and practical skills (including filling the gaps in their knowledge or skills) on the basis of their individual and psychological peculiarities, needs or interests” [6] and personalised learning is targeted at adapting learning to changing needs of students and to changes in their personal and professional development.

We define personalised learning as a teaching and learning approach focused on creating favourable learning conditions in the classroom with the aim to expand students’ knowledge and develop soft skills necessary for achieving success in the personal and professional lives. In the English language classroom personalisation of learning means considering the levels of students’ language proficiency, their learning styles, interests and needs with the aim to develop or master their English communication skills. Moreover, personalised learning in the English language classroom enables to increase students’ motivation of learning English, to develop their self-learning, independent and critical thinking skills, to adapt learning content to their interests, learning styles and evident knowledge.

We fully agree with Shah, Syeda and Naseer that “communication skills include the ability to use language efficiently” [7] and their development is important for all aspects of students’ lives, namely, personal, professional and social.

Gruba and Al-Mahmood focus on the fact that in Australia Computer Science graduates are expected to

have good communication skills including interpersonal skills, teamwork and effective writing [8].

Havill and Ludwig believe that “as communication is central to research, the practice of oral communication in computer science can serve to introduce students to and excite them about conducting their own research” [9], computer science students should have good oral communication skills which include preparation skills, delivery skills and presentation skills.

Asemanyi expresses the idea that university education should promote the development of oral and written communication skills among students [10]. The researcher who is convinced that students should have these skills to communicate in a proper manner gives some examples of them, namely, note-taking and note-making skills, reading skills, conventions of usage and writing skills.

Thus, we can state that good communication skills of professionals in the field of Computer Engineering and Information Technology are crucial. Communication skills in general and English communication skills enable them to cooperate and collaborate with their colleagues and to interact with clients, to express their ideas and to ensure effective knowledge transfer.

The research aim is to find out Computer Engineering and Information Technology undergraduates’ opinions on organising personalised learning in the English language classroom aimed at developing their communication skills.

II. MATERIALS AND METHODS

The researchers used a convenience sampling technique to select the research population. The research population comprised 273 Computer Engineering and Information Technology undergraduates from Kyiv National Economic University named after Vadym Hetman and Kyiv National University of Technologies and Design. Distribution of respondents is given in Table 1.

TABLE 1 DISTRIBUTION OF RESPONDENTS

Higher education Institution	Year of education	Respondents	
		Number	Percent
Kyiv National Economic University named after Vadym Hetman	1	67	24.54
	2	62	22.71
Kyiv National University of Technologies and Design	1	75	27.47
	2	69	25.27

Study: own study
N=273

To collect statistical data on Computer Engineering and Information Technology undergraduates’ opinions on organising personalised learning in the English language classroom the team of researchers developed a questionnaire and data collection took place in September-December 2023.

The main questions that guided the research:

1. Do you believe that learning in the English language classroom aimed at developing your

communication skills is personalised to your needs and interests?

2. Do you believe that learning in the English language classroom aimed at developing your communication skills is personalised to your learning styles?

3. What methods of personalised learning used in the English language classroom do you find effective in developing your communication skills? Please, list as many methods of personalised learning used for developing your communication skills as you can.

4. Are you given the opportunity to choose activities aimed at developing your communication skills in the English language classroom?

5. What are the advantages of personalised learning in the English language classroom aimed at developing your communication skills?

To interpret the research results the researchers use descriptive statistics.

III. RESULTS

Question 1 is aimed to find out if respondents believe that learning in the English language classroom aimed at developing their communication skills is personalised to their needs and interests. The research findings to question 1 are presented in Fig. 1.

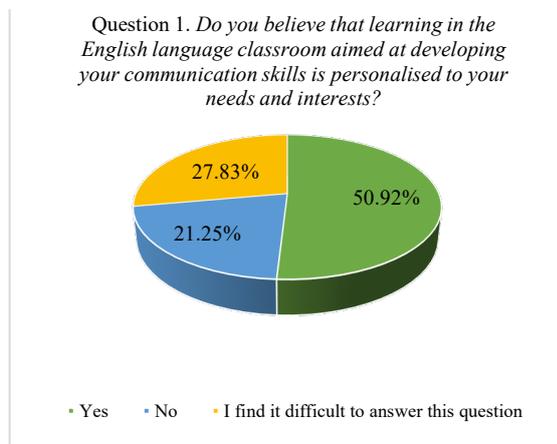


Fig. 1. Respondents' Responses to Question 1.

As results show, 139 respondents (50.92%) gave a positive answer to this question, 58 respondents (21.25%) gave a negative answer to the question and 76 (27.83) respondents found it difficult to answer.

Question 2 aims to find out if respondents believe that learning in the English language classroom aimed at developing their communication skills is personalised to their learning styles. The research findings to question 2 are presented in Fig. 2.

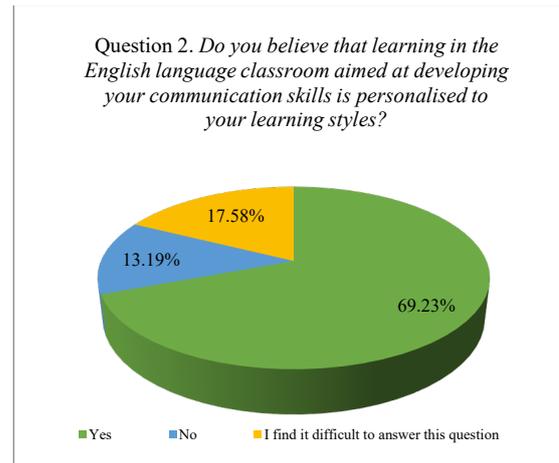


Fig. 2. Respondents' Responses to Question 2.

Replying to question 2, 189 respondents (69.23%) gave a positive answer, 36 respondents (13.19%) gave a negative answer and 48 (17.58%) respondents found it difficult to answer.

The main aim of question 3 is to single out personalised learning methods which, in respondents' opinion, are effective for developing their communication skills in the English language classroom. The research findings are demonstrated in Table 2.

TABLE 2 METHODS OF PERSONALISED LEARNING EFFECTIVE FOR DEVELOPING RESPONDENTS' COMMUNICATION SKILLS IN THE ENGLISH LANGUAGE CLASSROOM

Methods	Respondents	
	Number	Percent
Group projects	209	76.56
Group problem solving	203	74.36
Essay writing	185	67.76
Role games	228	83.52
Discussions and debates	251	91.94
Asking and answering questions to texts	139	50.92
Individual work with text	143	52.38
Group work with text	192	70.33
Presentation tasks	254	93.04
Word drawing games	93	34.07
Word guessing games	235	86.08
Story retelling	227	83.15
Discussing open-ended questions	183	67.03

Study: own study
 N=273

Question 4 is aimed at finding out if respondents are given the opportunity to choose activities aimed at developing their communication skills in the English language classroom. 57 respondents (20.88%) claim that they can choose activities aimed at developing their communication skills in the English language classroom, 192 respondents (70.33%) give a negative answer and 24 respondents (8.79) find it difficult to answer this question.

The results concerning advantages of personalised learning in the English language classroom aimed at developing respondents' communication skills are given in Table 3.

TABLE 3 ADVANTAGES OF PERSONALISED LEARNING AIMED AT DEVELOPING RESPONDENTS' COMMUNICATION SKILLS IN THE ENGLISH LANGUAGE CLASSROOM

Advantages	Respondents	
	Number	Percent
Increase of motivation	214	78.39
Development of self-learning skills	196	71.79
Development of independent thinking	148	51.21
Development of critical thinking	209	76.55
Understanding of one's own needs	247	90.48
Devising effective strategies for developing communicative skills	175	64.10
Usage of various digital apps	122	44.68

Study: own study
N=273

IV. CONCLUSIONS

The research aim was to find out Computer Engineering and Information Technology undergraduates' opinions on organising personalised learning in the English language classroom aimed at developing their communication skills. 139 respondents (50.92%) believe that learning in the English language classroom aimed at developing their communication skills is personalised to their needs and interests. 58 respondents (21.25%) do not believe that learning in the English language classroom aimed at developing their communication skills is personalised to their needs and interests and 76 respondents (27.83%) find it difficult to answer this question.

189 respondents (69.23%) are convinced that learning in the English language classroom aimed at developing their communication skills is personalised to their learning styles. 36 respondents (13.19%) do not believe that learning in the English language classroom aimed at developing their communication skills is personalised to their learning styles and 48 respondents (17.58%) find it difficult to answer this question.

According to the obtained results the most effective methods of personalised learning aimed at developing Computer Engineering and Information Technology undergraduates' communication skills in the English language classroom are as follows: group projects, group problem solving, essay writing, role games discussions and debates, asking and answering questions to texts, individual and group work with text, presentation tasks, word drawing games, word guessing games, story retelling, discussing open-ended questions. In respondents' opinions the main advantages of personalised learning aimed at developing communication skills in the English language classroom include the increase of motivation, the development of self-learning skills, independent thinking, critical thinking, understanding one's own needs, devising effective strategies for developing communicative skills and the

usage of various digital apps. Thus, the use of the identified activities in the English language classroom can strongly improve Computer Engineering and Information Technology undergraduates' communication skills.

REFERENCES

- [1] R. Palos and M. C. Petrovici, "Perceived importance of communication skills and their predictive value for academic performance", *Revista de Cercetare si Interventie Sociala*, vol. 46, pp. 85-98, 2014. [Online]. Available: https://www.researchgate.net/publication/286062837_Perceived_importance_of_communication_skills_and_their_predictive_value_for_academic_performance. [Accessed: Jan. 28, 2024].
- [2] V. Saravanan and G. Sankar, "Enhancing Communication Skills of Engineering Students", *European Journal of Molecular & Clinical Medicine*, vol. 7(11), pp. 5358-5362, 2020.
- [3] Y. Akyuz, "Personalized Learning in Education," *American Scientific Research Journal for Engineering, Technology and Sciences*, vol. 69(1), pp. 175-194, 2020. [Online]. Available: https://www.academia.edu/87065837/Personalized_Learning_in_Education. [Accessed: Nov. 29, 2023].
- [4] M. Bulger, "Personalised Learning: The Conversations We're Not Having," *Data and Society Research Institute*, 2016. [Online]. Available: https://www.datasociety.net/pubs/ecl/PersonalizedLearning_prime_r_2016.pdf. [Accessed: Nov. 27, 2023].
- [5] A. Shemshack and J. M. Spector, "A systematic literature review of personalized learning terms," *Smart Learning Environments*, 7:33, 2020. [Online]. Available: Springer Open, <https://slejournal.springeropen.com/articles/10.1186/s40561-020-00140-9>. [Accessed: Oct. 17, 2023], <https://doi.org/10.1186/s40561-020-00140-9>
- [6] O. Malykhin, N. Aristova and S. Melikova, "Developing Computer Engineering and Information Technology Undergraduates' Learner Autonomy: Individualised Instruction in English Classroom," In *Proc. ETR International Scientific and Practical Conference*, 2023, vol. 2, pp. 176-181, <https://doi.org/10.17770/etr2023vol2.7274>
- [7] A. A. Shah, Z. F. Syeda and S. Naseer, "University Students' Communication Skills as a Determinant of Academic Achievement," *Sir Syed Journal of Education & Social Research*, vol. 3, Issue 2, 2020 (April – June), pp. 107-114. [Online]. Available: [https://doi.org/10.36902/sjesr-vol3-iss2-2020\(107-114\)](https://doi.org/10.36902/sjesr-vol3-iss2-2020(107-114)) Available: Researchgate https://www.researchgate.net/publication/342645674_University_Students%27_Communication_Skills_as_a_Determinant_of_Academic_Achievement [Accessed Feb 2, 2024].
- [8] P. Gruba, R. Al-Mahmood, "Strategies in Communication Skills Development", 2004. [Online]. Available <https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=f7febc1da637afdacd7352c8fd11c067d8760d23> [Accessed: Dec. 17, 2023].
- [9] J. T. Havill and L. D. Ludwig, "Technically speaking: fostering the communication skills of computer science and mathematics students," *ACM SIGCSE Bulletin*, vol. 39 (1), pp. 185-189, <https://doi.org/10.1145/1227504.1227375>
- [10] A. A. Asemanyi, "An Assessment of Students' Performance in Communication Skills: A Case Study of the University of Education Winneba," *Journal of Education and Practice*, vol. 6, no. 1, pp. 1-7, 2015. [Online]. Available: <https://eric.ed.gov/?id=EJ1086368> [Accessed: Nov. 9, 2023].

Exploring Computer Engineering and Information Technology Undergraduates' Views on Developing Their Innovative Thinking in English Classroom

Oleksandr Malykhin

*Department of Didactics
Institute of Pedagogy
of NAES of Ukraine
Kyiv, Ukraine
malykhinalex1972@gmail.com*

Nataliia Aristova

*Department of International
Relations and Research Cooperation
Institute of Pedagogy of NAES of
Ukraine
Kyiv, Ukraine
n.aristova.na@gmail.com*

Maryna Vyshnevskia

*Department of Philology and
Translation
Kyiv National University of
Technologies and Design
Kyiv, Ukraine
vishnevskia.mo@knutd.com.ua*

Kseniia Kugai

*Department of Philology and
Translation
Kyiv National University of
Technologies and Design
Kyiv, Ukraine
kugaj.kb@knutd.com.ua*

Inna Makhovych

*Department of Philology and
Translation
Kyiv National University of
Technologies and Design
Kyiv, Ukraine
makhovych.ia@knutd.edu.ua*

Abstract. In our modern world, which is full of technological advancements, being able to think innovatively is essential for coping successfully with life and work challenges. For specialists who are going to work in the field of Computer Engineering and Information Technology innovative thinking is an ability that helps them adapt quickly to new challenges and opportunities and find non-standard solutions to various issues. In the study the researchers focused on finding out effective teaching and learning methods and techniques which can be used in the English language classroom for developing innovative thinking among Computer Engineering and Information Technology undergraduates. Considering the fact that the researchers are the English language teachers, to select the research sample they used a combination of a purposive sampling technique and a convenience sampling technique. To gather data on Computer Engineering and Information Technology undergraduates' views on developing their innovative thinking in the English Language classroom the researchers created a web-based questionnaire using Google Forms. The link to the questionnaire was distributed to the first- and second-year Computer Engineering and Information Technology students who study English as a second language at Kyiv National University of Technologies and Design. The results obtained enabled the researchers to identify teaching and learning methods and techniques effective for developing

innovative thinking among Computer Engineering and Information Technology undergraduates.

Keywords: *Computer Engineering and Information Technology undergraduates, English classroom, innovative teaching and learning methods and techniques, innovative thinking.*

I. INTRODUCTION

Life in our modern world, which is full of technological advancements in computer science and information technology, puts forward new requirements for the quality of the system of university training. To cope successfully with life and work challenges, university graduates should acquire core competencies which enable them both to navigate the current labour market conditions effectively and to navigate their careers confidently [1]. And one of these core competencies is the ability to think innovatively.

For professionals who are going to work in the field of computer engineering and information technology innovative thinking is an ability that helps them adapt quickly to new challenges and opportunities and find non-standard solutions to various issues. According to various classifications, innovative thinking is regarded as one of the most important job skills of the 21st century. Thus, for

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8096>

© 2024 Oleksandr Malykhin, Nataliia Aristova, Maryna Vyshnevskia, Kseniia Kugai, Inna Makhovych.

Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

instance, World Economic Forum [2] defines four categories of job skills of tomorrow which are of paramount importance for both present-day employees and employees who will enter the labour market in the future, namely, problem-solving, self-management, working with people and technology use and development. Such skills as analytical thinking and innovation; complex problem-solving; critical thinking and analysis; creativity, originality and initiative; reasoning, problem-solving and ideation represent the problem-solving category. Self-management category includes the following skills: active learning and learning strategies resilience, stress tolerance and flexibility. Working with people category contains leadership and social influence skills and technology use and development category consists of technology use, monitoring and control skills and technology design and programming skills.

The research conducted in 2021 by a group of Ukrainian scientists clearly demonstrates that analytical thinking and innovation as one of the job skills of tomorrow is praised rather high among Computer Engineering and Information Technologies undergraduates [3].

We fully agree with Ness, that "Innovation is the engine of scientific progress ..." [4, p. 114] and can add that innovation is also the main driving force of advances in computer science and information technology. What we mean is that technological advancements in computer science and information technology are made possible due to both profound subject matter knowledge and innovative thinking of their inventors and developers. Since Ness believes that "great innovators are great observers" [5, p. 115], the scientist is convinced that innovative thinking is inextricable linked with attention which has to be developed during studies.

In this regard it is difficult to disagree with Dunlop, who considers innovative thinking as "the ability to come up with new ideas and novel approaches to problems" [6]. In Dunlop's point of view innovative thinking is connected with a person's ability to be flexible, to adapt to change, to solve problems creatively, to remain competitive in the marketplace.

Wang & Zhu [7] suggest that innovative thinking is not an inborn ability. It is the ability that can be developed during the studies and English as a college discipline is an effective medium for its development. The researchers state that to guide students' innovative thinking when teaching various texts, English teachers have to ask students multi-angled questions. Wang & Zhu explain that "as long as the teacher asks questions in the classroom timely and cleverly, students will perform a variety of mental trainings, and then students will be able to get the full improvement of innovative thinking" [8, p. 1843]. The researchers also claim that creative retelling and making creative speeches are effective teaching methods in developing students' innovative thinking.

A similar view concerning the didactic potential of English in developing college and university students' innovative thinking ability is shared by Zhang [9]. The researcher makes an assumption that the development of students' innovative thinking should be based on the idea of Wisdom education and should include the following activities, namely, inquiry-based activities, simulation-

based learning activities, individualised learning activities, activities aimed at critical reading, writing and listening. Considering the fact that innovative thinking enables people to discover the world, the researcher states that it combines "perceptual skill, divergent thinking ability, and strong comprehension ability" [10, p. 136].

Believing that innovative thinking can be regarded as one of the main bridges between new and old knowledge, Cai defines innovative thinking as "the process of thinking activities that have novelty, uniqueness, and originality, that can reflect the essential attributes of things, and have internal and external organic connections, and can obtain new knowledge and new results [11, p. 218]. According to Cai [12], the structure of innovative thinking represents a trinity system which consists of logical thinking, critical thinking and creative thinking. The researcher is convinced that English reading teaching positively affects the formation of innovative thinking and therefore should be used in the English language classroom.

Literature review shows that present-day researchers consider English as an effective medium for promoting the enhancement of Computer Engineering and Information Technology undergraduates' soft skills or job skills of tomorrow which enable Computer Engineering and Information Technology undergraduates to be more adaptive and to successfully navigate various challenges and seize new opportunities [13], [14], [15]. To enhance soft skills development among Computer Engineering and Information Technologies undergraduates, Malykhin, Aristova & Melikova devised the soft skills development strategies that can be applied in the English language classroom [16]. The scientists proved the fact that if the learning content of English for Specific Purposes at universities meets the current requirements of the present-day globalized society, Computer Engineering and Information Technologies undergraduate students show more willingness to study English, on the one hand, and to acquire soft skills needed in their professional activities, on the other hand.

Thus, the research aim is to find out effective teaching and learning methods and techniques which can be used in the English language classroom for developing innovative thinking according to Computer Engineering and Information Technology undergraduates' views.

II. MATERIALS AND METHODS

Since the researchers are the English language teachers, they used a combination of a purposive sampling technique and a convenience sampling technique to select the research sample. The choice of the purposive sampling technique is explained by the researchers' interest in Computer Engineering and Information Technology undergraduate students' perspective on the stated problem and the choice of the convenience sampling technique is explained by the fact that the researchers teach English to Computer Engineering and Information Technology undergraduate students who study at Kyiv National University of Technologies and Design. To gather data on Computer Engineering and Information Technology undergraduates' views on developing their innovative thinking in the English Language classroom the researchers created a web-based questionnaire using Google Forms. The researchers distributed the link to the questionnaire to

the first- and second-year Computer Engineering and Information Technology students who studied English as a second language at Kyiv National University of Technologies and Design with a request to take part in the study. 173 first- and second- year students responded to the request and took part in the survey. It should be noted that all the respondents were assured of the anonymity of their responses.

The web-based questionnaire was aimed at finding out Computer Engineering and Information Technology undergraduates' views on the effective teaching methods and techniques which can be used in the English language classroom for developing their innovative thinking. The web-based questionnaire is composed of two parts. The first part of the questionnaire contains 3 questions and its main purpose is to gain insight into Computer Engineering and Information Technology undergraduates' views on their being able to think innovatively. The research questions are as follows:

1. *Do you believe that you are innovative and can create innovative ideas?*
2. *Do you believe that innovative thinking is essential for your future professional life?*
3. *Can you list some skills which in your opinion form an integral part of innovative thinking?*

The second part of the questionnaire contains two sets of items on a 5-Likert scale. The first set of items on a 5-Likert scale is targeted at finding out the frequency of use of the selected activities in the English language classroom aimed at developing Computer Engineering and Information Technology undergraduates' innovative thinking (1 – never, 2 – seldom, 3 – sometimes, 4 – often, 5 – always). Table 1 demonstrates the first set of items on a 5-Likert scale targeted at finding out the frequency of use of the selected activities in the English language classroom.

TABLE 1 THE FIRST SET OF ITEMS ON A 5-LIKERT SCALE

Activities	Variables				
	1 (Never)	2 (Seldom)	3 (Sometimes)	4 (Often)	5 (Always)
Note-taking mind mapping					
Drawing ambiguous pictures					
Incomplete pictures					
Expending and cutting down sentences					
Brainstorming					
Making up stories					
Chain story writing					
Reading comprehension mind mapping					
Writing storms					
Individual projects					
Group projects					
Finding associations					
Invention techniques: modifying and reversing					

Source: own study

The second set of items on a 5-Likert scale aims to find out Computer Engineering and Information Technology undergraduates' views on the most effective activities used in the English language classroom and intended for developing their innovative thinking (1 – strongly disagree, 2 – disagree, 3 – neutral, 4 – agree, 5 – strongly agree). Table 2 presents the second set of items on a 5-Likert scale aimed at finding out Computer Engineering and Information Technology undergraduates' views on the most effective activities used in the English language classroom.

TABLE 2 THE SECOND SET OF ITEMS ON A 5-LIKERT SCALE

Activities	Variables				
	1 (Strongly disagree)	2 (Disagree)	3 (Neutral)	4 (Agree)	5 (Strongly agree)
Note-taking mind mapping					
Drawing ambiguous pictures					
Incomplete pictures					
Expending and cutting down sentences					
Brainstorming					
Making up stories					
Chain story writing					
Reading comprehension mind mapping					
Writing storms					
Individual projects					
Group projects					
Finding associations					
Invention techniques: modifying and reversing					

Source: own study

The data obtained were analysed using frequency and mean percentage to interpret respondents' responses.

III. RESULTS AND DISCUSSION

The first research question is “*Do you believe that you are innovative and can create innovative ideas?*”. Replying to this question, 89 respondents (51.45%) gave an affirmative response. 34 respondents (19.65%) responded negatively and 50 respondents (28.90%) found it difficult to answer this question. Fig. 1 shows respondents' responses on question 1.

Taking into account the fact that innovative thinking is usually associated with the person's ability to brainstorm new and original ideas and identify new ways for solving non-standard problems, we strongly believe that the respondents who give a negative response and respondents who find it difficult to answer this question underestimate their innovative thinking ability although they have all the potential to innovate.

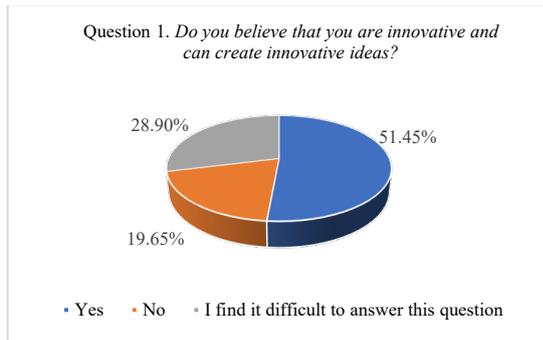


Fig. 1. Respondents' responses concerning the question if they are innovative and can create innovative ideas.

The second question is aimed at finding out if respondents believe that innovative thinking is essential for their future professional life. The obtained results show that 104 respondents (60.12%) answered positively, 31 respondents (17.92%) responded negatively and 38 respondents (21.96%) found it difficult to answer this question. Respondents' responses on question 2 are given in Fig. 2.



Fig. 2. Respondents' responses on the question if innovative thinking is essential for their future professional life.

The main aim of the third question is to figure out what skills, in respondents' views, form an integral part of innovative thinking. The results obtained are presented in Table 3.

Thus, as shown by the results obtained, in respondents' views innovative thinking skills include creativity (88.44%), ability to analyse information (86.18%), ability to think critically (76.30%), ability to see the differences (62.48%), openness to new experience (93.06%), willingness to experiment (32.95%), ability to summarise information (83.27%), ability to group different ideas (41.62%), ability to evaluate information critically (73.41%), ability to find the way out of the situation (52.60%), adaptability to change (71.68%) and ability to be agile (44.51%). It should be noted that all the skills mentioned by respondents enable a person to create some new ideas, be innovative and, what is more important, not to stop there. Listing the skills which, in their opinion, are associated with innovative thinking the respondents focus on the fact that innovative thinking requires a practice which is difficult and time-consuming.

TABLE 3 RESPONDENTS' VIEWS ON SKILLS ASSOCIATED WITH INNOVATIVE THINKING

Innovative Thinking Skills	Number (N)	Percent (%)
Creativity (ability to generate new ideas)	153	88.44
Ability to analyse information (data)	149	86.18
Ability to think critically	132	76.30
Ability to see the differences	108	62.48
Openness to new experience	161	93.06
Willingness to experiment	57	32.95
Ability to find the way out of the situation	91	52.60
Adaptability to change	124	71.68
Ability to be agile	77	44.51
Ability to summarise information	144	83.27
Ability to evaluate information critically	127	73.41
Ability to group different ideas	72	41.62
Ability to keep doing something difficult in order to achieve a goal	101	58.38

Source: own study (N=173)

The third question is "Do you believe that innovative thinking can be developed in the English language classroom?" Replying to this question, 91 respondents (52.60%) gave a positive answer. According to 29 respondents (16.76%), innovative thinking cannot be developed in the English language classroom. 53 respondents (30.64%) find it difficult to answer this question. Fig. 3 demonstrates Computer Engineering and Information Technology undergraduates' views on the effectiveness of English as a discipline in developing their innovative thinking.

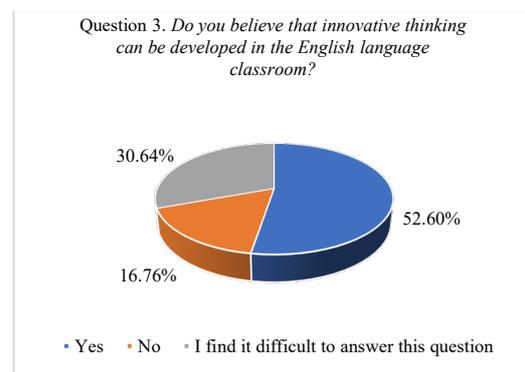


Fig. 3. Respondents' responses on the question on effectiveness of English in developing their innovative thinking.

Then, respondents are asked to rate the frequency of use of the activities aimed at developing innovative thinking in the English language classroom according to a 5-Likert scale (1 – never, 2 – seldom, 3 – sometimes, 4 – often, 5 – always). The obtained results are shown in Table 4.

TABLE 4 RESPONDENTS' VIEWS ON FREQUENCY OF USE OF ACTIVITIES AIMED AT DEVELOPING INNOVATIVE THINKING

Activities	Variables					(x̄)
	1 (N)	2 (N)	3 (N)	4 (N)	5 (N)	
Note-taking mind mapping	0	0	16	72	85	4.39
Drawing ambiguous pictures	0	93	80	0	0	2.46
Incomplete pictures	87	64	22	0	0	1.62
Expending and cutting down sentences	0	0	87	59	27	3.65
Brainstorming	0	0	0	74	99	4.57
Making up stories	0	0	12	53	108	4.55
Chain story writing	0	0	12	53	108	4.55
Reading comprehension mind mapping	0	0	25	86	62	4.21
Writing storms	0	0	59	82	32	3.84
Individual projects	0	0	0	55	118	4.68
Group projects	0	0	74	62	37	3.78
Finding associations	0	0	81	64	28	3.69
Invention techniques: modifying and reversing	34	83	56	0	0	2.12

Source: own study (N=173)

The obtained results show that the most frequently used activities aimed at developing Computer Engineering and Information Technology undergraduates' innovative thinking include individual projects ($\bar{x}=4.68$), brainstorming ($\bar{x}=4.57$), making up stories ($\bar{x}=4.55$), chain story writing ($\bar{x}=4.55$), reading comprehension mind mapping ($\bar{x}=4.21$). As the results show, in their classrooms English language teachers also use such activities as finding associations ($\bar{x}=3.69$), writing storms ($\bar{x}=3.84$), cutting down and expending sentences ($\bar{x}=3.65$) and group projects ($\bar{x}=3.78$) to develop Computer Engineering and Information Technology undergraduates' innovative thinking. The analysis of the results enables us to conclude that development of educational materials aimed at implementing these activities in the English language classroom is time-consuming and although English teachers use them in their classrooms, it does not happen very often. It is associated with the fact that during the first and second years of university education (English as a second language) and the following third and fourth years (English for Specific Purposes), the duration of face-to-face interaction of English teachers and students is not sufficient for paying special attention to the purposeful, comprehensive and systematic development of Computer Engineering and Information Technology undergraduates' skills of the 21st century including innovative thinking. Unfortunately, such invention techniques as modifying and reversing ($\bar{x}=2.12$), drawing ambiguous pictures ($\bar{x}=2.46$) and incomplete pictures ($\bar{x}=1.62$) are among those which are rarely used in the English language classroom, although their purposeful, comprehensive and systematic use can contribute greatly to the development of innovative thinking in general and each individual innovative thinking skill which constitutes innovative thinking in particular. All these activities, in our opinion, can be grouped in several categories which represent teaching and learning methods and techniques aimed at developing Computer Engineering and Information Technology undergraduates' innovative thinking in the English language classroom. Table 5

demonstrates both categories of teaching and learning methods and techniques and activities used for developing Computer Engineering and Information Technology undergraduates' innovative thinking in the English language classroom.

TABLE 5 TEACHING AND LEARNING METHODS AND TECHNIQUES AIMED AT DEVELOPING INNOVATIVE THINKING

Categories	Activities
Story-based teaching and learning methods and techniques	- making up stories - expending sentences - chain story writing - cutting down sentences - writing storms
Mind mapping teaching and learning methods and techniques	- note-taking mind mapping - brainstorming - reading comprehension mind mapping
Association-based teaching and learning techniques	- finding associations - drawing ambiguous pictures - incomplete pictures - invention techniques: modifying and reversing
Project-based teaching and learning techniques	- individual projects - group projects

Source: own study

The second set of items on a 5-Likert scale aims to find out if Computer Engineering and Information Technology undergraduates agree that the following activities are the most effective for developing their innovative thinking in the English language classroom. To describe the variables, the researchers use means (\bar{x}). Computer Engineering and Information Technology undergraduates' perspectives on effectiveness of the listed activities are measured from 'strongly disagree' to 'strongly agree' based on the 5-Likert scale intervals presented in Table 6.

TABLE 6 INTERVAL LEVEL OF 5-LIKERT SCALE

Mean Interval	Perspective
1.00–1.80	Strongly disagree
1.81–2.60	Disagree
2.61–3.40	Neutral
3.41–4.20	Agree
4.21–5.00	Strongly agree

Table 7 demonstrates the obtained results concerning respondents' views on effectiveness of activities aimed at developing innovative thinking skills in the English language classroom.

The obtained results clearly demonstrate that according to respondents' views brainstorming ($\bar{x}=4.61$), reading comprehension mind mapping ($\bar{x}=4.55$), writing storms ($\bar{x}=4.51$), making up stories ($\bar{x}=4.36$), chain story writing ($\bar{x}=4.36$), invention techniques: modifying and reversing ($\bar{x}=4.18$), finding associations ($\bar{x}=4.17$), note-taking mind mapping ($\bar{x}=4.45$), individual ($\bar{x}=4.53$) and group projects ($\bar{x}=4.37$) are among the most effective activities aimed at developing innovative thinking in the English language classroom.

TABLE 7 RESPONDENTS' VIEWS ON EFFECTIVENESS OF ACTIVITIES AIMED AT DEVELOPING INNOVATIVE THINKING IN ENGLISH CLASSROOM

Activities	Variables					(x̄)
	1 (N)	2 (N)	3 (N)	4 (N)	5 (N)	
Note-taking mind mapping	0	0	10	76	87	4.45
Drawing ambiguous pictures	0	3	52	83	35	3.87
Incomplete pictures	0	2	54	79	38	3.88
Expending and cutting down sentences	0	29	87	40	17	3.09
Brainstorming	0	0	0	67	106	4.61
Making up stories	0	0	29	53	91	4.36
Chain story writing	0	0	27	56	90	4.36
Reading comprehension mind mapping	0	0	7	64	102	4.55
Writing storms	0	0	0	85	88	4.51
Individual projects	0	0	5	72	96	4.53
Group projects	0	0	17	75	81	4.37
Finding associations	0	12	22	63	76	4.17
Invention techniques: modifying and reversing	0	0	31	80	62	4.18

Source: own study (N=173)

IV. CONCLUSIONS

The research was targeted at finding out effective teaching methods and techniques which could be used in the English language classroom for developing innovative thinking among Computer Engineering and Information Technology undergraduates. The obtained results enable us to state that the majority respondents (51.45%) believe that they are innovative and are able to create new ideas. The majority of respondents (60.12%) are convinced that innovative thinking is essential for their future professional life. According to respondents, innovative thinking is associated with the following skills, namely: creativity (88.44%), ability to analyse information (86.18%), ability to think critically (76.30%), ability to see the differences (62.48%), openness to new experience (93.06%), willingness to experiment (32.95%), ability to find the way out of the situation (52.60%), adaptability to change (71.68%) and ability to be agile (44.51%). It should be also noted that 91 respondents (52.60%) are confident that innovative thinking can be developed in the English language classroom. The present research enabled its authors to identify effective teaching methods and techniques which can be used in the English language classroom with the aim to develop Computer Engineering and Information Technology undergraduates' innovative thinking. Among these techniques, we single out story-based teaching and learning methods and techniques (making up stories, chain story writing and writing storms), mind mapping teaching and learning methods and techniques (note-taking mind mapping, brainstorming, reading comprehension mind mapping), association-based teaching and learning techniques (finding associations, drawing ambiguous pictures, incomplete pictures, invention techniques: modifying and reversing etc.), project-based teaching and learning techniques (individual and group projects).

V. REFERENCES

- [1] M. Caeiro-Rodríguez et al., "Teaching Soft Skills in Engineering Education: An European Perspective," *IEEE Access*, vol. 9, pp. 29222-29242, February 15, 2021. [Online]. Available: <https://ieeexplore.ieee.org/document/9354626> [Accessed: Dec. 19, 2023], 10.1109/ACCESS.2021.3059516
- [2] World Economic Forum, "These are the top 10 job skills of tomorrow – and how long it takes to learn them", *World Economic Forum*, 2020. [Online]. Available: <https://www.weforum.org/agenda/2020/10/top-10-work-skills-of-tomorrow-how-long-it-takes-to-learn-them/> [Accessed: Oct. 22, 2023].
- [3] O. Malykhin, N. Aristova, N. Dichek, and N. Dyka, "Formation of Top Job Skills of Tomorrow Among Computer Engineering and Information Technologies Undergraduate Students in the Process of Learning English," In Proc. ETR International Scientific and Practical Conference, vol. 2, pp. 249-254, 2021, <https://doi.org/10.17770/etr2021vol2.6642>
- [4] R. B. Ness, "Promoting innovative thinking," *Am J Public Health*, vol. 105 Suppl 1(Suppl 1):S114-8, 2015 Mar. [Online]. Available: National Library of Medicine, <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4340012/> [Accessed: Dec. 1, 2023], 10.2105/AJPH.2014.302365
- [5] R. B. Ness, "Promoting innovative thinking," *Am J Public Health*, vol. 105 Suppl 1(Suppl 1):S114-8, 2015 Mar. [Online]. Available: National Library of Medicine, <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4340012/> [Accessed: Dec. 1, 2023], 10.2105/AJPH.2014.302365
- [6] M. Dunlop, "Innovative Thinking: Why It's The Skill of The Future," December 2020. [Online]. Available: <https://www.viima.com/blog/innovative-thinking> [Accessed: Nov. 12, 2023].
- [7] J. Wang and Y. Zhu, "The Cultivation of Students' Innovative Thinking Ability in the College English Teaching," In Proc. 2015 International Conference on Social Science, Education Management and Sports Education (SSEMSE 2015), 2015, pp. 1842-1844. [Online]. Available: <https://www.atlantispress.com/article/25842444.pdf> [Accessed: Sept. 25, 2023].
- [8] J. Wang and Y. Zhu, "The Cultivation of Students' Innovative Thinking Ability in the College English Teaching," In Proc. 2015 International Conference on Social Science, Education Management and Sports Education (SSEMSE 2015), 2015, pp. 1842-1844. [Online]. Available: <https://www.atlantispress.com/article/25842444.pdf> [Accessed: Sept. 25, 2023].
- [9] Q. Zhang, "Cultivation of College Students' Innovation Thinking in English Under the Idea of Wisdom Education," In Proc. 2020 International Conference on Modern Education Management, Innovation and Entrepreneurship and Social Science (MEMIESS 2020), vol. 523, pp. 135-138, 2020. [Online]. Available: https://www.researchgate.net/publication/353305160_Cultivation_of_College_Students'_Innovation_Thinking_in_English_Under_the_Idea_of_Wisdom_Education [Accessed: Feb 25, 2024].
- [10] Q. Zhang, "Cultivation of College Students' Innovation Thinking in English Under the Idea of Wisdom Education," In Proc. 2020 International Conference on Modern Education Management, Innovation and Entrepreneurship and Social Science (MEMIESS 2020), vol. 523, pp. 135-138, 2020.
- [11] F. Cai, "Cultivation of Innovative Thinking Ability in English Reading Teaching," presented at 3rd International Conference on Education Technology and Information System (ETIS 2020), 2020, pp. 218-222. [Online]. Available: http://166.62.7.99/conferences/AETP/ETIS%202020/ETIS202004_2.pdf [Accessed: Nov. 12, 2023].
- [12] F. Cai, "Cultivation of Innovative Thinking Ability in English Reading Teaching," presented at 3rd International Conference on Education Technology and Information System (ETIS 2020), 2020, pp. 218-222. [Online]. Available: http://166.62.7.99/conferences/AETP/ETIS%202020/ETIS202004_2.pdf [Accessed: Nov. 12, 2023].
- [13] O. Malykhin, N. Aristova, N. Dichek, and N. Dyka, "Formation of Top Job Skills of Tomorrow Among Computer Engineering and Information Technologies Undergraduate Students in the Process of Learning English," In Proc. ETR International Scientific and

- Practical Conference, vol. 2, pp. 249-254, 2021, <https://doi.org/10.17770/etr2021vol2.6642>
- [14] K. Kugai and M. Vyshnevskaya, "Peculiarities of teaching foreign languages to computer specialties students", *Baltic Journal of Legal and Social Sciences*, vol. 3, pp. 93-100, October, 2023. [Online serial]. Available: <http://baltijapublishing.lv/index.php/bjls/article/view/2170>. [Accessed Dec.12, 2023], <https://doi.org/10.30525/2592-8813-2023-3-12>
- [15] O. Malykhin, N. Aristova, and S. Melikova, "Soft Skills Development Strategies for Computer Engineering and Information Technologies Undergraduate Students Devised in the Process of Learning English," In Proc. ETR International Scientific and Practical Conference, vol. 2, pp. 255-260, 2021, <https://doi.org/10.17770/etr2021vol2.6602>
- [16] O. Malykhin, N. Aristova, and S. Melikova, "Soft Skills Development Strategies for Computer Engineering and Information Technologies Undergraduate Students Devised in the Process of Learning English," In Proc. ETR International Scientific and Practical Conference, vol. 2, pp. 255-260, 2021, <https://doi.org/10.17770/etr2021vol2.6602>

Synthesis of Eight Middle Lost Mechanisms Finally Discharged Discreet Positions

Marin Jordanov Marinov
 Technical University - Gabrovo
 Department of Industrial Design and
 Textile Engineering
 Gabrovo, Bulgaria
 marinov@tugab.bg

Abstract. The author has developed the algorithm for the synthesis of eight kinematic structures to generate random function of the positions by given n-number approximate nodes. Synthesis was performed at extreme distances at $n \leq 6$. In practice, an approximate synthesis is proposed, with the error being zero only in the approximate nodes, and in the remaining points the error is plotted graphically. According to preset 6 approximate nodes we determine the metric parameters of a family of mechanisms from which we choose the optimal (with the least relative error in the movement of the executive unit). The determination of the position, speed and acceleration function of the executive unit is shown graphically. To establish the authenticity of synthesis is an example.

Keywords: eight axial lever mechanisms, metric syntheses at far-off positions, marginal synthesis, function of the position.

I. INTRODUCTION

When it is necessary to determine the geometric dimensions of an arbitrary mechanism that generates an arbitrary continuous function of positions and this generated function has n number of predetermined points called extremely distant points [Galabov 1992], precise points [Galabov 1992], approximation nodes [Enchev 1986] or points corresponding to n discrete positions of the mechanism, a metric synthesis of this mechanism must be performed. We will call the specified metric synthesis from [Marinov 2014] marginal (finite, at finitely distant precise points) including n number of discrete positions, fixed on the continuous function of the positions of the investigated mechanisms.

The metric synthesis of this mechanism in extremely distant positions can be performed by means of the vector-matrix method, using the generalized approach applied to planar lever mechanisms [Marinov 2012].

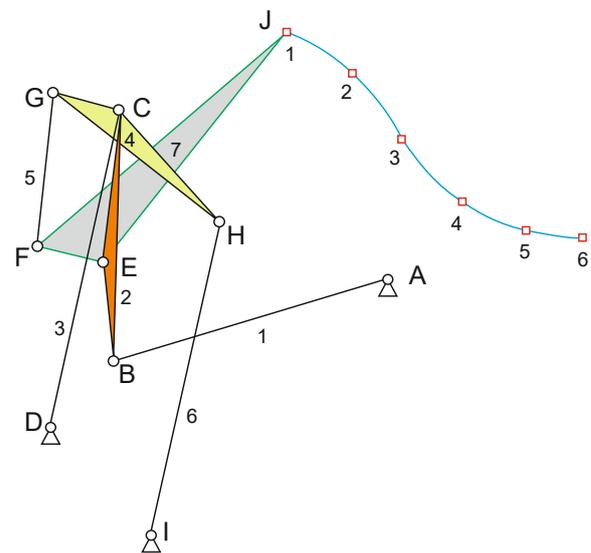


Fig.1 shows an eight-link lever mechanism serving a transport manipulator.

II. MATERIALS AND METHODS

A. Synthesis of the mechanism:

The synthesis conditions are determined by the relative discrete angular orientations θ_{li} of link 1 and the relative linear displacements S_{li} of link 3. The coordinates of the center of the spherical pair **B**, at any discrete position of the mechanism, are:

$$\begin{aligned} X_{B_i} &= X_{B_1} + S_{li} \ , \\ Y_{B_i} &= Y_{B_1} \ , \\ Z_{B_i} &= Z_{B_1} \ . \end{aligned} \quad (1)$$

After a kinematic inversion of the mechanism, at stand unit **1**, the coordinates of any inverted position of

Print ISSN 1691-5402
 Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8067>

© 2024 Marin Jordanov Marinov. Published by Rezekne Academy of Technologies.
 This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

the center of the spherical pair **B** have the following form:

$$\begin{bmatrix} X'_{B_i} \\ Y'_{B_i} \\ Z'_{B_i} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos \theta_{li} & \sin \theta_{li} \\ 0 & -\sin \theta_{li} & \cos \theta_{li} \end{bmatrix} \begin{bmatrix} X_{B_i} + S_{li} \\ Y_{B_i} \\ Z_{B_i} \end{bmatrix} \quad (2)$$

The geometric constraint condition of unit **2** can be written in vector form as:

$$[\overline{RB'_i} - \overline{RA_i}]^T [\overline{RB'_i} - \overline{RA_i}] = [\overline{RB_i} - \overline{RA_i}]^T [\overline{RB_i} - \overline{RA_i}] \quad (3)$$

In scalar-matrix form, condition (3) has the following form:

$$\begin{bmatrix} X_{B'_i} \\ Y_{B'_i} - Y_{A1} \\ Z_{B'_i} - Z_{A1} \end{bmatrix}^T \begin{bmatrix} X_{B'_i} \\ Y_{B'_i} - Y_{A1} \\ Z_{B'_i} - Z_{A1} \end{bmatrix} = \begin{bmatrix} X_{B_i} \\ Y_{B_i} - Y_{A1} \\ Z_{B_i} - Z_{A1} \end{bmatrix}^T \begin{bmatrix} X_{B_i} \\ Y_{B_i} - Y_{A1} \\ Z_{B_i} - Z_{A1} \end{bmatrix} \quad (4)$$

At **n** extremely distant positions of the mechanism, **n-1** equations of the type (4) can be written, namely:

$$a_i X_{B_i} + b_i Y_{A1} + c_i Z_{A1} = d_i, \quad (5)$$

where

$$\begin{aligned} a_i &= 2S_{li} \\ b_i &= -2(Y_{B'_i} - Y_{B_i}) \\ c_i &= -2(Z_{B'_i} - Z_{B_i}) \\ d_i &= Y_{B_i}^2 + Z_{B_i}^2 - Y_{B'_i}^2 - Z_{B'_i}^2 - S_{li}^2, \quad i = 2, 3, \dots, n \end{aligned} \quad (6)$$

When **n=4**, there are three equations of the type (5). Two of the parameters of the mechanism (**Y_{B1}** and **Z_{B1}**) are assigned constant values, the system of equations (5) is solved and the remaining three parameters (**X_{B1}**, **Y_{A1}** and **Z_{A1}**) are determined.

With **n=5**, there are four equations of the type (5). In this case, the synthesis can be done in two ways. In both ways, three (**X_{B1}**, **Y_{A1}** and **Z_{A1}**) are assumed for calculation parameters.

In the first way, one of the remaining two parameters (**Z_{B1}**) is assigned a constant value, and the other (**Y_{B1}**) is assumed to be variable within certain limits and with a certain step.

The calculation parameters are determined from the first three equations of (5):

$$\begin{aligned} X_{B1} &= X_{B1}(Y_{B1}) \\ Y_{A1} &= Y_{A1}(Y_{B1}) \\ Z_{A1} &= Z_{A1}(Y_{B1}). \end{aligned} \quad (7)$$

With the fourth equation, the function of the variable parameter is written:

$$F(Y_{B1}) = a_5 \cdot X_{B1} + b_5 \cdot Y_{A1} + c_5 \cdot Z_{A1} - d_5. \quad (8)$$

Graphs of functions (7) and (8) are drawn. From the graph of the function (8), the values of the variable parameter **Y_{B1}** are determined at the points where this function is zeroed and for which the system of equations (5) has a solution. For the thus reported values of the variable parameter from the graphs of the functions (7), the calculation parameters (**X_{B1}**, **Y_{A1}** and **Z_{A1}**) are reported.

In the second way, the synthesis can be carried out by assuming the two parameters (**Y_{B1}** and **Z_{B1}**) to be variable within certain limits and at certain steps of changes.

The calculation parameters are determined from the first three equations of (5):

$$\begin{aligned} X_{B1} &= X_{B1}(Y_{B1}, Z_{B1}) \\ Y_{A1} &= Y_{A1}(Y_{B1}, Z_{B1}) \\ Z_{A1} &= Z_{A1}(Y_{B1}, Z_{B1}). \end{aligned} \quad (9)$$

With the fourth equation, a function of the variable parameters is written:

$$F(Y_{B1}, Z_{B1}) = a_5 X_{B1} + b_5 Y_{A1} + c_5 Z_{A1} - d_5. \quad (10)$$

The isoline of the surface defined by the function (10) is drawn for zero values of this function. The coordinates of the points on this isoline give a set of values of the variable parameters for which the system of equations has solutions. With these values and the functions (9), the corresponding set of calculation parameters is determined.

With **n=6**, there are five equations of type (5). In this case, the calculation parameters are determined from the first three equations as functions of the variable parameters, which are written in the form (9). With the remaining two equations, the two functions of the variable parameters are written:

$$\begin{aligned} F(Y_{B1}, Z_{B1}) &= a_5 X_{B1} + b_5 Y_{A1} + c_5 Z_{A1} - d_5 \\ Q(Y_{B1}, Z_{B1}) &= a_6 X_{B1} + b_6 Y_{A1} + c_6 Z_{A1} - d_6. \end{aligned} \quad (11)$$

The isolines of the surfaces determined by the functions (11) are drawn for zero values of these functions. The coordinates of the intersection points of the two isolines determine the values of the variable parameters for which the system of equations (5) has a solution. With these values and the functions (9), the values of the calculation parameters are determined.

II.2. Synthesis algorithm designed for Watt-2023 programming environment.

1. Enter the relative linear displacements **S_{li}** of the centre of the cylindrical pair **B**, the relative angular orientations **θ_{li}** of the coil 1, the limits and steps of changing the variable parameters.

2. Enter the expressions (2) to determine the coordinates, and of the centre of the spherical pair **B**.

3. Enter the expressions (6) to determine the coefficients of the system of equations (5).

4. With **n=5** and one variable parameter, the functions (7) and (8) are entered. The graphs of these functions are

drawn and the values of the variable and the calculation parameters are determined from them.

5. With two variable parameters, the functions (9) and (10) are introduced. The isoline of the surface defined by the function (10) is drawn for zero values of this function. With the coordinates of points of this isoline (which are values of the variable parameters) and the functions (9), the calculation parameters are determined.

6. With two variable parameters, the functions (9) and (11) are introduced. The isolines of the surfaces determined by the functions (11) are drawn. The coordinates of their intersection points (which give the values of the variable parameters) are calculated from them, and with them and the functions (9) the calculation parameters are determined.

III. RESULTS AND DISCUSSION

Example: To synthesize an eight-link lever mechanism for moving loads between two belt conveyors at given: $y_{16}=0.6m$; relative linear displacements $S_{12}=0.1m$, $S_{13}=0.18m$, $S_{14}=0.24m$, $S_{15}=0m$; relative angular orientations of the leading link $\theta_{12}=\pi/3$, $\theta_{13}=2\pi/3$, $\theta_{14}=\pi$, $\theta_{15}=2\pi$, $\theta_{16}=\pi/2$.

After carrying out the synthesis, plot the resulting eight link mechanisms, for the six pre-fixed positions where the errors are equal to zero (fig. 2 to fig. 7) of the mechanism to show the real results of the so-called marginal synthesis.

In positions $n=1$ to $n=6$, the error in the specific momentary centres of the synthesis, the error shown in figures fig.2, fig.3, fig.4, fig.5, fig.6 and fig.7 have zero values, and in the intervals between the points, the corresponding error is shown in the lower diagram on each figure in red color. The maximum synthesis error is between $n=5$ and $n=6$ and is 5.2mm in size.

As a result of the computer analysis, 3700 variants were generated, and the optimal synthesized eight-link mechanism is number 1980. The program has calculated and can be seen from the bottom row all the

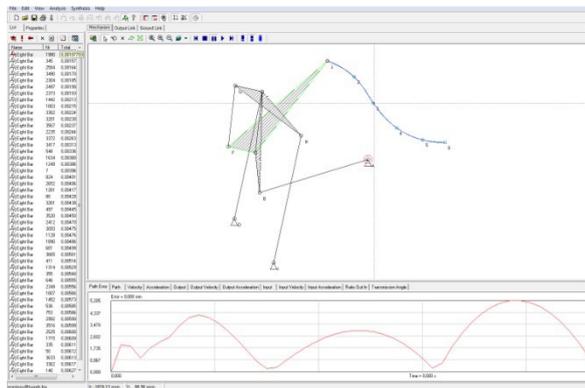


Fig.2 First extreme remote position

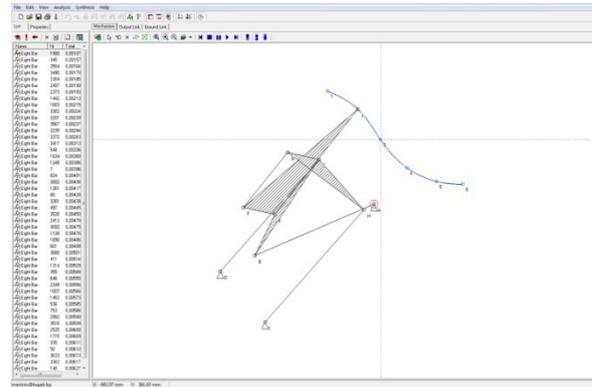


Fig.3 Second extreme remote position

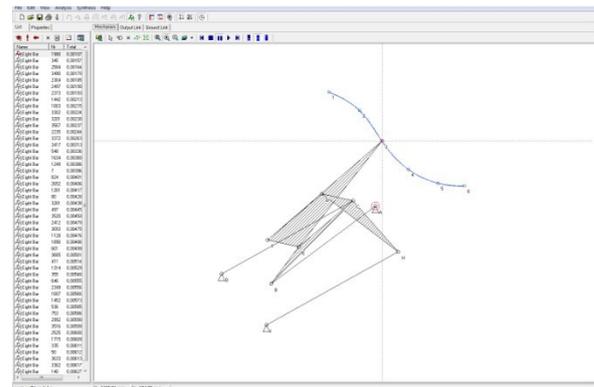


Fig.4 Third extreme remote position

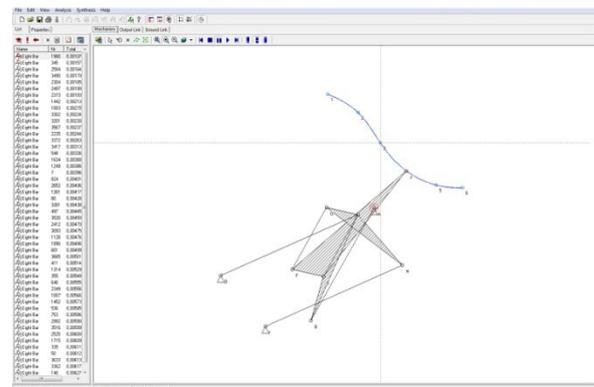


Fig.5 Fourth extreme remote position

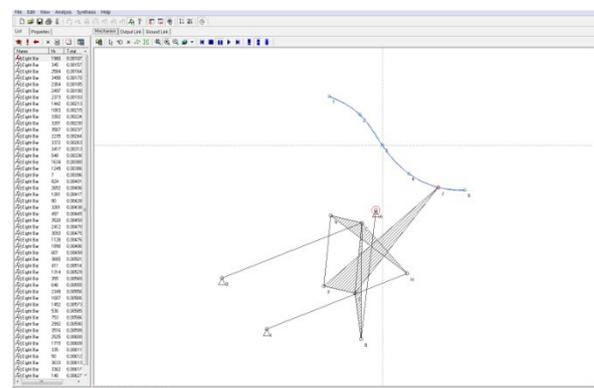


Fig.6 Fifth extreme remote position

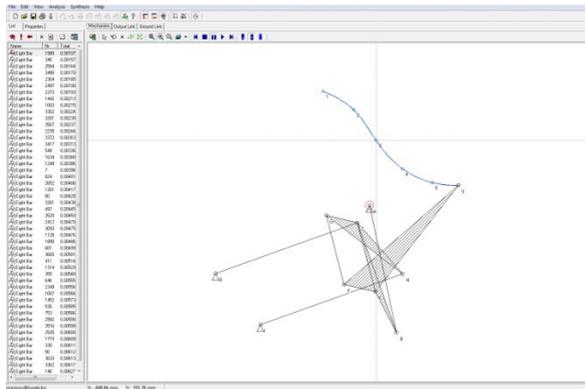


Fig.7 Sixth extreme remote position

kinematic parameters of the synthesized mechanism (movement of all links as coordinates, linear velocities and accelerations fig.8).

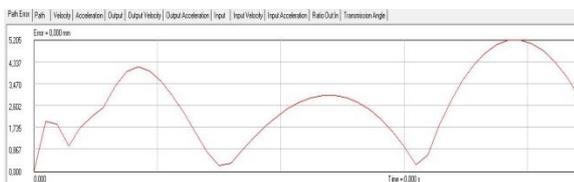


Fig.8 Modification of the movement error of the mechanism

IV. CONCLUSION

This article is intended for teaching bachelor's and master's students in the direction of mechanical engineering and the field of application synthesis of mechanisms and machines for industry. An illustrative drawing of such a mechanism is shown here in Fig.9.

The Watt program was used, which can be used to synthesize various types of mechanisms, both in infinitely close and infinitely distant positions of the executive unit. The classic Burmester principle was used as the basis of the synthesis, but adapted by the author for multi-link machines in industry.



Fig.9 Illustrative scheme of a mechanism

On the condition that an eight-link guide mechanism is to be synthesized, it is most appropriate to synthesize a family of eight-link lever mechanisms, in which, after a subsequent kinematic analysis, the relative error in the

predetermined trajectory between points 1,2,3,4,5 and 6 (fig.1). The author proposes a unified approach for the synthesis of such mechanisms on extremely distant discrete positions.

The example made shows the synthesis of an industrial sanitary ware load transfer manipulator, where the main problems are high velocity values at points 1 and 6 of the executive unit reactor. The linear accelerations at points 1, 2, 3, 4, 5 and 6 shown in Fig. 2, Fig. 3, Fig. 4 and Fig. 5 are also non-constant.

In order to carry out an optimal synthesis of the shown mechanism with subsequent kinematic analysis and establishing the effect of the synthesis, the following activities were carried out:

1. Fig. 1 shows an eight-link lever mechanism connected to an industrial manipulator, characterized by the fact that it intercepts a load in one plane and moves it to another parallel plane with a different deviation. As the position function of the original and reduced mechanism is identical.

2. Initially, the characteristic points 1, 2, 3, 4, 5 and 6 are set. The Watt program is introduced and 3700 variants of eight-link mechanisms are synthesized. From them, after a thorough kinematic analysis, we choose the 1980 version.

3. Draw the kinematic diagrams for the same positions (Fig. 3, Fig. 4, Fig. 5, Fig. 6, Fig. 7 and Fig. 8).

4. The linear and angular velocities and accelerations of the characteristic points are compared, and in each figure the function of the change of the relative error of the executive unit between the output and the reduced mechanism is depicted.

5. The peak values of the linear and angular accelerations of the manipulator at characteristic points 1,2,3,4,5 and 6 of the mechanism are minimal.

6. The author proposes a unified approach for the synthesis of eight-link mechanisms using the Watt synthesis program at finitely spaced discrete positions, which can be applied to various types of transport robots and manipulators, both for guides and for actuators.

7. The obtained numerical results were obtained theoretically and based on them a prototype was developed, which shows increased reliability during operation in real conditions, compared to that of existing models. The prototype of the mechanism is made in a real industrial environment.

The purpose of this publication is to raise the level of teaching in the field of the theory of machine mechanisms and automatic lines in industrial production.

V. REFERENCES

- [1] I.I.Artobolevskiy, Theory of Mechanisms and Machines. Science, Moscow, 1967.
- [2] V.B. Bhandari, Design of Machine Elements Fifth Edition, McGraw Hill 2020.
- [3] V.B.Galabov, M. J. Marinov, N.B. Nikolov, Synthesis on a guiding MF at two points, respectively phase relation and double midpoint, "Mechanics of machines" 1999, booklet 26.
- [4] V.B.Galabov, M. J. Marinov, Synthesis of articulated four-link mechanism by discrete relative positions. "Mechanics of the machines", Varna, 2002.
- [5] Jhon Uicker, G. Pennok, J. Shigley, Theory of Machines and Mechanisms, Fifth Edition, Oxford University Press 2017.
- [6] M.Marinov, Synthesis of planar mechanisms by extremely distant discrete positions. Dissertation abstract to get the scientific and educational degree "PhD" - TU Sofia 2002, pp.36.
- [7] Myszka David, Machines & Mechanisms: Applied Kinematic Analysis, 2011.
- [8] M.J.Marinov, B.I. Stoychev, D.M. Guteva, M.V. Georgiev, Computer modeling and geometric analysis of Click-Clack mechanisms. "Mechanics of the machines" 2016 booklet 118 pp.35-39.
- [9] Michael Stanisic, Mechanisms and machines; Kinematics, Dinamics and synthesis, Stamford 2015.
- [10] L.L.Harrisberger, An overview of structural synthesis of three-dimensional mechanisms, constructing science and technology of mechanical engineering, World, Moscow, 1965.
- [11] R.A.Rusev, V.B. Galabov, Structuring of rational planet-lever mechanism for passing the weft through the weaving machines. "Mechanics of machines" 2002 pp.26 booklet 33.
- [12] Sadhu Singh, Theory of Machines: Kinematics and Dynamics, Pearson Education, India 2011
- [13] S. Stefanov, Theoretical mechanics, statics, kinematics and dynamics, Sofia 2014.
- [14] P.T.Stoyanov, Geometric precision synthesis of planar lever mechanisms. "Mechanics of the machines" 2002 p.56 vol. 33.
- [15] G.A.Timofeev, Theory of Mechanisms and Machines, Moskow Urde 2010.

Vector-Matrix Computer Method for Drafting Circling-Point Curves and Centering-Point Curves of Burmester

Marin Jordanov Marinov
Technical University - Gabrovo
Department of Industrial Design and
Textile Engineering
Gabrovo, Bulgaria
marinov@tugab.bg

Abstract. The author suggests a method for drafting circling-point curves and centering-point curves of Burmester in the present paper. The geometrical compulsion makes the best use of synthesis of levers mechanisms by vector-matrix computer method under existing circumstances.

Propose the drafting of the Burmester circling-point and centering-point curves are more applicable and more approach for engineers and constructors in the manufacture.

Keywords: circling-point curves of Burmester, centering-point curves of Burmester, vector-matrix computer method for synthesis linkage of bars.

I. INTRODUCTION

The foundations of kinematic geometry, laid down by Burmester [1888], for the finitely distant discrete positions in general plane motion of a rigid body, are built from the position of the projection geometry. He created a theory according to which points on a moving plane have four discrete positions on a circle fixed in a stationary plane. Burmester's name is associated with the concepts known in the literature: circle point curves (CPC), center point curves (CPC), Burmester points and centers.

Graphical solutions for determining CPC and CCT proposed by Burmester [1888] and Alt [1921] lead to laborious graphical procedures and do not provide accuracy in reproducing these curves. However, the indicated difficulties are one of the reasons for the evolution of the task of determining and drawing the CPC and CCT, especially after the computer technology entered massively with its powerful computing and graphic capabilities.

The tasks for the synthesis of the mechanisms according to the method of Burmester [1888], were

significantly expanded by Alt [1921], who managed to reduce the synthesis of transmission four-link mechanisms to the task of determining circular points. The next development of the theory of Burmester [1888] and the development of graphic methods for the synthesis of mechanisms based on this theory is connected with the developments of many German scientists, which are reflected in the summarized monographs of Bayer [1953,1959,1963], Hain [1967], Lichtenheld [1964]. Graphical solutions of the mechanism synthesis task lead to time-consuming graphical procedures and do not always ensure accuracy in reproducing the specified displacements. Such difficulties existed until the moment after which computer technology entered the graphics technologies massively, based on software products such as MathCAD, AutoCAD, Mat LAB, etc. However, these difficulties are one of the reasons for the evolution of the kinematic synthesis of mechanisms, in the direction of the development of the analytical methods of the extremely remote positions of a rigid body performing planar motion.

In this work, a practical method for drawing KKT and KCT is proposed, based on the condition of geometric constraint between a point of KKT and a point of KCT. Because this geometric constraint condition is mostly used in the vector-matrix method of lever mechanism synthesis, and the proposed method can be implemented in a software product environment with powerful computing and graphics capabilities, we name it the computerized vector-matrix method.

II. MATERIALS AND METHODS

II.1 Conditions and algorithm for plotting Burmester's circle point curves and center point curves.

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8072>

© 2024 Marin Jordanov Marinov. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

For a rigid body (most often a unit of a mechanism) that performs a general planar movement, the coordinates X_{Ci} and Y_{Ci} ($i = 1, \dots, 4$) are set (or can be determined in some way) for four discrete positions of point **C** from the body and its three relative angular orientations φ_{1i} ($i= 2, 3, 4$).

To be drawn: the circle point curve (CPC) which represents the GMTs which for the four discrete positions of the body will lie on circles of a fixed plane and the center point curve (CCT) which represents the GMTs which are the centers of these circles.

The algorithm for solving the task set in this way has the following form:

1. It is denoted by **B**₁ point of (KKT). The index of this notation indicates that it is a point of the moving plane at the first discrete position of the body;

2. It is denoted by **A** a point of (KCT), which is the center of a circle lying on the stationary plane and determined by the four discrete positions of the so-called **B**;

3. Using the plane displacement matrix, express the coordinates **X**_{B_i} and **Y**_{B_i} ($i=2,3,4$) of the discrete positions of point **B** in terms of the coordinates **X**_{B1} and **Y**_{B1} of the same point.

$$(1) \begin{bmatrix} X_{B_i} \\ Y_{B_i} \\ 1 \end{bmatrix} = \begin{bmatrix} \cos \varphi_{1i} & -\sin \varphi_{1i} & X_{C_1} - X_{C_i} \cos \varphi_{1i} + Y_{C_1} \sin \varphi_{1i} \\ \sin \varphi_{1i} & \cos \varphi_{1i} & Y_{C_1} - X_{C_1} \sin \varphi_{1i} - Y_{C_i} \cos \varphi_{1i} \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X_{B_1} \\ Y_{B_1} \\ 1 \end{bmatrix}$$

4. The equations for the geometric constraint of the segment \overline{AB} are written down.

$$(2) \quad a_i X_A + b_i Y_A = c_i \quad i=2,3,4, \quad \text{where}$$

$$(3) \quad \begin{aligned} a_i &= 2(X_{B_i} - X_{B_1}), \\ b_i &= 2(Y_{B_i} - Y_{B_1}), \\ c_i &= X_{B_i}^2 + Y_{B_i}^2 - X_{B_1}^2 - Y_{B_1}^2; \end{aligned}$$

5. The coordinates are also accepted for variable parameters **X**_{B_i}, **Y**_{B_i} and the expression for the function of these parameters is recorded: Marinov [2002].

$$(4) \quad K = \frac{(c_2 \cdot b_3 - c_3 \cdot b_2)}{(a_2 \cdot b_3 - a_3 \cdot b_2)} - \frac{(c_2 b_4 - c_4 \cdot b_2)}{(a_2 \cdot b_4 - a_4 \cdot b_2)}.$$

6. An isoline is drawn on the surface determined by the function (4) for zero values of this function in the area determined by the limits of the variable parameters ($\min X_{B_1} \leq X_{B_i} \leq \max X_{B_i}$), ($\min Y_{B_1} \leq Y_{B_i} \leq \max Y_{B_i}$). The dashed isoline is the CCP in this area.

$$(5) \begin{bmatrix} X_{A_i} \\ Y_{A_i} \\ 1 \end{bmatrix} = \begin{bmatrix} \cos \varphi_{1i} & \sin \varphi_{1i} & X_{C_1} - X_{C_i} \cos \varphi_{1i} - Y_{C_1} \sin \varphi_{1i} \\ -\sin \varphi_{1i} & \cos \varphi_{1i} & Y_{C_1} + X_{C_1} \sin \varphi_{1i} - Y_{C_i} \cos \varphi_{1i} \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X_{A_1} \\ Y_{A_1} \\ 1 \end{bmatrix}$$

7. A kinematic inversion is performed (the moving plane becomes stationary, and the stationary plane becomes mobile). Using the inverse plane displacement matrix, the coordinates X_{A_i} , Y_{A_i} of the inverse positions of point **A** ($i=2,3,4$) are also expressed through the coordinates **X**_{A1} and **Y**_{A1} of the same point.

8. The equations for the geometric constraint of the inverse position of the segment \overline{AB} are recorded.

$$(6) \quad a'_i \cdot X_{B_1} + b'_i Y_{B_1} = c'_i \quad i=2,3,4, \quad \text{where}$$

$$(7) \quad \begin{aligned} a'_i &= 2(X_{A_i} - X_{A_1}), \\ b'_i &= 2(Y_{A_i} - Y_{A_1}), \\ c'_i &= X_{A_i}^2 + Y_{A_i}^2 - X_{A_1}^2 - Y_{A_1}^2; \end{aligned}$$

9. The coordinates X_{A_1} and Y_{A_1} are accepted for variable parameters and the expression for the function of these parameters is written Marinov [2002].

$$(8) \quad Q = \frac{(c'_2 \cdot b'_3 - c'_3 \cdot b'_2)}{(a'_2 \cdot b'_3 - a'_3 \cdot b'_2)} - \frac{(c'_2 b'_4 - c'_4 \cdot b'_2)}{(a'_2 \cdot b'_4 - a'_4 \cdot b'_2)}$$

10. The isoline of the surface determined by the function (8) is drawn for zero values of this function, in the areas determined by the limits of the variable parameters ($\min X_{A_1} \leq X_{A_1} \leq \max X_{A_1}$) and ($\min Y_{A_1} \leq Y_{A_1} \leq \max Y_{A_1}$). The dashed isoline is the CCT in this area.

11. If a circular point of the CCT is selected using (2), the corresponding center point of the CCT is determined. When the center point is selected, by substituting in (6) the corresponding circular point is determined.

III. RESULTS AND DISCUSSION

III.1. Computer solution

Example: To draw the CCT and CCT of a link of a mechanism that performs general planar movement at given: $X_{C_1} = 150\text{mm}$, $Y_{C_1} = 90\text{mm}$, $X_{C_2} = 100\text{mm}$, $Y_{C_2} = 70\text{mm}$, $X_{C_3} = 50\text{ mm}$, $Y_{C_3} = 40\text{mm}$, $X_{C_4} = 20\text{mm}$, $Y_{C_4} = -20\text{mm}$, $\varphi_{12} = 30^\circ$, $\varphi_{13} = 70^\circ$, $\varphi_{14} = 120^\circ$.

The algorithm compiled above can only be implemented by means of an appropriately constructed program module, in the environment of a modern software product. For this purpose, the author compiled such a product in the environment of Mat LAB R2021b for Windows.

Through the compiled algorithm in the operating environment of MatLAB R2021b for Windows, calculations were performed and the curve of circular points (CCP) was drawn in an area with limits $-0.2m \leq X_{B1} \leq 0.4m$; $-0.2m \leq Y_{B1} \leq 0.4m$ depicted in Fig.1 and the curve of the center points (CCP) in an area with limits $-0.2m \leq X_{A1} \leq 0.4m$, $-0.2m \leq Y_{A1} \leq 0.4m$ - respectively depicted in Fig.2.

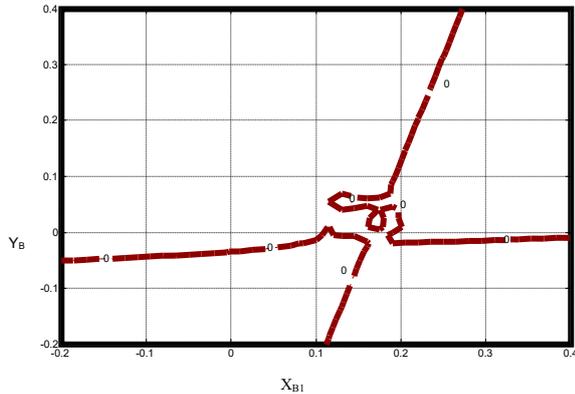


Fig.1 Burmester circle points curve

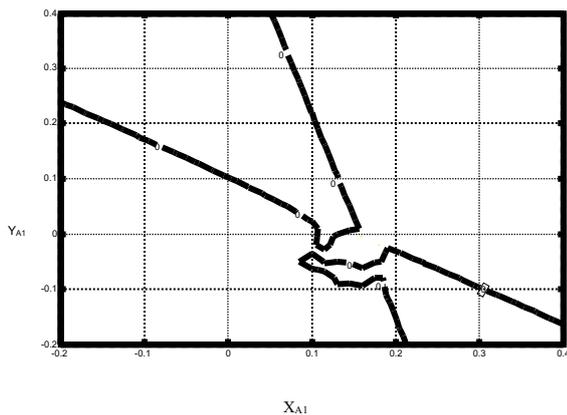


Fig.2 Burmester center points curve

IV. CONCLUSION

This article is intended for teaching bachelor's and master's students in the direction of mechanical engineering and the field of applied synthesis and kinematic analysis of mechanisms and machines for industry. The vector-matrix approach is applied to solving random problems from the theory of mechanisms and machines and automatic lines in industrial conditions. An example is shown through which a real solution to problems related to actuators and devices can be achieved.

A MatLAB R2021b for Windows program was used, with which different types of mechanisms can be synthesized, both in infinitely close and infinitely far positions of the input and output units. The classic Burmester principle was used as the basis of the synthesis, but adapted by the author for multilink mechanisms in industry [5].

Following the directions in which the synthesis of the mechanisms is developed on the basis of a relatively limited number of literary sources published in a relatively

long period of time, the following classification of these directions can be proposed:

1. Kinematic geometry of finitely distant and infinitely close positions in planar motion of a rigid body.
2. Graphical synthesis of planar mechanisms in extremely distant and infinitely close positions, using the graphic methods of kinematic geometry in planar motion of a rigid body.
3. Analytical synthesis of planar mechanisms in extremely distant and infinitely close positions, using the analytical methods of kinematic geometry in planar motion of a rigid body.
4. Spatial kinematic geometry of extremely distant positions of a rigid body performing spatial motion.
5. Synthesis of spatial mechanisms in extremely distant positions, using the methods of spatial kinematic geometry.
6. Approximation synthesis of planar and spatial mechanisms, using quadratic, Chebyshevski and other approximations.

In order to carry out an optimal synthesis of an arbitrary mechanism with subsequent kinematic analysis and establishing the effect of the synthesis, the following activities were carried out:

1. In fig. 1 shows the isoline of the curve of Burmester circular points, the results obtained from a family of points so closely spaced as to form a curve which is characteristic of any synthesis of spatial or planar mechanism.
2. While fig. 2 shows the isoline of the curve of the Burmester center points, resulting in a family of points so closely spaced as to form a curve which is also characteristic of the synthesis of a spatial or planar mechanism.
3. The variable parameters are selected for Cartesian coordinates in the range: $-0.2m \leq X_{B1} \leq 0.4m$; $-0.2m \leq Y_{B1} \leq 0.4m$ for point B and $-0.2m \leq X_{A1} \leq 0.4m$, $-0.2m \leq Y_{A1} \leq 0.4m$ for point A .

4. Two or three calculation parameters are selected. The remaining two parameters are assumed to be variable at $n=4$ and $n=5$, or assigned appropriate values at $n=3$. A system of 2 (or 3) linear equations with unknown quantities - the calculation parameters - is compiled. The coefficients in front of the unknown quantities and the free terms are constants for $n=3$ or functions of the variable parameters for $n=4$ and $n=5$. At $n=4$, one function of the two variable parameters is compiled, and at $n=5$ - two such functions. These functions define a surface from the points of the isoline of the surface at $n=4$ with a zero value of the function defining the surface, the values of the variable parameters satisfying the synthesis conditions are taken into account. At $n=5$, the intersection points of the isolines of the surfaces of the two functions with zero values of these functions determine the variable parameters satisfying the synthesis conditions.

5. Variable parameters can also be selected in polar coordinates.

6. The author proposes a unified approach for the synthesis of circular point curves and center point curves using a computer and appropriate software, which can be applied to various types of transport robots and manipulators, both for moving and driving mechanisms.

7. Using the reported values of the variable parameters, the calculation parameters are determined.

8. For all compiled algorithms, synthesis program modules have been developed in the Math LAB for Windows environment.

9. The obtained numerical results were obtained theoretically and based on them a prototype was developed, which shows increased reliability when working in real conditions, compared to that of the existing models. The prototype of the mechanism is made in a real industrial environment.

The purpose of this publication is to raise the level of teaching in the field of the theory of machine mechanisms and automatic lines in industrial production.

V. REFERENCES

- [1] I.I. Artobolevskiy, *Theory of Mechanisms and Machines*. Science, Moscow, 1967.
- [2] V.B.Bhandari, *Design of Machine Elements* Fifth Edition, McGraw Hill 2020.
- [3] V.B.Galabov, M. J. Marinov, N.B. Nikolov, Synthesis on a guiding MF at two points, respectively phase relation and double midpoint, "Mechanics of machines" 1999, booklet 26.
- [4] V.B.Galabov, M. J. Marinov, Synthesis of articulated four-link mechanism by discrete relative positions. "Mechanics of the machines", Varna, 2002.
- [5] G. Iliev, H.Hristov, "Modelling and Simulation of Electropneumatic Positioning System Including the Length of Pneumatic Lines" ENVIRONMENT. TECHNOLOGY. RESOURCES 14th International Scientific and Practical Conference. June 15-16, 2023, Rezekne Academy of Technologies, Rezekne, Latvia, Page 106-111 ISSN 1691-5402 Online IS. DOI 10.17770/etr2023vol3.7186
- [6] Jhon Uicker, G. Pennok, J. Shigley, *Theory of Machines and Mechanisms*, Fifth Edition, Oxford University Press 2017.
- [7] M.Marinov, Synthesis of planar mechanisms by extremely distant discrete positions. Dissertation abstract to get the scientific and educational degree "PhD" - TU Sofia 2002, pp.36.
- [8] Myszka David, *Machines & Mechanisms: Applied Kinematic Analysis*, 2011.
- [9] M.J.Marinov, B.I. Stoychev, D.M. Guteva, M.V. Georgiev, Computer modeling and geometric analysis of Click-Clack mechanisms. "Mechanics of the machines" 2016 booklet 118 pp.35-39.
- [10] M. Stanisic, *Mechanisms and machines; Kinematics, Dynamics and synthesis*, Stamford 2015.
- [11] L.L.Harrisberger, *An overview of structural synthesis of three-dimensional mechanisms, constructing science and technology of mechanical engineering*, World, Moscow, 1965.
- [12] R.A.Rusev, V.B. Galabov, Structuring of rational planet-lever mechanism for passing the weft through the weaving machines. "Mechanics of machines" 2002 pp.26 booklet 33.
- [13] Sadhu Singh, *Theory of Machines: Kinematics and Dynamics*, Pearson Education, India 2011
- [14] S. Stefanov, *Theoretical mechanics, statics, kinematics and dynamics*, Sofia 2014.
- [15] P.T.Stoyanov, Geometric precision synthesis of planar lever mechanisms. "Mechanics of the machines" 2002 p.56 vol. 33.
- [16] G.A.Timofeev, *Theory of Mechanisms and Machines*, Moskow Urde 2010.

Ethical concerns in using of Generative Tools in Higher Education: Cross - Country Study

Jūlija Mironova

*Department of Management
ISMA University of Applied Sciences
Riga, Latvia*

julija.mironova@isma.lv

Viktorii Riashchenko

*Department of Management
ISMA University of Applied Sciences
Riga, Latvia*

viktorii.riashchenko@isma.lv

Remigijus Kinderis

*Klaipeda University of Applied
Sciences
Klaipeda, Lithuania*

r.kinderis@kvk.lt

Valentina Djakona

*Department of Management
ISMA University of Applied Sciences
Riga, Latvia*

valentina.djakona@isma.lv

Sevdalina Ilieva Dimitrova

*Scientific research and innovation
activities Institute
Vasil Levski National Military
University)*

*Veliko Tarnovo Bulgaria
sevdalina_id@abv.bg*

Abstract. Even though the historical development of artificial intelligence started in the mid-20th century, since the launching of Chat GPT this concept emerged in the scientific and educational agenda. Different concerns are arising at different education levels, starting from a discussion about whether should it be considered plagiarism, and ending with ethical aspects of the usage of Chat GPT by students and educators.

The research aims to research the main recent scientific findings about generative tools in artificial intelligence and the ethical aspects of its usage in education.

Methods used – analysis of recent scientific findings and statistical analysis of the answers of the respondents on authors created a survey for students of Higher Education Institutions about their attitudes and knowledge towards Generative Tools of Artificial Intelligence. Analysis was performed via SPSS comparing the opinion of students towards ethics of Generative Tools of AI from different countries.

Results of the research show the attitudes of students towards the usage of Generative Tools of Artificial Intelligence from different countries.

Keywords: *artificial intelligence, Chat GPT, education, ethics.*

I. INTRODUCTION

Artificial intelligence generative tools such as Chat GPT and similar innovations have sparked significant discourse within scientific and academic circles. In the scientific community, researchers are deliberating the ethical use of generative tools in their research endeavors, while in the academic realm, concerns arise regarding the ethicality of students employing AI-driven tools.

Artificial intelligence (AI) has long captured the interest of scholars, but its recent integration into education has garnered heightened attention. Tools like Chat GPT and others are swiftly reshaping the educational landscape for both students and educators. With the ability to complete assignments in mere seconds using generative AI applications, it becomes crucial for Higher Education Institutions (HEIs) to adapt, offering tailored environments equipped with suitable tools and methodologies. These generative tools not only inspire students and foster creativity but are increasingly embraced by students to fulfill academic requirements—a phenomenon that cannot be ignored. Nevertheless, comprehending the nuances and potential of AI tools holds the promise of revolutionizing the educational process, ushering it into a more dynamic and engaging realm. Embracing novel perspectives on learning stands to mutually benefit students and educators, provided these tools are effectively implemented and utilized.

The current paper includes an introduction, an AI Overview section exploring the ethical considerations surrounding AI usage. Sections 4 and 5 elaborate on the methodology utilized in the research. The Results section outlines the findings, and the concluding section provides conclusions and proposes future research avenues.

II. MATERIALS AND METHODS

As Artificial Intelligence (AI), specifically Generative AI (GAI) like ChatGPT and Bard, gains unprecedented traction, the demand for ethical guidelines in higher education institutions (HEIs) worldwide has surged [6],

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8097>

© 2024 Jūlija Mironova, Viktorii Riashchenko, Remigijus Kinderis, Valentina Djakona, Sevdalina Ilieva Dimitrova.

Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

[15]. This heightened concern stems from the remarkable ability of these tools to produce human-like texts, challenging even the expertise of discerning professionals [7]. Compounding the issue is the rapid adoption of these technologies by students, with reports indicating widespread usage. For instance, nearly half of Cambridge University students in the United Kingdom admitted to utilizing ChatGPT in their studies [9], while Forbes reported that 20% of college students in the United States confessed to the same [11]. With GAI functionality becoming embedded in everyday tools like word processors and presentation software (e.g., Microsoft Co-Pilot), these figures are poised to escalate.

GAI signifies a revolutionary leap from prior AI models, leveraging deep learning to generate human-like content across various mediums, including audio, code, images, text, simulations, 3D objects, and videos [16]. This transformative technology responds to diverse and intricate prompts, such as languages, instructions, and questions, producing unexpected outputs [16].

A pivotal concern for HEIs revolves around the potential misuse of GAI by students for cheating or plagiarism in written assignments and exams [2]. This not only jeopardizes academic integrity but also poses a threat to the reputation of HEIs. Scholars further caution against students becoming overly reliant on GAI, foreseeing a decline in writing and critical thinking skills [10], potentially impacting the quality of education and student learning outcomes [2].

In an era where technological advancements redefine human existence, artificial intelligence emerges as a revolutionary force. Since the November 2022 release of OpenAI's ChatGPT [OpenAI ChatGPT, 2023], the AI landscape has witnessed an unprecedented transformation. ChatGPT, drawing from a vast language database, generates responses from human-entered text-based inputs [14]. Its rapid ascent to popularity, boasting an estimated 100 million monthly active users [4], spurred other tech giants to introduce their own AI-powered innovations, such as Google's Bard [5] and GitHub's Copilot [4].

The impact of AI extends far and wide, triggering discussions on diverse topics, from its potential to transform learning and teaching methods [13] to its role in research and the imperative considerations of ethics and academic integrity [8].

As this article unravels the ethical dimensions of integrating Generative Artificial Intelligence in higher education, it not only underscores the promising advancements but also critically examines the ethical considerations intrinsic to its application. Drawing from these insights, the paper delineates a roadmap for future research, aiming to propel the field of Generative AI in educational contexts. The outlined directions encompass transparency enhancement, bias mitigation, collaborative AI exploration, longitudinal studies, privacy measures, long-term impact assessment, ethical considerations, student acceptance research, interdisciplinary collaborations, and inclusivity initiatives. Through a global exploration, this article aims to foster responsible and ethical integration of Generative Tools in higher education.

The questionnaire crafted by the authors was uploaded onto QuestionPro and disseminated to students via email. Participants from Latvia, Lithuania, Uzbekistan, Ukraine, and Bulgaria joined in the survey, with a total of 414 students responding. The survey was conducted in the initial semester of the academic year 2023/2024, running from January 1st to January 20th, 2024. Table 1 outlines the survey's structure.

TABLE 1 STRUCTURE OF THE SURVEY (SOURCE:CREATED BY AUTHORS)

Part of the survey	Description		
	Types of the questions	Evaluation scale	Codes
A: Respondent profile (gender, age, location, field of education, level of education, country of residence)	Open/Closed	Multiple-choice	A_1-A_6
B: Attitude and Knowledge of Chat GPT (8 statements to assess knowledge and attitude)	Closed	Multiple-choice	B_1-B_8

First part of the questionnaire includes questions related to the respondent profile.

Distribution of respondents by countries is represented in Table 2.

TABLE 1 DISTRIBUTION OF RESPONDENTS BY COUNTRY OF STUDY (SOURCE:CREATED BY AUTHORS)

Country	Distribution of respondents
Latvia	40%
Lithuania	32%
Ukraine	14%
Uzbekistan	4%
Bulgaria	7%
Other	3%

As depicted in Table 2, 377 participants indicated their country of study. The majority of respondents identified studying in Latvia, comprising 40% of the total, while Lithuania followed closely with 32%. Other countries were each represented by less than 20% of the overall respondents.

The gender distribution among survey participants was fairly even, with 51% identifying as female and 49% as male.

Table 3 represents age of the respondents, level of education and field of education.

As depicted in Table 3, the majority of respondents, comprising 83% of the total, are students enrolled in bachelor-level programs, totaling 173 individuals. A smaller portion, 10%, are pursuing short cycle programs, while 5% are engaged in master's degree studies. The smallest fraction, accounting for 2% of respondents, are enrolled in PhD programs.

TABLE 3. AGE OF THE RESPONDENTS, LEVEL OF EDUCATION AND FIELD OF EDUCATION (SOURCE:CREATED BY AUTHORS)

Age	Amount of respondents	Level of Studies	Amount of respondents	Field of education	Amount of respondents
<20	88	Short Cycle	21	Education	20
21-25	158	Bachelor	173	Economics	14
26-30	47	Masters	10	Finance	30
31-45	49	PhD	5	Management	24
36-40	10			Information Technologies	10
>40	28			Mathematics	0
				Engineering	24
				Manufacturing	2
				Medicine	34

Regarding their fields of education, the largest contingent, constituting 17% or 34 students, are pursuing medicine. This is followed by finance, with 15% of respondents, and management and entrepreneurship, each comprising 12% of the total. Engineering also accounts for 12% of respondents. Other fields of study each represent less than 10% of respondents, while 23% of participants mentioned pursuing studies in different fields.

III.RESULTS AND DISCUSSION

In general, students consider usage of Chat GPT ethical, as 278 of students who participated in research answered, but 132 students noted that usage of it in education is unethical.

To achieve the goal of the research, authors designed hypothesis:

H: There is statistically significant difference between perception of is using Generative AI tool in education is ethical or not within the respondents from different countries.

Respondents were asked to answer the question “In your opinion, is usage of generative Tools of AI in study process by students ethical”, by offering them two options – yes or no.

To the the Hypothesis authors used Kruscal-Wallis non-parametric test. Results of the test showed that there is statistically significant difference between perception if usage of Generative Tools of AI is ethical or not within the countries of respondents study in, as Asym.Sig. is 0.15(the standard alpha level is 0.05). Mean rank of the answers of students from Bulgaria is higher than of students from other countries, what shows that students from Bulgaria stastically consider usage of Chat GPT more unethical than sudents from other countries.

CONCLUSIONS

Shedding light on the promising advancements facilitated by the integration of Generative Artificial Intelligence (GAI) in educational settings, this comprehensive review meticulously scrutinizes the ethical considerations inherent in its application. Navigating through the intricate landscape of ethical implications, responsible GAI usage, the imperative need for data privacy safeguards, potential biases, and the preservation of academic integrity, this article critically examines the assimilation of GAI within higher education.

Drawing insights from this exhaustive review, the paper puts forth several avenues for future research, seeking to propel the field of GAI in educational contexts:

Enhancing Transparency: Future research endeavors should focus on augmenting the transparency of GAI models. Gaining a comprehensive understanding of how AI-generated outputs manifest and providing transparent explanations to end-users can cultivate trust and foster acceptance of GAI tools within educational environments.

Mitigating Biases and Ensuring Fairness: As GAI models inherently learn from existing data, there is a risk of perpetuating biases present in the data. Future research should prioritize identifying and mitigating biases in GAI tools, especially within educational settings, to prevent the reinforcement of stereotypes or discrimination against specific groups of learners.

GAI in Teacher Professional Development: Research initiatives can delve into the transformative role of GAI tools in assisting educators to refine their teaching methodologies, craft tailored instructional materials, and receive real-time feedback on their performance.

Collaborative AI in Education: Exploring the potential of collaborative AI systems in education, wherein human and AI entities collaborate synergistically to achieve common educational objectives.

Longitudinal Studies: Conducting comprehensive longitudinal studies to track the enduring effects of GAI integration in education. Such studies can furnish valuable insights into the sustained impact of GAI on learning outcomes, retention rates, and academic performance over prolonged durations.

Privacy and Data Security: Research initiatives should concentrate on formulating robust data protection measures, ensuring responsible and secure handling of student data in the realm of GAI integration in education.

Long-term Impact on Learning Outcomes: Investigating the enduring influence of GAI integration on learning outcomes, academic achievements, and the development of students' problem-solving skills.

Ethical Considerations and Responsible AI: Delving deeper into the ethical implications of deploying GAI in education, particularly addressing concerns related to plagiarism, academic integrity, and potential impacts on students' critical thinking skills. Developing guidelines and policies to uphold the responsible and ethical use of GAI technologies in educational settings.

Student Acceptance and Adoption: Conducting research to comprehend students' attitudes toward and acceptance of GAI technology in the learning process. Identifying factors influencing their perceptions and formulating strategies to augment student engagement and acceptance.

Interdisciplinary Collaborations: Fostering collaborative endeavors between educators, AI researchers, and policymakers to formulate comprehensive frameworks for the seamless integration of GAI into education.

Inclusivity and Accessibility: Exploring avenues to enhance the accessibility of GAI-powered educational tools for diverse learners, including those with disabilities or language barriers.

In general, students consider usage of Chat GPT ethical, as 278 of students who participated in research answered, but 132 students noted that usage of it in education is unethical.

Hypothesis of the research is approved, as there is statistically significant difference between perception is usage of generative tools like Chat GPT is ethical within the students of different countries, as students from Bulgaria noted that it is unethical statistically more than students from other countries.

Authors believe that future research would help to establish strong understanding for universities the need of creation guidelines for usage of generative tools of Chat GPT in order to help students and educators to understand for what exactly this tool can be used, and for what not.

REFERENCES

- [1] A.Bahrini, M.Khamoshifar, H.Abbasimehr, R.J.Riggs, M.Esmaeili, R.M.Majdabadkohne, M. Pasehvar, ChatGPT: Applications, opportunities, and threats. In Proceedings of the 2023 Systems and Information Engineering Design Symposium (SIEDS), Charlottesville, VA, USA, 27–28 April 2023. (Google Scholar, CrossRef)
- [2] C.K.Y. Chan A comprehensive AI policy education framework for university teaching and learning *Int. J. Educ. Technol. High. Educ.*, 20 (1) (2023), 10.1186/s41239-023-00408-3 38–25
- [3] C.K.Y. Chan, K.K.W. Lee The AI generation gap: are gen Z students more interested in adopting generative AI such as ChatGPT in teaching and learning than their gen X and millennial generation teachers? *arXiv.org* (2023)
- [4] Github(2024). Copilot. Available online: <https://copilot.github.com/> (accessed on 28 July 2023).
- [5] Google Bard (2024). Gemini. Available online: <https://bard.google.com/> (accessed on 28 July 2023).
- [6] J. Crawford, M. Cowling, K. Allen Leadership is needed for ethical ChatGPT: character, assessment, and learning using artificial intelligence (AI) *J. Univ. Teach. Learn. Pract.*, 20 (3) (2023), 10.53761/1.20.3.02
- [7] J.E. Casal, M. Kessler Can linguists distinguish between ChatGPT/AI and human writing?: a study of research ethics and academic publishing *Res. Methods Appl. Linguist.*, 2 (3) (2023), 10.1016/j.rmal.2023.100068
- [8] C.Kooli, Chatbots in education and research: A critical examination of ethical implications and solutions. *Sustainability* 2023, 15, 5614. [Google Scholar] [CrossRef]
- [9] L. Sleator Almost half of Cambridge students admit they have used ChatGPT April 21 *The Times* (2023) <https://www.thetimes.co.uk/article/cambridge-university-students-chatgpt-ai-degree-2023-rmsv7mw7z>
- [10] M. Warschauer, W. Tseng, S. Yim, T. Webster, S. Jacob, Q. Du, T. Tate The affordances and contradictions of AI-generated text for second language writers *SSRN Electron. J.* (2023), 10.2139/ssrn.4404380
- [11] M.T. Nietzel More than half of college students believe using ChatGPT to complete assignments is cheating March 20 *Forbes* (2023) <https://www.forbes.com/sites/michaelt Nietzel/2023/03/20/more-than-half-of-college-students-believe-using-chatgpt-to-complete-assignments-is-cheating/>
- [12] OpenAI (2024). ChatGPT. Available online: <https://chat.openai.com> (accessed on 28 July 2023).
- [13] M.M.Rahman, Y. Watanobe, ChatGPT for education and research: Opportunities, threats, and strategies. *Appl. Sci.* 2023, 13, 5783. [Google Scholar] [CrossRef]
- [14] M.Sullivan, A. Kelly, P. McLaughlan, ChatGPT in higher education: Considerations for academic integrity and student learning. *J. Appl. Learn. Teach.* 2023, 6, 31–40. [Google Scholar] [CrossRef]
- [15] Holmes, W., Porayska-Pomsta, K., Holstein, K., Sutherland, E., Baker, T., Shum, S. B., Santos, O. C., Rodrigo, M. T., Cukurova, M., Bittencourt, I. I., & Koedinger, K. R. (2022). Ethics of AI in Education: Towards a Community-Wide Framework. In *International Journal of Artificial Intelligence in Education* (Vol. 32, Issue 3, pp. 504–526).
- [16] W.M. Lim, A. Gunasekara, J.L. Pallant, J.I. Pallant, E. Pechenkina Generative AI and the future of education: ragnarök or reformation? A paradoxical perspective from management educators *Int. J. Manag. Educ.*, 21 (2) (2023), Article 100790, 10.1016/j.ijme.2023.100790

Application of Electronic Platforms to Increase the Knowledge of Learners

Daniela Mirtcheva-Ivanova

Bulgarian Defense Institute

"Professor Tsvetan Lazarov"

Sofia, Bulgaria

mirtchevadany@gmail.com

Abstract. The article examines the use of online platforms and the possibilities they offer for supplementary and complementary learning. Some commonly used platforms among learners are presented and various studies have been conducted. The results were analyzed and a comparative assessment was made for the effectiveness of digital platforms in learning through described results of real tests. An increase in the knowledge of learners when using online platforms has been reported.

Keywords: electronic platforms, e-learning, test, learner

I. INTRODUCTION

The world in the 21st century is developing too fast, thanks to new digital technologies. The changes are reflected in every sphere of society – finance, healthcare, business, transport, electrical appliances. New technologies are an invariable part of public life, they are constantly present and used in modern education. Education is an important and basic activity of society, in its quality of education, training and building a fully developed personality. To achieve higher results in education, it is necessary to use new pedagogical approaches using digital technologies. Learning technologies include virtual reality, use of mobile devices, interactive multimedia technologies, online materials and videos.

In educational institutions, the use of digital technologies as a means of teaching and learning is increasing, which supports teachers and trainers to achieve higher results [6]. The education development strategies of the Ministry of Education and Culture in the Republic of Bulgaria are also aimed at full and fruitful use of digital technologies [7], [8].

In the program of educational institutions in technical specialties, the subject of informatics is studied. It involves algorithms and programming by learning a specific computer language in a programming environment with many practical tasks [1], [2], [3], [4]. The study of computer science begins at school, in the elementary stage

to reach the compilation of computer programs in the 11th and 12th grade in the profiled classes and continue in the universities in the technical specialties [5].

Тест по информатика

Номер в клас: _____ Клас: _____

1. От какъв тип е условното в структурата на оператора if:

```
if (<условие>) <оператор_true>
else <оператор_false>
```

а) реален тип, б) целочислен тип,
в) булев тип, г) стринг.

2. Как се присвоява стойност на променлива:

```
а) a==5; б) a=5;  
в) a<>5; г) a!=5;
```

3. Какво ще бъде изведено на конзолата след изпълнението на показания код?

```
static void Main(string[] args)
{
int a = 12, b = 6;
bool flag;
flag = a > b;
Console.WriteLine("flag = {0}", flag);
}
```

а) flag = False; б) True;
в) flag = True; г) False;

Fig. 1. Test questions.

Some of the schools in Bulgaria have a software and hardware profile. One of the schools with computer science in Sofia is 44 Secondary School "Neofit Bozveli" [22], [23]. Students in the 11th grade study the computer language C#, according to the program of the Ministry of Education and Culture [20], [21]. The results of the tests in the first academic term of the 2022/2023 academic year are not high. The studied material includes basic constructions of the C# language. Achieving high results leads to better

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8090>

© 2024 Daniela Mirtcheva-Ivanova. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

assimilation and learning of the computer language in the next stage using materials and videos from electronic platforms from part by the students after one month of training. Here are some of the questions included in the test trial shown in Fig. 1:

Some of the test questions include C# program fragments and a requirement to indicate a correct answer to the task result shown in Fig. 2.

5. Какво ще бъде изведено на конзолата след изпълнението на показания код?

```
static void Main(string[] args)
{
    int x=2;
    if(x>3)
    { Console.WriteLine("x е по-голямо от 3"); }
    else
    { Console.WriteLine("x не е по-голямо от 3"); }
```

- а) x е по-голямо от 3;
- б) 0;
- в) програмата дава грешка;
- г) x не е по-голямо от 3;

6. Кой израз има стойност 1?

- а) 2 % 1;
- б) 5 % 3;
- в) 12 % 2;
- г) 29 % 4;

Fig. 2. Test questions include C# program.

The test includes questions about calculating the value of an expression depending on the value of variables, implemented by a program in the computer language C#, shown in Fig. 3.

9. Какво ще бъде изведено на конзолата след изпълнението на показания код?

```
static void Main(string[] args)
{
    int a, b;
    a = -10;
    b = 5;
    if (a>0)
    { Console.WriteLine(a = a + b); }
    else
    { Console.WriteLine(a = a * 2); }
    Console.WriteLine(a = a - 2);
}
```

- а) -20 -22;
- б) -12 -5;
- в) 10 -8;
- г) -20 -8;

10. Какво ще бъде изведено на конзолата след изпълнението на показания код?

```
static void Main(string[] args)
{
    int a;
    a = 10;
    if (a>0)
    { Console.WriteLine(a + 2); }
    else
    { Console.WriteLine(a - 2); }
}
```

- а) -12;
- б) 12;
- в) 8;
- г) -8;

Fig. 3. Test questions about calculating.

Although teachers and students use digital technologies at school, good results were achieved from the tests done in 44 Secondary schools, during the first academic term of the 2022/2023 academic year, in computer science education, in the Object-Oriented Programming Module, Topics: "C# Programming". 16 students participated in the test assessment. The average score on the test is Good 4.19. The scores and scores obtained can be seen in Table 1.

TABLE 1. SCORES OBTAINED BY STUDENTS.

Learner number	Number of points received	Max points	Assessment	Assessment in words
1	15	30	4	Good
2	18	30	4.4	Good
3	15	30	4	Good
4	21	30	4.8	Very Good
5	9	30	3.2	Acceptable
6	27	30	5.6	Excellent
7	24	30	5.2	Very Good
8	9	30	3.2	Acceptable
9	24	30	5.2	Very Good
10	18	30	4.4	Good
11	15	30	4	Good
12	15	30	4	Good
13	9	30	3.2	Acceptable
14	9	30	3.2	Acceptable
15	30	30	6	Excellent
16	12	30	3.6	Good

The average success rate of students is Good 4.19. A total of 4 students have shown an average result, 7 students have a good result, 3 students have a very good result and 2 students have an excellent result. Everyone has a desire to succeed in the educational process Fig. 4. Student Scores on the Scoring Test

Number of points received against the learner's number sub-title

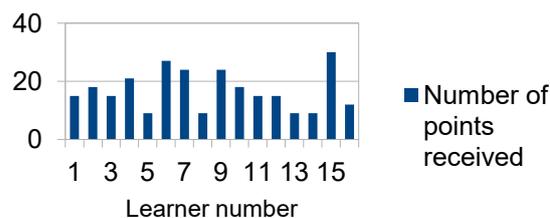


Fig. 4. Student Scores on the Scoring Test.

According to the previously prepared formula for converting points into grades, a diagram was made that illustrates the number of students in relation to their grades Table 2

TABLE 2. STUDENTS IN RELATION TO THEIR GRADES .

Total number of students		16
Assessments	Number of students	
3	4	
4	7	
5	3	
6	2	
Average		4.19

Looking at the chart Fig. 5 of the percentages of the learners' test scores, the overall performance is clearly visible.

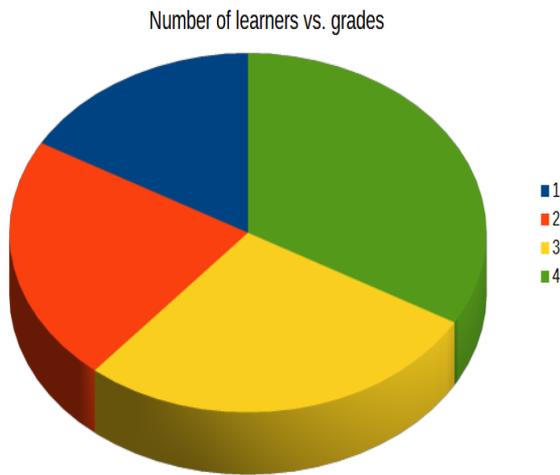


Fig. 5. Percentage ratio of students by test scores in grades

Here is the detailed information in Table 3, for each student by points received on each of the questions in the e-test. Each correctly solved task is evaluated with 3 points.

TABLE 3. STUDENT ACHIEVEMENT SCORES.

Learner number	Task number from the test										Number of points received
	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9	Task 10	
1	3	0	3	3	0	3	3	0	0	0	15
2	3	3	3	0	3	3	0	0	0	3	18
3	3	0	3	0	3	0	0	0	3	3	15
4	3	3	3	3	3	3	0	3	0	0	21
5	3	0	0	0	0	0	3	0	3	0	9
6	3	3	3	3	0	3	3	3	3	3	27
7	0	3	3	3	3	3	3	3	3	0	24
8	3	0	3	0	3	0	0	0	0	0	9
9	0	3	3	3	3	3	0	3	3	3	24
10	0	3	3	3	3	0	3	0	0	3	18
11	3	0	3	3	3	0	0	3	0	0	15
12	3	0	3	0	3	3	0	0	0	0	12
13	3	0	3	0	0	0	0	0	3	0	9
14	0	3	0	0	0	0	3	3	0	0	9
15	3	3	3	3	3	3	3	3	3	3	30
16	3	3	3	0	3	0	0	0	0	0	12

The results were analyzed and a recommendation was made to the learners to use electronic platforms to eliminate the gaps and absorb more knowledge [9], [10].

There are 52 students in the 11th grade, divided into 2 classes. Only 16 of them wished to receive additional training to eliminate gaps and gain new knowledge.

Teachers and students who have expressed a desire to learn further have considered the possibility of e-learning and have chosen appropriate platforms for the subject of computer science.

Skillshare offers a variety of courses in design, entrepreneurship, business, programming and more. The training is conducted by experts in the respective fields and the user interface is easy to use. Many of the courses are a few hours long and can be completed quickly. The training includes video tutorials and many practical tasks. The payment for the courses is low, quite acceptable and is based on a monthly or annual fee, and unlimited brief courses can be studied during the paid period [9], [10], [11].

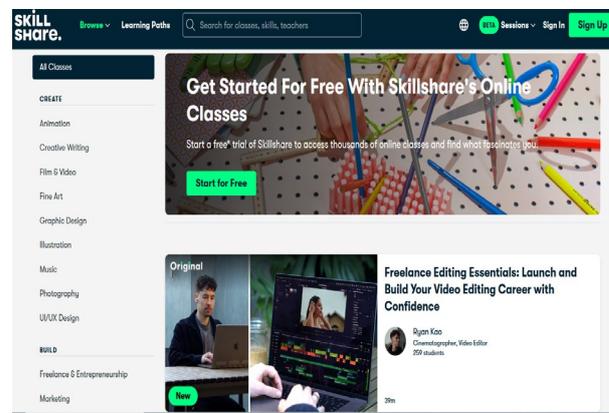


Fig. 6. . Site Skillshare

Udemy is one of the largest online learning platforms, with 60,000 instructors, 62 million students, and a huge database of courses Fig. 7. Training is available in business, programming, design, finance, teaching and more. Courses vary in length, but usually cover a large amount of information and take up a longer period of time. There is no monthly or annual fee, but an individual price per course, which is affordable and in most cases – low. Those who sign up for a course receive a certificate upon completion and lifelong access to the course, and in case of refusal of training within 30 days, the amount paid is returned to the learner [12], [13], [14].

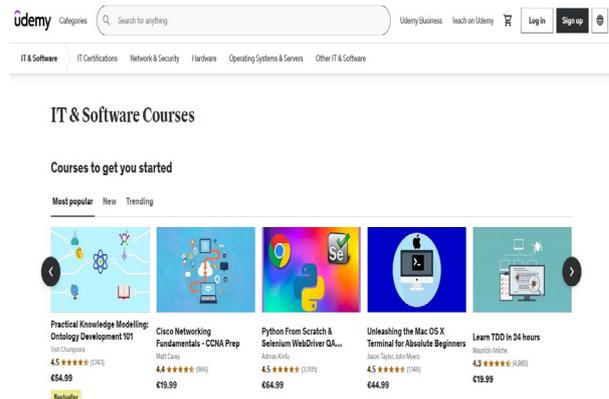


Fig. 7. Site Udemy

After a month of training, using the Skillshare and Udemy platforms to eliminate the gaps in the knowledge of the learners, a test was made to all the learners and a higher score was reported for the 16 students who worked extra Table 4.

TABLE 4. STUDENT SCORES ON THE TEST SCORES AND GRADES .

Learner number	Number of points received	Max points	Assessment	Assessment in words
1	21	30	4.8	Very Good
2	24	30	5.2	Very Good
3	21	30	4.8	Very Good
4	21	30	4.8	Very Good
5	24	30	5.2	Very Good
6	27	30	5.6	Excellent
7	24	30	5.2	Very Good
8	24	30	5.2	Very Good
9	21	30	4.8	Very Good
10	24	30	5.2	Very Good
11	27	30	5.6	Excellent
12	18	30	4.4	Good
13	21	30	4.8	Very Good
14	18	30	4.4	Good
15	30	30	6	Excellent
16	21	30	4.8	Very Good

The average success rate of the learners is Very good 5.06. A total of 2 students have shown a good result, 11 students have a very good result and 3 students have an excellent result. The result is shown in Fig. 8.

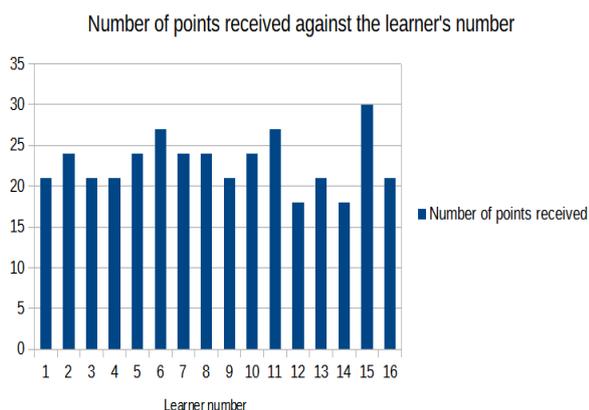


Fig. 8. Student scores on the point test.

The results achieved by learners after using the Skillshare and Udemy platforms have significantly improved. Here are the summary scores in Table 5.

TABLE 5. SUMMARY SCORES.

Total number of students	
16	
Assessments	Number of students
4	2
5	11
6	3
Average	5.06

Learners who showed interest and took additional training, a total of 16, increased their success by one unit when given a second test of the same material after one month of additional training. The other 11th graders

showed an identical level of knowledge on the second test, similar to the initial test trial.

The report examines digital platforms as a means of supplementary and complementary learning. Additional training of a group of computer science trainees through materials and videos on electronic platforms on studied topics has been set and requested. Some of the platforms have been implemented among some of the trainees for working at home and tests have been carried out. A test was conducted on all students from one graduating class before and after using materials and videos from educational online platforms with a difference of one month on the same material. The results were analyzed and an assessment was made of the effectiveness of their use in training. An increase in the knowledge of learners who used digital platforms for computer science training was reported.

New technologies and innovations complement and support traditional learning methods. The use of cloud technologies [17] has been increasingly used recently, and the widespread use in educational institutions of modern information models and resources gives a new impetus to learning [15, 16, 18, 19]. New technological tools such as online platforms, mobile applications and e-books can fundamentally contribute to higher learning efficiency. In order for education to be complete, effective and modern, digital technologies must be used to increase the effectiveness of learning and teaching.

ACKNOWLEDGEMENTS

This work was supported by the National Science Program "Security and Defence" program, which has received funding from the Ministry of Education and Science of the Republic of Bulgaria under the grant agreement no. Д01-74/19.05.2022.

REFERENCES

- [1] Programs, Faculty of Mathematics and Informatics, SU "St. Kliment Ohridski". [Online]. Available: <https://www.fmi-uni-sofia.bg/bg/programi> [Accessed Jan 15, 2024].
- [2] Plovdiv University "Paisii Hilendarski", Faculty of Mathematics and Informatics. [Online]. Available: <https://fmi-plovdiv.org/index.jsp?id=4416&ln=1> [Accessed Jan 15, 2024].
- [3] OKS "Bachelor", Specialty "Computer Systems and Technologies". [Online]. Available: <https://www.nvu.bg/bg/%D1%81%D0%BF%D0%B5%D1%86%D0%B8%D0%B0%D0%BB%D0%BD%D0%BE%D1%81%D1%82%D0%B1%D0%B0%D0%BA%D0%B0%D0%BB%D0%B0%D0%B2%D1%80%D0%B8/grazhdanska-specialnost-kompyutarni-sistemi-i-tehnologii> .[Accessed Jan 17, 2024]. (in Bulgarian)
- [4] OKS "Bachelor", Computer systems and cyber security. [Online]. Available: <https://www.nvu.bg/bg/%D1%81%D0%BF%D0%B5%D1%86%D0%B8%D0%B0%D0%BB%D0%BD%D0%BE%D1%81%D1%82%D0%B1%D0%B0%D0%BA%D0%B0%D0%BB%D0%B0%D0%B2%D1%80%D0%B8/grazhdanska-specialnost-kompyutarni-sistemi-i-kibersigurnost> .[Accessed Jan 17, 2024]. (in Bulgarian)
- [5] Training programs for profiled preparation, Ministry of Education and Science. [Online]. Available: <https://www.mon.bg/obshto-obrazovanie/uchebni-planove-i-programi-2/uchebni-programi-za-profilirana-podgotovka/> [Accessed Jan 19, 2024].

- [6] Mariyana Nikolova, Tanya Evtimova , Digital Educational Tools – Potential, Application, and Perspectives ; Journal of Mathematics, Computer Science and Education Vol. 5, No. 1, 2022, DOI: 10.54664/MALF1684
- [7] Ministry of Education and Science, Strategic documents, Strategy for the development of higher education in the Republic of Bulgaria for the period 2021-2030. [Online]. Available: <https://www.mon.bg/mon/strategii-i-politiki/strategicheski-dokumenti-2/> [Accessed Jan 19, 2024].
- [8] Strategic documents for the development of education of the Ministry of Education and Culture.. [Online]. Available: https://www.navet.government.bg/bg/media/strategicheska-ramka_obrobuuchene_110321-1.pdf [Accessed Jan 19, 2024].
- [9] Top 10 E-Learning Platforms for Effective Development.[Online]. Available: <https://www.hurix.com/top-10-e-learning-platforms-for-effective-development/>
- [10] Digital skills as a way to access learning opportunities. [Online]. Available: <https://epale.ec.europa.eu/bg/newsletters/digitalniteni-umeniya-kato-nachin-za-dostp-do-vzmozhnosti-za-uchene>. [Accessed Feb. 5, 2024].
- [11] Skillshare Official Site.[Online]. Available: <https://www.skillshare.com/>. [Accessed Feb. 5, 2024].
- [12] The Top 10 Online Learning Platforms for 2024.[Online]. Available: <https://www.thinkific.com/blog/online-learning-platforms/>. [Accessed Feb. 7, 2024].
- [13] Official udemy site [Online]. Available: <https://www.udemy.com/>. [Accessed Feb. 11, 2024].
- [14] Udemy Review: Is it The Right Platform for You?[Online]. Available: <https://upskillwise.com/reviews/udemy/> . [Accessed Feb. 11, 2024].
- [15] P. Boyanov, Educational exploiting the information resources and invading the security mechanisms of the operating system Windows 7 with the exploit Eternalblue and backdoor Doublepulsar, a refereed Journal Scientific and Applied Research (Licensed in EBSCO, USA), Konstantin Preslavsky University Press, ISSN 1314-6289, vol. 14, 2018, pp.34-41.
- [16] P. Boyanov, Construction and simulation of optical local area computer networks for the needs of the academic institutions, International Scientific Online Journal, www.sociobrain.com , Publ.: Smart Ideas - Wise Decisions Ltd, ISSN 2367-5721 [online], Issue 54, February 2019, pp. 89-96..[Accessed Feb. 23, 2024].
- [17] R. Iliev and K. Ignatova. Implementation of cloud technologies for building data centers in defence and security. Information & Security: An International Journal 43, no. 1 (2019): 89-97.[Online]. Available: <https://doi.org/10.11610/isij.4308> ..[Accessed Feb. 27, 2024].
- [18] S. Spasov, International academic programs and training models for combating corruption and their application in the UNSS. Scientific works of UNSS, pp. 69-95, 2022.
- [19] S. Marinov, I. Ivanov and A. Kolev, Modeling of a controllable communication environment, Collection of reports from the Scientific Conference "Modern trends in aviation training", NSU "V. Levski", Faculty of "Aviation" - Dolna Mitropolia, 2017, ISBN
- [20] Curriculum in Computer Science (Profiled Preparation).[Online]. Available: <https://www.mon.bg/nfs/2018/12/profil-informatika.pdf> .[Accessed Feb. 27, 2024]. (in Bulgarian)
- [21] Ministry of Education and Science, Training programs for profiled preparation. <https://www.mon.bg/obshto-obrazovanie/uchebni-planove-i-programi-2/uchebni-programi-za-profilirana-podgotovka/> [Accessed Feb. 28, 2024].
- [22] 44 Neophyte Bozveli Secondary School, Sofia, Bulgaria.[Online]. Available: <https://44sou.eu/>. [Accessed Feb. 28,2024]
- [23] Curriculum 11th grade.[Online]. Available: <http://44sou.eu/staging/wp-content/uploads/2018/09/Ucheben-plan-11.-a-klas.pdf>. [Accessed Feb. 28, 2024]

ESG Competences and Skills in Lifelong Education for Sustainability

Tatyana Odintsova

IDEA Academy,

Mosta, Malta

tatyana@ideamalta.com

Abstract. Sustainability paradigm being a global trend nowadays embraces not only a shift in problematics numerous areas of knowledge, but primarily a leap in mindset, which involves a revision of values and priorities for humanity at all. Thus, education for sustainable development and acquiring ESG (Environmental, Social, Governance) competences start to be a relevant drift in learning space. This area becoming a targeting for international regulation and an extensive part of educational services in response to labour market demands. This paper is focused on analysis of current state and prospectives of ESG education in EU. Based on the assessment of existing frameworks and stakeholders' needs an ESG-competences map was proposed. In this research a qualitative approach was applied. Thus, mostly secondary scholars' studies, databases, ESG and education regulatory documents and analytics, open access information from internet resources. Logical and comparative analysis was used for data processing. It was assessed educational models applying, content and institutional forms of existing ESG-programs, in higher education, specialists' upskilling, and lifelong education as well. There were considered main programs offered in education for sustainability and top ESG-skills required as far. Existing problems in education for sustainability were identified and a set of recommendations to develop lifelong acquiring ESG-knowledge system was provided.

Keywords: *ESG-education, Sustainability, Competences, Lifelong Learning.*

I. INTRODUCTION

The contemporary world is completely altering many basic concepts in all human life spheres. The turbulence of environment brings to the forefront new objects of attention in economy, social politics, corporative and state governance, education, science and knowledge creation, high technologies etc. Intangible forms of the capital are embodied in knowledge, human competencies, skills, and abilities. Knowledges and competences elaboration and managing underlies competitiveness, social progress, total human capital enhancing and sustainability.

Initially sustainability supposed harmonization of the economic development with the ecological concerns and United Nations Brundtland Commission in 1987 defined it as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." For the moment, this idea developed into the global conception of humanity progress and well-being embracing economic growth, social responsibility, environmental concern, and new level governance approach, so far, the "Agenda for Sustainable Development" of UN defines 17 Sustainable Development Goals. This embodied in Sustainability concept set a wide scope of linked practices: such as green thinking, ESG informational and management assurance, responsible and impact investment, green skills, stability measurements and others. This paradigm led to a new outlook and changes in the research agenda, main highlights, questions to solve and methodology of a few sciences related.

Last time term "ESG" became popular and widely used, but it is incorrect to identify it with sustainability. These two notions, being closely related, nevertheless have certain and essential differences. Sustainability in a broad sense means long-term vitality of company, its ability to operate and develop providing not only economic efficiency, but also social responsibility and ecological safety in holistic policy to interplay these three considerations. ESG is a set of techniques and criteria to identify target indicators, evaluate and measure companies' performance in in environmental resilience, social-oriented policy, and proper governance approaches to ensure sustainable development. Whilst sustainability exposes company's commitments to universal human values in its activity and elevates them to the strategy, ESG converts them into measurable format to define ways implement this strategy and evaluate the extent to which it will be or has been achieved. It should be pointed out these concepts turns applicable not only to the company's level but might be extended to the branch, region, state as well.

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8091>

© 2024 Tatyana Odintsova. Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

Such a trend affects many practical and scientific areas – full range of information practices, starting from accounting which called to identify and show in reporting new untypical components, analysis and scoring to provide reliable ESG-data for stakeholders, “green” data quality assurance and other informational activities. One can define a big scope of linked control, compliance, finance and investment, managerial practices. It moves on the fore new gen of competences and skills coming relevant for companies, markets, territories, states and world community, individuals either looking for work, moving their career or just accepting new life values, mindset, and behaviour patterns for safe future. ESG-competences of employees start to consider as assets making important contributions to total human and organizational capital what leads to the intensive development education for sustainability (with ESG-learning as a part of it), driving knowledge and skills for people to provide new kinds of thinking. The concept embodies a wide scope of educational and learning practices targeting more than new competences and knowledge creation, rather setting on new kind of thinking and life priorities of humanity. Evidently the educational system remains the key element of this structure, but besides, the new paradigm extends spectrum of ways to spread and gain “sustainable” proficiency.

II. MATERIALS AND METHODS

This study based on the existing frameworks in sustainable education and professional training consideration and includes analysis of academic programs suggestion in Europe. A qualitative approach was applied, and logical and comparative analysis was used for data processing. There were used mostly secondary sources of information were used, particularly similar-topic scholars’ studies, databases, educational portals, regulatory documents and analytics, another open access information from internet resources. It was assessed educational models applying, content and institutional forms of existing ESG-programs, in higher education, specialists’ upskilling, and livelong education as well.

III. RESULTS AND DISCUSSION

Education for sustainable development (ESD) is continuing to be a new global trend in educational and knowledge area. According to the UNESCO this kind of education empowers learners of all ages with the knowledge, skills, values, and attitudes to address the interconnected global challenges we are facing, including climate change, environmental degradation, loss of biodiversity, poverty, and inequality. “ESD is a lifelong learning process and an integral part of quality education that enhances cognitive, social and emotional, and behavioural dimensions of learning. It is holistic and transformational and encompasses learning content and outcomes, pedagogy, and the learning environment itself” [1]. Moreover, being the main conductor of SDG in education, UNESCO stated the four main elements that should be transformed in the relevant agenda - pedagogy and learning environment, learning content, learning outcomes, societal transformation.

“Sustainable” education has been developing dynamically over the last two decades and brings to the fore a set of new issues and questions to solve. Particularly, “it remains a challenge for employers,

students, educators, and program administrators to clearly articulate what competencies these programs develop in students” [2], [3], [4]. Although hundreds of educational programs in the sustainability field have been launched, till now not are ambiguous understanding of alumni competences. “Proposals for sustainability competencies continue to be presented as lists of items [4], [5]. This makes difficult for the employers and labour market to determine competency needs. Notions of sustainable development skills and competences applying in educational practice and research not always clearly distinct [6].

A drift in education can be proved by plenty of international and European frameworks, regulatory and recommendation documents for “green education” development. The European Union contributed a vast base grounding new educational trend. There are numerous recent EU documents concerning education in sustainability that could be referred to and subjected to analysis. One of the substantial program documents in EU strengthening efforts towards ESG education, is the European Council recommendation of 16 June 2022 on learning for the green transition and sustainable development (2022/C 243/01) [7]. Referring to several important frameworks in Sustainability, this recommendation emphasizes the importance of learning for the green transition and sustainable development as one of the priority areas in education and training policies. Some of regulations noted there are directly related with educational and tied practices, amongst we can highlight the UNESCO Strategy Education for Sustainable Development 2021-2030 [1], related UNECE Framework for the Strategy Implementation [8], the Strategic Framework for European Cooperation in Education and Training Towards the European Education Area And Beyond 2021-2030 [9], European Skills Agenda for Sustainable Competitiveness, Social Fairness and Resilience [10], European Competence Framework on Sustainability “Green Comp” [11], European Reference Framework of Key Competences for Lifelong Learning [12], Communication on a New ERA for Research and Innovation [13] and others. The trend is illustrated by unidirectional documents of voluntary associations, professional coalitions and NGOs developed beyond the official bodies and regulators. A good example of such “declarations of intent” calling under the sustainable education for business banner can be a global business coalition for education report (2022) “Unlocking Potential and Performance: Recognizing Education’s Position at the Core of ESG” [14].

All these documents affect matters of education for a sustainable world and colligating them can be highlighted main trends in European educational area for sustainability:

- prioritizing education for sustainable development for the near and long term,
- spreading idea of sustainability to promote conscious lifestyle and mindset, habits of responsible behaviour, consumption patterns, production, and life activities,
- creation of learning environment and motivation for lifelong studying,

- all possible forms usage and combining traditional education, training and upskilling, self-learning,
- providing opportunities for the ESG-knowledge and skills acquiring in formal, non-formal and informative options,
- applying both traditional and innovative approaches, transformative and interdisciplinary teaching, online and blended models, case studies, gamification, service learning, hackathons etc.,
- support of educators and developing their knowledge and skills, including research in education,
- jointing of education and research activities, innovative practices and smash experience dissemination in new knowledge making.
- active businesses' involvement to the ESG skills-creating programs for the employees and education programs investing.

There are a few indicators revealing that this leap is imminent. Firstly, one can note a high research interest in the issues of education for sustainability. According to Castellanos and Queiruga-Dios, "Europe is the continent with more research about ESD and 33.7% of the papers of the total search were dedicated to research on this subject on the continent or in European countries" [15].

A growing number and diversity of appropriate educational programs both in higher education and in professional retraining for companies and governance employees involved in sustainability agenda. Screening of programs web-suggested on allows to identify two major institutional forms for sustainability education – training programs in HEI (from bachelor's to doctoral level) and ESG - courses for professionals' training and certification. The first line of educational services provides a full range of programs in different areas of knowledge, merged by "sustainability" verbal semantic construct. "HEIs are seeing the value and importance of education for sustainable development in recent years" [16].

Analysis of few web-resources with databases of educational programs of HEI in Europe with built-in search engines shows high level of high education programs in sustainability studies popularity (mostly there are master's level programs). According to the data of <https://www.masterstudies.com>, <https://www.mastersportal.com>, <https://www.topuniversities.com> total number of master's programs on numerous aspects of sustainability in Europe is really extensive and vary depending on resource from 274 to 663 (Figure 1).

Degrees obtained by alumni of sustainability programs are mostly represented by Master of Science (from 57 to 76 percents in different databases, figure 2).

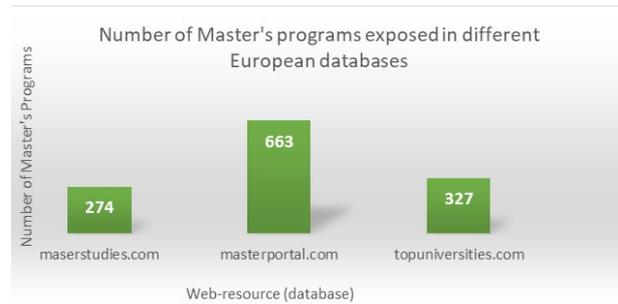


Fig. 1. Number of European Master's programs in sustainability studies in different databases (<https://www.masterstudies.com>, <https://www.mastersportal.com>, <https://www.topuniversities.com>)

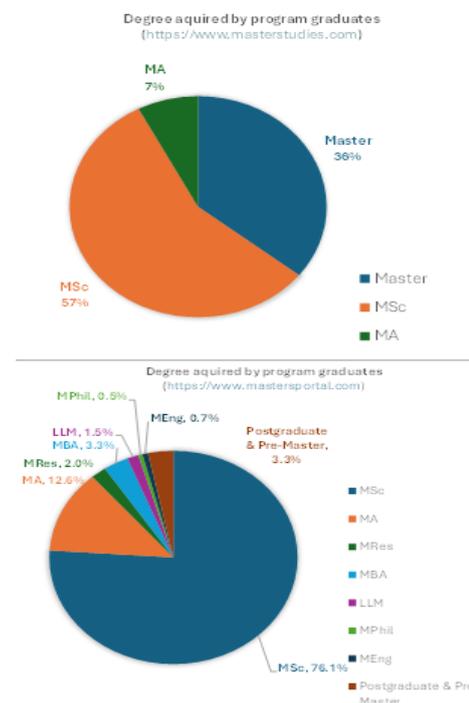


Fig. 2. Degrees of European Master's programs in sustainability alumni (<https://www.masterstudies.com>, <https://www.mastersportal.com>, <https://www.topuniversities.com>)

At the same time in Financial Times analytical review to assess sustainability education differences in quality and seniority possibilities were included only three masters' degree types: MBA, Executive MBA, or master's in management what is allocate sustainability education significance for the governance systems in business and behind [17].

Regarding study pace, format and programs' duration, European universities mostly suggest full-time education (73 – 83 %), campus-based (86 – 88 %) with terms up to 2 years (Figure 3). Thus, it is obvious that higher education in sustainability becomes an important part of educational space and covers a constantly growing share of the market.

immanent for any economic system. This is confirmed by known facts of businesses' ESG usage mostly for the reputational goals in greenwashing, formal rather than substantive approach for "responsible" reporting, companies' rejection of non-mandatory reporting, disclosures, and management standards. Each paradigm should be accepted by most scientists and practitioners and define a way of related activities advancement for a certain stage of development. Till now one can face an opinion about some sustainability values artificiality and imposition for the "as usual" business, this reduces comprehension of ESG education importance as well. To make green thinking doctrinal not declarative it is necessary to create a mechanism of all businesses' real interest in valid movement to sustainability. It can be implemented by two main ways of stimulation combo: strengthening the mandatory ESG-regulatory component and green assets financial markets development by responsible and impact investments promotion.

Then, given the wide circle of stakeholders involved in the educational agenda for sustainability, we must define a scope of traditional and novel educational models that could be employed. With priority of formal education and training in secondary, higher education and vocational training, there are also can be applied non-formal modes such as extra-curriculum activities, online forms, youth engagement in volunteer, research and creative practices, hackathons, etc. Considering extensive adult audience of professionals, interested in receiving ESG-competences and knowledge, the models of upskilling, reskilling, online and blended courses, few-days intensives, workshops and case studies courses and many others could be engaged. And to for carry out the paradigm of green thinking important to provide educational practices embracing all the society circles, to incentive for "acquiring the knowledge, skills and attitudes needed to live more sustainably, changing patterns of consumption and production". It corresponds to the lifelong learning idea and maintain life skills excellence.

One of the key questions that must be considered in building ESG-education is range of competences and skills required in accordance with demands both of labour market of the day and for future skills map for sustainability managing in the long-term prospective.

Competences according to "Key Competences for Lifelong Learning" are a combination of knowledge, skills and attitudes "that people need to meet their professional, personal, and social needs" [6]. The OECD Future of Education and Skills 2030 project "defines competency as more than just "skills", but as "a holistic concept that includes knowledge, skills, attitudes and values [18]. Skills are a prerequisite for exercising competency. To be ready and competent for 2030, students need to be able to use them to act in coherent and responsible ways that change the future for the better". Sustainability competences can be defined as the knowledge, skills, values and attitudes that enable graduate students to cope with the complexity and uncertainty of sustainability issues in society [19].

TABLE 1 COMPETENCES FOR SUSTAINABLE DEVELOPMENT IN RECENT STUDIES

Source	Area of competence	Competence
Alberton et al., 2020 [21]	Manager's competences for sustainability	Focus on systemic thinking Preventive competence Normative competence Strategic competence Interpersonal competence
Ploum et al., 2018 [22]	Essential Sustainable Entrepreneurship Competences	Strategic management competence and action competence Embracing diversity and interdisciplinary competence Systems thinking competence Normative competence Foresighted thinking competence Interpersonal competence
Kleef & Roome, 2007 [23]	Competence in Innovation for Sustainable Business Management	Systemic thinking Learning and development Integrating business, environmental and social problems Developing alternative business models Networking and social capabilities Coalition and collaboration building
UNESCO. Education for Sustainable Development Goals: Learning Objectives [24]	Core sustainability competences	Systems thinking competence Future-orientated thinking (or anticipatory) competence Value-based thinking (or normative) competence Strategic thinking (or action-orientated) competence Collaboration (or interpersonal) competence
Wiek et al. 2011, 2016 [25, 26]	Key competencies in sustainability	Systems-thinking competency Anticipatory/futures-thinking competency Normative/values-thinking competency Strategic-thinking competency Interpersonal/collaborative competency Integrated problem-solving competency (meta-competency)
Katja Brundier et al. [4]	Refined key competencies in sustainability	Systems-thinking competency Anticipatory/futures-thinking competency Normative/values-thinking competency Strategic-thinking competency Interpersonal/collaborative competency Integrated problem-solving competency (meta-competency) Intrapersonal Competency/ Mindset Implementation competency
Laasch et al. [20]	Interdisciplinary Responsible Management Competences	Independent and interdependent 33 competences in domains: Being (Character) Becoming (Maturity) Acting (Action) Interacting (Relation) Knowing (Knowledge) Thinking (Analysis)

Competences’ analysis, presented in recent research shows a giant accent’s shift from professional to supra-professional competency-based approach. Numerous studies in this area tend to combine different kinds of competences to make them more comprehensive and sustainable-oriented, like in exploration of responsibility management competences in the study of Laasch et al. [20].

The list of competences for Sustainable development varies in different research and includes mostly abilities for new values moving, thinking, interaction, self-development, and knowledge appliance to create the resilient reality. Competences noted in some recent researches are in the Table 1.

Important step in direction towards competences in Sustainable development was elaboration of European Competence Framework on Sustainability, approved in 2022 and adopting four groups of competences: embodying sustainability values (valuing sustainability, supporting fairness, promoting nature), embracing complexity in sustainability (systems thinking, critical thinking, problem framing), envisioning sustainable futures (futures literacy, adaptability, exploratory thinking), acting for sustainability (political agency, collective action, individual initiative). Being systematical and comprehensive this approach can be used for further competences grounding and detailing. To develop competency model, we can use the following matrix (table 2).

TABLE 2 MATRIX OF COMPETENCES FOR SUSTAINABLE DEVELOPMENT

Elements of competence	Domains	Group of competences from Framework	Refined key competences/ Knowledge
Attitudes and Values	Being Acting	Embodying sustainability values	Mindset Values-thinking
Skills	Thinking Becoming Acting Interacting	Embracing complexity in sustainability Envisioning sustainable futures Acting for sustainability	Systems thinking Futures-thinking Values-thinking Strategic thinking Interpersonal/collaborative competency Integrated problem-solving. Implementation Intrapersonal Competency
Knowledge	Knowing		Economy Management Finance Governance Law Engineering Environment and ecology Education Sociology Psychology Digital technologies

IV. CONCLUSIONS

Education for sustainable development is becoming global reality and one of the main drivers of achieving humanity’s goals. Significance of this trend in Europe can

be confirmed by numerous documents and recommendations, emerging the legal framework and methodological ground for this performance, activity of the educational services market offering hundreds of higher education and training programs, and high level of communication between stakeholders in ESG area.

The most popular sustainability education models are higher education (mostly represented by master’s programs (approximately 80 % of universities’ programs suggested) and upskilling or reskilling programs for professionals aimed both at obtaining in a short competence required to solve practical tasks and certification by, international bodies and organisations, standard-makers and implementors. These models are different by objectives, terms, scope, main participants, and performance, it shows real need for different ESG-educational practices. Most of the programs existing for the moment are concentrated in the fields of economics, management, and governance, however ecological, engineering, digital, social, educational directions currently being actively developed.

Education for sustainability becomes more than just process of transfer and acquisition of knowledge, it starts to be a part of creation new mindset, consciousness, lifestyle and habits not only for individuals directly involved in ESG-management, but for all society. It is exactly the approach corresponding to the lifelong learning education concept. Therefore, it should include a much wider range of applying educational forms, techniques and competences formed.

Analysis of the competencies which should be formed by ESG-education conducted using recent researching materials, international and European regulations show that in the competency model should dominate not only special knowledge and hard skills rather sustainability attitudes and values, abilities to think and analyse, foresight and assess possibilities and threats, act and interact for implementation ESG-politics and self-develop. Achieving precisely these competencies is the main goals of ESG-education development.

ACKNOWLEDGEMENTS

The author thanks management of IDEA Academy (Malta) for organizational help in researching.

REFERENCES

- [1] UNESCO “Strategy Education for Sustainable Development 2021-2030”, 2020. [Online]. Available: https://www.env.go.jp/policy/entaku06_ref03_1.pdf [Accessed: Feb. 12, 2024].
- [2] M. Barth, J. Godemann, M. Rieckmann, U. Stoltenberg, “Developing key competencies for sustainable development in higher education”. *Int J Sustain High Educ* Vol. 8(4), pp. 416–430, 2007.
- [3] M. Rieckmann, “Future oriented higher education: which key competencies should be fostered through university teaching and learning?”. *Futures* Vol. 44(2), pp.127–135, 2012.
- [4] K. B. Barth, M. C. Gisela, M.Cohen, L.Diaz, S. Doucette-Remington, D. Weston, H. Geoffrey, and others, “Key competencies in sustainability in higher education—toward an agreed-upon reference framework”. *Sustainability Science*, Vol. 16(1), pp. 13-29, 2021.
- [5] S. Wilhelm, R. Förster, A. Zimmermann, “Implementing competence orientation: towards constructively aligned education for sustainable development in university-level teaching-and-learning”. *Sustainability*, Vol. 11(7), pp. 1891, 2019.

- [6] S.Montanari, E. Agostini, D. Francesconi, “Are We Talking about Green Skills or Sustainability Competences? A Scoping Review Using Scientometric Analysis of Two Apparently Similar Topics in the Field of Sustainability”. *Sustainability*, Vol. 15(19), pp. 14142, 2023.
- [7] European Commission “Council Recommendation on learning for the green transition and sustainable development (2022/C 243/01)”, European Education Area. Quality education and training for all. [Online]. Available: [https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32022H0627\(01\)](https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32022H0627(01)) [Accessed: Feb. 12, 2024].
- [8] UNECE “Framework for the implementation of the United Nations Economic Commission for Europe Strategy for Education for Sustainable Development from 2021 to 2030” [Online]. Available: <https://unece.org/environment/documents/2022/05/working-documents/framework-implementation-united-nations-economic> [Accessed: Feb. 20, 2024]
- [9] European Commission “Council Resolution on a strategic framework for European cooperation in education and training towards the European Education Area and beyond (2021-2030)” 2021/C 66/01 [Online]. Available: <https://op.europa.eu/en/publication-detail/-/publication/b004d247-77d4-11eb-9ac9-01aa75ed71a1> [Accessed: Feb. 20, 2024]
- [10] European Commission “European Skills Agenda for sustainable competitiveness, social fairness and resilience”, 2020 [Online]. Available: https://migrant-integration.ec.europa.eu/library-document/european-skills-agenda-sustainable-competitiveness-social-fairness-and-resilience_en [Accessed: Feb. 20, 2024]
- [11] European Commission “GreenComp The European sustainability competence framework, 2022 [Online]. Available: https://green-comp.eu/wp-content/uploads/2022/02/jrc128040_greencomp_f2.pdf [Accessed: Feb. 20, 2024]
- [12] European Commission “European Commission “Key Competences For Lifelong Learning”, 2019 [Online]. Available: <https://op.europa.eu/en/publication-detail/-/publication/297a33c8-a1f3-11e9-9d01-01aa75ed71a1/language-en> [Accessed: Feb. 20, 2024]
- [13] European Commission “A New ERA for Research and Innovation. Staff Working Document”, 2020 [Online]. Available: <https://op.europa.eu/en/publication-detail/-/publication/f8f19fc4-2888-11eb-9d7e-01aa75ed71a1/> [Accessed: Feb. 20, 2024]
- [14] A Global Business Coalition for Education Report “Unlocking Potential and Performance: Recognizing Education’s Position at the Core of ESG”, 2022 [Online]. Available: <https://gbc-education.org/resources/environmental-social-governance/> [Accessed: Feb. 20, 2024]
- [15] P.M. Acosta Castellanos, A. Queiruga-Dios, “From environmental education to education for sustainable development in higher education: a systematic review”. *International Journal of Sustainability in Higher Education*, vol. 23(3), pp. 622-644, 2022.
- [16] M. Dzurenda, “Leadership Development in Education for Sustainable Development: Evaluation of Higher Education Students in Sustainable Development Programs,” Dr. Ph. thesis, Coastal Carolina University, US, 2022.
- [17] Financial Times “In charts: Business school teaching on ESG” 2021 [Online]. Available: <https://www.ft.com/content/1177bd03-22a4-42e1-9d83-bec979755c4d> [Accessed: Feb. 20, 2024].
- [18] OECD Future of Education and Skills 2030, 2018 [Online]. Available: [https://www.oecd.org/education/2030/E2030%20Position%20Paper%20\(05.04.2018\).pdf](https://www.oecd.org/education/2030/E2030%20Position%20Paper%20(05.04.2018).pdf) [Accessed: Feb. 20, 2024].
- [19] W.Lambrechts, P.Van Petegem, “The interrelations between competences for sustainable development and research competences”, *International Journal of Sustainability in Higher Education*, Vol. 17 (6), pp. 776-79. 2016.
- [20] O. Laasch, D.C. Moosmayer, E.P.Antonacopoulou, “The Interdisciplinary Responsible Management Competence Framework: An Integrative Review of Ethics, Responsibility, and Sustainability Competences”. *Journal of Business Ethics*, Vol. 187(4), pp. 733-757, 2023.
- [21] A. Alberton, A. P. Kieling, F. R. Lyra, E. M. Hofmann, M. P. V. Lopez, S. R. Stefano, “Competencies for sustainability in hotels: Insights from Brazil”. *Employee Relations: the International Journal*. Vol. 44 No. 3, pp. 555-575, 2020. <https://doi.org/10.1108/ER-01-2019-0093>
- [22] L. Ploum, V. Blok, T. Lans, O. Omta, “Toward a validated competence framework for sustainable entrepreneurship”. *Organization and Environment*, Vol. 31(2), pp. 113–132, 2018.
- [23] J. A. G. Kleef, N. J. Roome, “Developing capabilities and competence for sustainable business management as innovation: A research agenda”. *Journal of Cleaner Production*, Vol. 15, pp. 38–51, 2007.
- [24] UNESCO “Education for Sustainable Development Goals: Learning Objectives”; UNESCO Publishing: Paris, France, 2017. [Online]. Available: <https://unesdoc.unesco.org/ark:/48223/pf0000247444> [Accessed: Feb. 20, 2024]
- [25] A. Wiek, D.J. Lang, “Transformational sustainability research methodology”. In: Heinrichs H, Martens P, Michelsen G, Wiek A (eds) *Sustainability science: an Introduction*. Springer, Dordrecht, pp 31–41, 2016.
- [26] A. Wiek, L. Withycombe, C.L. Redman, “Key competencies in sustainability: a reference framework for academic program development”, *Sustain Science*, Vol. 6(2):, pp. 203–218, 2011. <https://doi.org/10.1007/s11625-011-0132-6>

Problems and Solutions to Improve the Efficiency of Using Electronic Information Resources at Universities in Uzbekistan

Nargiza Pazilova
«E-Line Press» LLC
Tashkent, Uzbekistan
nargiza.pazilova@gmail.com

Abstract. The relevance of studying the needs of users of global information resources in scientific and educational institutions of Uzbekistan, access to which is provided as part of a National subscription, is due to several factors: despite the expansion of access to electronic databases of leading foreign publishers and aggregators and an increase in the number of universities in the republic, statistics on the use of these resources leaves much to be desired, the passive work of library staff to promote information resources in universities and research centers, the lack of interaction of information resource centers with departments for the training of scientific and pedagogical personnel and academic work, the low level of information culture of young scientists, teachers, researchers and applicants about current sources of scientific information in their organization and in public libraries of the country, the lack of knowledge and skills to work with international databases of scientific and analytical information. In order to receive feedback from users of global information resources and study their needs, a survey was conducted. Based on the analysis and generalization of the survey data, proposals are formulated to enhance the use of scientific and educational resources in universities and research centers: in each information resource center of the university and research center, select a responsible specialist for organizing trainings, master classes on working with electronic resources and their promotion, organize regular webinars on working with certified trainers databases and analytical systems in Uzbek for teachers, doctoral students, applicants and researchers.

Keywords: *access to information, databases, electronic library, electronic scientific and educational resources.*

I. INTRODUCTION

Nowadays, called the information age, it is impossible to imagine scientific research, student education, or even school education without powerful information support. Information support for the processes of education, scientific research, production, and business largely

determines the further development of society. The use of electronic resources significantly increases the effectiveness of education and research. Today it is already obvious that the development of scientific activity directly depends on the effectiveness of its information support. At all stages of planning and execution of research work, it is necessary to study and analyze domestic and international scientific experience. In-depth study of information on the subject of research allows you to eliminate the risk of unnecessary time spent on an already solved problem, study in detail the entire range of issues on the topic under study and find a scientific and technical solution that meets a high level. Therefore, it is necessary to provide wide access for specialists to huge streams of reliable scientific information and, above all, to electronic publications that allow them to quickly gain knowledge about new trends in science and society [1].

Many publications in foreign literature are devoted to the problems of working with electronic information resources (EIR). Thus, in the works of Russian authors E.M. Polnikova [2], [3], E.V. Avramova [4], S.A. Morozova, I.K. Razumova, etc., there are practical examples of organizing work to promote and popularize electronic resources in university libraries, the organization of effective work with EIR in the technical aspect is reflected in the publications of V.V. Pisyakov, N.N. Litvinova et al. A huge number of scientometric studies show that the level of publication activity in various countries is directly related to research funding [6]-[8], the level of information support [9], [10] and the amount of subscription costs [11]. Confirmation of this can be found in open data on the cost of subscription of universities in the UK, the Netherlands and Finland to databases of the world's leading aggregators of scientific information [12]-[15].

Print ISSN 1691-5402
Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8093>

© 2024 Nargiza Pazilova. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

The reforms carried out in Uzbekistan since the early 2000s in the field of science and education have also touched upon the urgent tasks of access to valuable information, databases of scientific and educational resources, electronic journals and books for researchers, doctoral students and students. To improve the quality of education and the effectiveness of scientific research, it is necessary to ensure prompt access to global arrays of scientific and educational resources. In this regard, in recent years, Uzbekistan has implemented projects of National subscription to electronic databases of leading publishers and aggregators such as EBSCO Information Services, Clarivate Analytics, Springer Nature, Elsevier, etc. Currently, universities and research centers of the republic already have access to the resources of the databases EBSCOhost, Web of Science, Science Direct, Scopus, Springerlink, Proquest, etc., which significantly increased the effectiveness of scientific research and the quality of the educational process [16], [17].

The information support system in Uzbekistan includes three main components:

1. Resources acquired as part of government subscription projects for global citation indexes, and full-text and abstract databases. Access to resources is paid for within the framework of projects of the Ministry of Higher Education, Science and Innovation and the National Library of Uzbekistan named after Alisher Navoi (NL), which is a subordinate organization of the Information and Mass Communications Agency under the Administration of the President of the Republic of Uzbekistan. Access is free for subscription-recipient organizations. Subscription is carried out at the consortium level for a fixed number of organizations, or at the national level when any organization that meets the conditions regulated by the Ministry or Agency can become the recipient of access. Since 2016, the NL has organized a National subscription to electronic databases of the world's leading provider of information resources EBSCO Information Services for 125 organizations, including universities, scientific institutes, and libraries, a Consortium subscription to the international database of dissertations ProQuest Dissertations&Thesis Global for large state universities, libraries and scientific institutes of the Academy of Sciences of the Republic of Uzbekistan has been organized during 2018-2021. As part of the World Development Bank project, all universities under the Ministry of Higher Education were given access to full-text and analytical databases of Elsevier Publishing House. Since January 2019, the Ministry of Higher Education, Science, and Innovation has organized a National subscription to the electronic resources of the Springer Nature publishing house for 105 scientific and educational institutions of the republic.

2. Along with this, information and library centers (ILC) play an important role in providing information to specialists, teachers, and doctoral students, whose library fund has been expanded with electronic databases of world scientific and educational resources with the support of the NL. The NL and its branches, the leading

ILC of the republic serve researchers, doctoral students, undergraduates, and students of universities and research institutes, and play a significant role in providing, acquiring, storing, and distributing scientific information, without which it is impossible to conduct scientific research. The NL pays great attention to the multidimensional study of users' information needs, a comprehensive analysis of the use of printed and electronic publications, coordination and cooperation in the acquisition of funds. A correct and methodically sound assessment of resources and a forecast of their importance will make it possible to develop a fund acquisition strategy, organize collective access to electronic publications, and meet users' information needs [18].

3. In recent years, some universities have begun to complete funds with specialized electronic resources at their own expense.

II. MATERIALS AND METHODS

The quality of information support for scientists and specialists depends almost entirely on what information resources are used in information service systems aimed at these tasks. Therefore, it is necessary to study the information needs of higher educational institutions and research centers in Uzbekistan and develop recommendations on relevant information sources according to their specifications. For this purpose, a survey was conducted among teachers and doctoral students of universities and scientific centers of the republic. The questionnaire includes the following questions: "What are the main sources of scientific and educational information for your scientific and pedagogical activities?", "What is the level of information support for your scientific work? The level of access to scientific journals in your scientific field", "Electronic full-text resources and analytical systems of which publishers and aggregators do you use for your research activities?", "What difficulties do you experience when working with these electronic resources?", "Which international databases of scientific and educational resources are currently subscribed to in your organization?", "Have you previously attended webinars, seminars, trainings, or master classes on working with these platforms, and in what format?", "What topics would you like to discuss on the webinars, master classes, and presentations on global information resources?", "What do you consider to be the most effective way to improve the level of scientific research, publications, and dissertation defenses?", "What is the role of plagiarism verification systems?"

II. RESULTS AND DISCUSSION

190 respondents participated in the survey, of which 85 were teachers, 83 were doctoral students and applicants, and 21 were researchers.

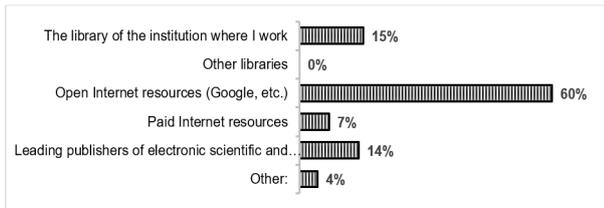


Fig. 1. Responses to the question “The main sources of scientific and educational information for your scientific and pedagogical activities?”

Fig.1. Based on the survey, it was revealed that despite the available access to reputable sources of scientific information, 60% of respondents use open Internet sources like Google and others, 14% use databases of leading publishers, 15% use the resources of the institution's library, 7% use paid Internet resources. Unfortunately, none of the survey participants visits other public and scientific libraries to obtain the necessary scientific and educational information. This suggests that the majority of users of scientific and educational resources are not aware of access to electronic scientific and educational resources in the National Library and its branches.

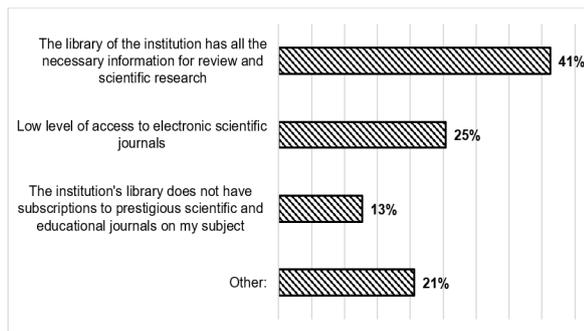


Fig. 2. Responses to the question What is the level of information support for your scientific work? (The level of access to scientific journals in your scientific field)

Fig. 2. 41% of respondents replied that the library of the institution where they work has all the necessary information for a review of the study, and this is not a bad indicator although it is not uncommon for doctoral students to use not entirely relevant sources when writing their scientific papers. 25% of the survey participants noted a low level of access to electronic scientific journals, and 13% stated that there was no subscription to prestigious journals in the institution's library.

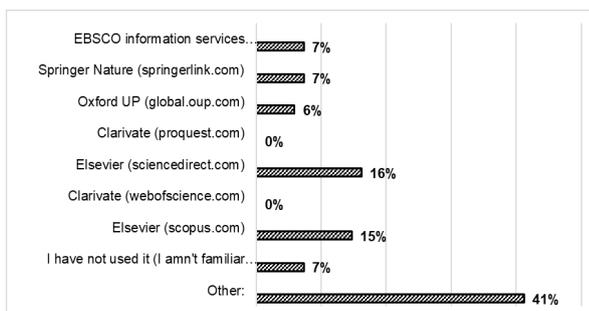


Fig. 3. Responses to the question Electronic full-text resources and analytical systems of which publishers and aggregators do you use for your research activities?

Fig. 3. The survey results showed that among the respondents, only 6% use Oxford UP electronic resources for their research activities, 7% - EBSCO, 7% - Springer Nature, 15% - Scopus, 16% - Science Direct, 7% - do not use resources at all, and 41% - use other sources of information.

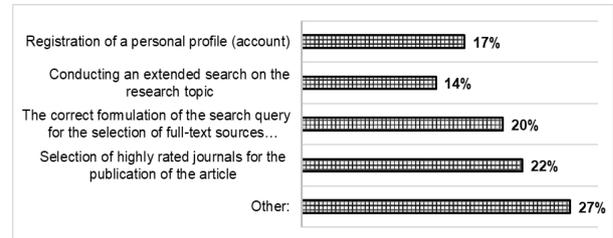


Fig. 4. Responses to the question What difficulties do you have when working with these electronic resources?

Fig. 4. When working with electronic resources, 14% of respondents find it difficult to conduct an extended search, 17% - register, 20% - have difficulties in correctly formulating a search query, 22% - cannot choose a highly-rated magazine for publication, and 27% choose another one.

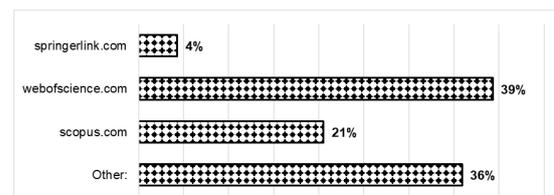


Fig. 5. Responses to the question Which international databases of scientific and educational resources are currently subscribed to in your organization?

Fig. 5. Currently, only 4% of respondents named Springer resources, 21% - Scopus, 39% - Web of Science, and 42% - chose another.

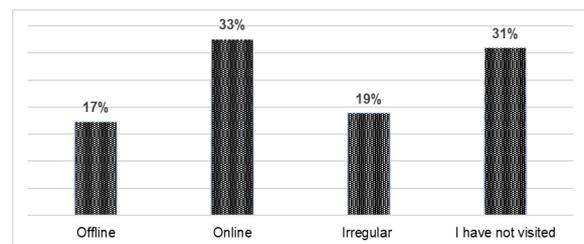


Fig. 6. Responses to the question Have you previously attended webinars, seminars, trainings, master classes on working with these platforms and in what format?

Fig.6. When asked about attending webinars and workshops on working with electronic resources, 33% of respondents participated online, 17% - offline, 19% - not regularly, and 31% - did not attend at all.

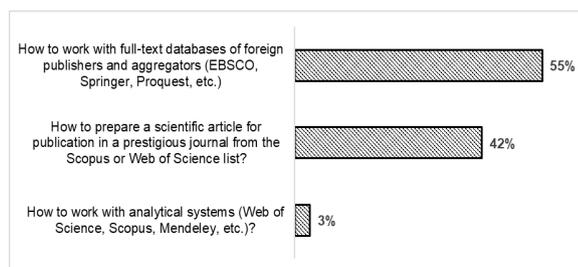


Fig. 7. Responses to the question What topics would you like to discuss in webinars, workshops and presentations on global information resources?

Fig. 7. When asked about the topics of webinars, master classes, and presentations on world information resources, 55% chose the topic “How to work with WIR databases”, 42% - “How to prepare a scientific article for publication in a prestigious journal” and 3% - “How to work with analytical systems?”.

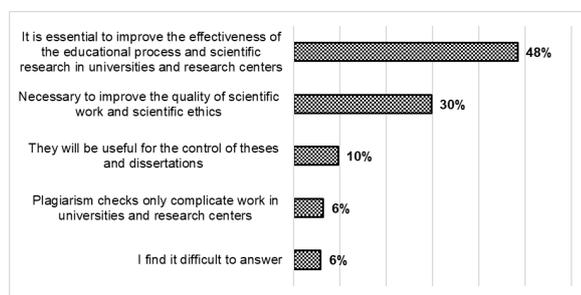


Fig. 8. Responses to the question What do you consider to be the most effective way to improve the level of scientific research, publications and dissertation defenses?

Fig. 8. It was interesting to know the respondents' opinion on the role of plagiarism verification systems: 48% said that such systems are extremely necessary to improve the effectiveness of the educational process and scientific research, 30% confirmed the need to improve the quality of scientific papers and scientific ethics, 10% - to control graduation and dissertation papers, 6% - noted that such systems only complicate the work in universities and research centers, and 6% found it difficult to answer the question.

IV. CONCLUSIONS

The main reason for the non-use or inefficient use of EIR is the lack of awareness of users about their presence in the organization or inability to work with them. Many other reasons contribute to this:

- lack of awareness of users about the EIR available in libraries
- lack of support and training for users on information retrieval issues
- low-quality websites of libraries of institutions;
- non-working usernames and passwords, links;
- uninformative or incorrect description of resources;
- incompetence of librarians in working with EIR.

All these shortcomings can be corrected by following some recommendations:

- regularly notify users about the availability of EIR in libraries (website, social network networks, etc.);
- information and library centers to establish cooperation with universities, research centers (scientific and educational departments, doctoral studies department, library) in order to promote EIR among end users and involve them in training webinars, master classes, etc.;
- regularly conduct training sessions, seminars, master classes on working with EIR for end users;
- it is necessary to work on the library website;
- use direct links to databases, their correct names and descriptions;
- make multiple access points to the resource in each information resource center of the university and research center, select a responsible specialist for organizing pieces of training, master classes on working with electronic resources and their promotion;
- organize regular webinars on working with databases and analytical systems in Uzbek by certified trainers for teachers, doctoral students, applicants, and researchers;
- the management of universities and research centers should ensure the participation of all employees in webinars organized by the coordinators of National Subscriptions;
- organize training seminars for young scientists and teachers on the preparation and writing of scientific articles for publication in highly rated journals.

We believe that such studies make it possible to study and identify user needs, introduce new forms of information and bibliographic services, and find ways to increase demand for information resources and services. They need to be continued, as the effectiveness of the use of electronic resources and the quality of end-user service depend on their results.

REFERENCES

- [1] N. Pazilova, Rol mirovykh informatsionnykh resursov v povyshenii effektivnosti nauki i obrazovaniya. Central Asia -2021, XIV International Conference, May 19-21, 2021, Uzbekistan, Tashkent: National Library of Uzbekistan named after Alisher Navoi, 2021.
- [2] E. Polnikova, “Librarian of the future. In searching of virtual comfort. VII International Conference ‘NEICON: Electronic Scientific and Educational Resources Creation, Promotion and Use’”. Crete, 2019.
- [3] E. Polnikova, Drive of Promotion. XVI International Conference ‘Science Online: Electronic Information Resources for Science and Education’. La Pineda, 2012.
- [4] E. Avramova, “Collection development technology of international electronic resources”, 2013. Available: <http://www.unkniga.ru/biblioteki/bibdelo/1585-elektronnye-resursy-v-publichnoy-biblioteko.html>.
- [5] A.V. Sokolov and I.G. Serjan, “O probleme populyarizatsii elektronnykh informatsionnykh resursov. Kak pomoch polzovatelyam nayti to, chto yest v biblioteke. Scholarly Research and Information, vol. 5, no. 2, p.76+, 2022. <https://doi.org/10.24108/2658-3143-2022-5-2-4>

- [6] U. Sandström, "Research quality and diversity of funding: A model for relating research money to output of research", *Journal of Scientometrics*, vol. 79, no. 2, p. 341+, 2009. [Online] DOI: 10.1007/s11192-009-0422-2
- [7] L. Leydesdorff and C. Wagner, "Macro-level indicators of the relations between research funding and research output", *Journal of Informetrics*, vol. 3, no. 4, 353+, 2009. [Online]. DOI: 10.1016/j.joi.2009.05.005
- [8] X. Wang [et al.], "Science funding and research output: a study on 10 countries", *Journal of Scientometrics*, vol. 91, no. 2. p. 591+, 2012. DOI: 10.1007/s11192-011-0576-6
- [9] H.F. Moed, "Statistical relationships between downloads and citations at the level of individual documents within a single journal", *Journal of the American Society for Information Science and Technology*, vol. 56, no. 10, p. 1088+, 2005. DOI: 10.1002/asi.20200
- [10] Y. Jung [et al.], "Statistical relationships between journal use and research output at academic institutions in South Korea", *Journal of Scientometrics*, vol. 103, issue 3, p. 751+, 2015 [Online] DOI: 10.1007/s11192-015-1563-0
- [11] O.V. Moskaleva and I.K. Razumova, "Twelve years of access to electronic serials in Russia: Results and perspective", *The Serials Librarian*, vol. 73, no. 3-4, p. 305+, 2017. DOI: 10.1080/0361526X.2017.1391151
- [12] B. Kelly, C. Hamasu, B. Jones, "Applying return on investment (ROI) in Libraries", *Journal of Library Administration*, vol. 52, no. 8, p. 656+, 2012. DOI: 10.1080/01930826.2012.747383
- [13] *The Society of College. National and University Libraries* SCONUL. *Annual Library Statistics*. 2010–2011. 2012. 147 URL <http://www.sconul.ac.uk/sites/default/files/documents/ALS1011.pdf>
- [14] M. Kyriallidou. *Research library trends: A historical picture of services, resources and spending*. *Research Library Issues: A Quarterly Report of ARL, CNI and SPARC*. 2012. No. 280. P. 20. URL: <http://publications.arl.org/rli280>
- [15] K. Hormia-Poutanen [et al.], *Consortia in Europe: Describing the various solutions through four country examples* *Library Trends*. 2006. Vol. 54, no. , p. 359–381. URL: <https://pdfs.semanticscholar.org/8b69/da488e2708957685d11fcd124239508f25cb.pdf>
- [16] N. Pazilova. "Rol bibliotek v povyshenii kachestva nauchnyx issledovaniy i dissertatsionnyx rabot". *Scientific Conference 2021. Uzbekistan, Tashkent: TUIT 2021.*
- [17] B.Sh. Usmonov, "Sistema podgotovki nauchnyx i nauchno-pedagogicheskix kadrov vysshey kvalifikatsii v Yevrope: opyt i problemy", *Vestnik TSPU*, vol. 3, pp. 192. 2018[18] T.N. Xarybina, N.A. Slasheva, Yu.V. Moxnacheva. "Kompleksnaya metodika izucheniya informatsionnyx potrebnostey polzovateley. Opyt sentralnoy biblioteki Pushkinskogo nauchnogo sentra RAN" *Nauchnye i texnicheskie biblioteki*. №4, 2008.

Automated Creation of Educational Questions: Analysis of Artificial Intelligence Technologies and Their Role in Education

Todor Rachovski

Faculty of Mathematics and
Informatics
Plovdiv University "Paisii
Hilendarski"
Plovdiv, Bulgaria
todormr@gmail.com

Desislava Petrova

Department Management
Technical university of Gabrovo
Gabrovo, Bulgaria
des_petrova@abv.bg

Ivan Ivanov

Faculty of Mathematics and
Informatics
Plovdiv University "Paisii
Hilendarski"
Plovdiv, Bulgaria
ivanivanov1040@gmail.com

Abstract. This study explores the integration of artificial intelligence (AI) in education, focusing on its potential benefits and challenges. Through an in-depth analysis of contemporary AI platforms and software technologies, it examines their suitability for educational environments. The study highlights AI's capacity to enhance personalized learning experiences, facilitate educational gaming and simulations, and support teachers in various tasks. However, ethical considerations regarding data privacy and algorithmic bias, as well as technical challenges related to software reliability, require careful attention. By providing insights into the transformative potential of AI in education, this research aims to inform stakeholders about the opportunities and risks associated with its implementation.

Keywords: Artificial Intelligence (AI), educational technology, personalized learning, ethical considerations, technological challenges, algorithmic bias, data privacy.

I. INTRODUCTION

In recent years, the advancement of technology in the field of artificial intelligence (AI) and machine learning has transformed numerous aspects of our world, including education. The ability to use artificial intelligence for algorithmic generation of test questions from text introduces new opportunities for optimizing the educational process. This methodology involves the utilization of AI algorithms for analyzing educational resources and generating exam tests and questions. Such technology not only streamlines the time and efforts of educators but also offers opportunities for personalized and adaptive learning. Natural Language Processing (NLP) plays a pivotal role in this process, enabling computer systems to "understand" and process human language texts, extract significant information, and generate relevant questions [1]. Thus, artificial intelligence has the potential

to change traditional methods of creating educational resources, offering a personalized, scalable, and efficient approach. This material provides a comprehensive overview of various contemporary artificial intelligence platforms used for generating test questions, along with their applications and significance in the educational context. It examines the technologies behind these platforms, their advantages, challenges, and potential ethical issues. It explores how algorithmic generation of test questions using artificial intelligence can alter the educational process [2]. The primary aim of this publication is to examine the transformative potential of artificial intelligence technologies in the education sector. By conducting a thorough review of modern artificial intelligence platforms and their applications in test question generation, the document aims to highlight how these advanced tools can optimize and enrich the educational process. The focus is not only on technological capabilities and innovations but also on understanding the ethical implications and practical challenges accompanying the integration of artificial intelligence into educational environments [3]. The goal is to provide educators, policymakers, and technology developers with a comprehensive overview of the role of artificial intelligence in education, encouraging informed decision-making and strategic implementation to improve learning outcomes.

II. MATERIALS AND METHODS

In this section, we will explore the key technologies and processes used for automated generation of educational questions. Our analysis will focus on question generation technologies, integration with educational platforms, as well as analysis and evaluation of the questions. Question Generation Technology: We will examine various

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8101>

© 2024 Todor Rachovski, Desislava Petrova, Ivan Ivanov. Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

technologies used for algorithmic creation of questions from educational texts. These technologies include Natural Language Processing (NLP), Machine Learning, Semantic Analysis, Automated Summarization, and Fact Extraction. We will investigate how these methods assist in generating suitable and diverse questions appropriate for the context and difficulty level of the material. We have identified several key technologies used for automated generation of educational questions:

- **Natural Language Processing (NLP):** We utilize NLP for analyzing educational texts and extracting important information for transformation into questions [4].
- **Machine Learning:** We employ machine learning algorithms trained on large datasets of educational resources to generate suitable and diverse questions [5].
- **Semantic Analysis:** We utilize semantic analysis technologies to understand the deep meaning of words and phrases in the text and to identify suitable themes and concepts for the questions [6].
- **Automated Summarization:** We use automated summarization technologies to condense lengthy texts into shorter versions that describe the main ideas [7].
- **Fact Extraction:** We utilize fact extraction technologies to identify and extract key facts, dates, names, and relationships between objects in the text to create questions that require memorization and recall of specific data [8].

Integration with Educational Platforms: There are several existing educational platforms and learning management systems that allow question generation technologies to integrate directly into the educational process [9][10]. Table 1 presents the main platforms, along with their key functionalities and applications in the field of generating educational questions.

Watson (IBM)	Offers robust natural language processing capabilities with a focus on understanding semantics and nuances in language.	Efficient in generating a wide range of question types by analyzing complex datasets and educational materials.	Notable for its industry-specific solutions, making it versatile for generating discipline-specific educational content.
Azure AI (Microsoft)	Provides a comprehensive suite of AI tools including language understanding, speech, and decision-making capabilities.	Capable of automating the generation of questions across various subjects, scaling according to educational needs.	Stands out for its scalability and the integration of various AI services, offering a holistic approach to question generation.
Baidu's PaddlePaddle	Deep Learning and Machine Learning	Suitable for developing personalized and adaptive educational platforms.	Strong focus on Chinese language and machine learning.
SAS Viya	Analytical tools and machine learning capabilities.	Analysis of educational outcomes, personalization of learning plans.	Flexibility and power in analyzing large volumes of data.
Salesforce Einstein	Integration with cloud CRM services, data analysis.	Management of interactions with learners, analysis of their behaviour and performance	Various analytical functionalities integrated into the CRM platform.

TABLE 1

AI Platform	Core Functionalities	Application in Question Generation	Unique Features
GPT (OpenAI)	Utilizes deep learning to generate human-like text based on the input provided. Capable of understanding and generating natural language responses.	Can create nuanced and contextually relevant test questions by processing educational content.	Exceptional at producing creative and varied questions, adapting to different subjects and complexity levels.
BERT (Google)	Focuses on interpreting the structure of sentences and the context of words within them, using bidirectional training.	Excellent suited for generating detailed and specific questions that require a deep understanding of the text.	Its bidirectional nature allows it to understand text context more deeply than other models, leading to highly relevant question generation.

Feedback Analysis and Evaluation: The technologies for feedback analysis and evaluation, which analyze students' responses and feedback, aim to improve the quality and relevance of the generated questions [11]. These technologies not only analyze students' responses but also monitor their learning process and reaction to the generated questions. Through feedback analysis and evaluation, we can identify the strengths and weaknesses of the questions, allowing us to adapt and improve our question generation methods, thus providing more suitable and effective educational tools.

III. RESULTS AND DISCUSSION

The present study explores contemporary artificial intelligence (AI) platforms used for generating test questions and optimizing the educational process. Analysis of the practical applications of these technologies led to the following key conclusions, supported by specific examples:

- **Efficiency:** Artificial intelligence significantly reduces the time required for creating test questions and improves their accuracy and relevance. The "Carnegie Learning" system utilizes machine learning to adapt educational material to the learning needs of each student, leading to increased success and engagement. This technology notably decreases the time needed for generating test questions and enhances their accuracy and relevance.

- **Personalization:** AI platforms successfully tailor educational content to the individual needs of students. Tools like Turnitin and IBM Watson Education provide automated assessments, facilitating classroom management and offering deeper personalized engagement for students. These platforms effectively adjust educational content according to the individual needs of students [12].

- **Scalability:** Artificial intelligence facilitates scaling the generation of test questions according to the needs of various educational institutions or student groups, allowing rapid adaptation of educational programs and materials. For example, Microsoft Azure AI facilitates scaling the generation of test questions according to the needs of different educational institutions [13]. This platform enables rapid adaptation of educational programs and materials, making it exceptionally useful for scalable education.

In addition to these positive aspects, the research also highlights certain challenges:

- **Ethical Issues:** The use of AI in education requires a strict balance between innovation and protecting students' personal data. It is important to ensure that AI systems are used in a manner that respects the rights and confidentiality of students.

- **Technical Limitations:** The complexity of educational content and the diversity of learning needs necessitate continuous development of AI platforms to adequately process and integrate new educational methodologies and technologies. Platforms must adapt to specific educational systems and maintain high standards of accuracy and reliability to ensure effective and quality learning [14].

IV. CONCLUSIONS

Undoubtedly, artificial intelligence provides powerful tools with the potential to revolutionize education. Their use allows educational institutions to optimize various aspects of the educational process, such as:

- **Personalized Learning:** Artificial intelligence can be used to create personalized educational experiences tailored to the individual needs of each student [15]. This can be achieved through analyzing learning data and student performance to identify their strengths and weaknesses.

- **Educational Games and Simulations:** Artificial intelligence can be used to develop educational games and simulations that are more engaging and effective than traditional instructional materials.

- **Teacher Support:** Artificial intelligence can be used to develop assistants that help teachers with various tasks, including lesson planning, classroom management, and providing personalized educational support to students [16].

- **Expanding Access to Education:** Creating online courses and platforms accessible in remote geographical areas increases access to education.

However, it is important to consider some challenges posed by the use of artificial intelligence:

- **Ethical Issues:** It is crucial to ensure that artificial intelligence systems are not used for discrimination or exacerbating existing inequalities.

- **Practical Challenges:** Software systems need to be developed that are reliable, accurate, and accessible, with a focus on data protection [17].

To address these challenges, educational institutions, researchers, and software developers must work closely together. Only through careful planning and implementation can artificial intelligence be used to create a better future for education.

ACKNOWLEDGMENTS

This work was partly funded by the MUPD23-FMI-021 project of the Research Fund of the University of Plovdiv "Paisii Hilendarski".

REFERENCES

- [1] L. Chen, Q. Liu, 2020. Enhancing Personalized Learning with Artificial Intelligence in Education. *International Journal of Artificial Intelligence in Education*, 30(3), 456-478
- [2] K. Soh, L. Lim, A survey on automatic question generation for educational assessment. *Educational Technology & Society*, 23(3), 220-235 (2020).
- [3] G. Cetin, M. Kayacik, The use of chatbots in education: A systematic review of the literature. *Educational Technology Society*, 24(3), 174-191 (2021).
- [4] N. Mostafazadeh, M. Mostafazadeh, Automatic question generation for educational contexts: A survey. *ACM Computing Surveys (CSUR)*, 51(2), 1-36 (2018).
- [5] T. Nguyen, H. Hoang, Automatic question generation for educational purposes: A systematic review. *Education and Information Technologies*, 24(3), 2213-2240 (2019).
- [6] V. Aleven, McLaren, A new paradigm for intelligent tutoring systems: Example-tracing tutors. *International Journal of Artificial Intelligence in Education*, 19(2), 105-154 et. al. 2009.
- [7] Y. Li, B. Zhang, Artificial intelligence in education: A review of recent research. *Educational Technology and Society*, 25(1), 192-211 (2022).
- [8] C. Conati, K. Vanlehn, Towards computer-based support of meta-cognitive skills: A computational framework to coach self-explanation. *International Journal of Artificial Intelligence in Education*, 20(4), 377-412 (2010).
- [9] N. Mostafazadeh, M. Mostafazadeh, Automatic question generation for educational contexts: A survey. *ACM Computing Surveys (CSUR)*, 51(2), 1-36 (2018).
- [10] C. Chen, C. Chang, A neural network-based question generation approach for educational assessment. *IEEE Transactions on Learning Technologies*, 15(2), 223-233 (2022).
- [11] C. Chou, W. Wang, Artificial intelligence in education: A review of recent research. *Educational Technology and Society*, 21(3), 82-102 (2018).
- [12] Y. Hwang, K. Chang, The use of artificial intelligence in education: A systematic review of research on benefits, challenges, and future directions. *Educational Technology & Society*, 25(1), 212-233 (2022).
- [13] M. Khan, R. J. Mislevy, The future of automated scoring. *Educational Measurement: Issues and Practice*, 37(3), 2-10 (2021).
- [14] T. Brown, B. Mann, N. Ryder, Subbiah, (2020). Language models are few-shot learners. *arXiv preprint arXiv:2005.14165* (2020).
- [15] Y. Cai, A survey of automated scoring for educational assessments. *ACM Computing Surveys (CSUR)*, 55(2), 1-35 (2022).
- [16] I. Hsiao, J. Yang, Artificial intelligence in personalized learning: A systematic review. *IEEE Transactions on Education*, 63(3), 276-291 (2020).
- [17] A. Holton, The impact of artificial intelligence on learning, teaching, and education. *Journal of Educational Technology Development and Exchange*, 11(1), 68-84 (2018).

Developing managers' intercultural competence in small manufacturing enterprises

Ausra Repeckiene
Kaunas University of Technology
Kaunas, Lithuania
ausra.repeckiene@ktu.lt

Renata Zvireliene
Panevėžio kolegija/State Higher
Education Institution
Panevezys, Lithuania
renata.zvireliene@panko.lt

Karolina Janickiene
zilinskaitekrolina@gmail.com

Abstract. Diverse and multicultural environment requires that managers of manufacturing enterprises should be able to work with representatives of different cultures. Seeking to maintain long-term commercial relationships, employees should strive for high level of intercultural competence through constant development. Object of the study – development of intercultural competence of managers. Aim of the study – to assess the development of intercultural competence of managers of small manufacturing enterprises. The qualitative research revealed that managers of small manufacturing companies develop intercultural competence informally, by learning from their own experiences, interacting and communicating in different intercultural situations with foreign customers, buyers, and suppliers. It was identified that the primary obstacle to intercultural communication is the inadequate foreign language proficiency of managers. Small manufacturing enterprises do not contribute to the development of managers' intercultural competence. It is noteworthy that the managers develop their intercultural competence in work setting, by sharing intercultural experiences, especially when they face with challenges or when work in unfamiliar cultural environments or unexpected situations. It can be stated that the Story Circles is an appropriate method for developing the intercultural competence of managers in small manufacturing and export companies with limited financial and human resources.

Keywords: *intercultural competence development, managers, small manufacturing enterprises.*

I. INTRODUCTION

Rapidly changing environment makes an impact on manufacturing enterprises seeking to export their products to other countries. Employees of companies engaged in exports have to adapt to rapid changes themselves too, seeing that proper communication with representatives of different cultures may help preserve long-term international commercial relationships. Thus, employees should strive for high level of intercultural competence through constant development.

Intercultural competence is a multi-layered concept encompassing the following key components: knowledge, attitudes, skills, awareness, and foreign languages [1] – [3]. The following aspects are important for intercultural competence assessment: self-awareness and motivation of the individual; foreign language skills; knowledge about another culture, skills and behaviour; cultural affinity; and intercultural competence development [2], [4] – [5]. Intercultural competence development should be constant and carried out both at the individual and organisational level.

Knowledge of a foreign language as well as ability to communicate, cultural flexibility, knowledge about cultures and their differences, and attitudes are all important for the development of intercultural competence [4], [6] – [7]. Individuals who have attained a higher level of intercultural competence interact in a multicultural setting impartially, without any discomfort. They show more respect and empathy to other cultures [8]. Moreover, a high level of intercultural competence mitigates anxiety in intercultural situations [9].

Intercultural competence might be developed formally, non-formally and informally [10]. Formally, intercultural competence is developed through various training programmes and courses, with focus placed on its certain elements, such as intercultural communication and relationship building or ethnic and gender studies [10]. Intercultural learning may also occur by formalised experiential learning (for example, learning at the workplace, in the course of studies or work abroad. Naturally, this promotes better understanding of the intercultural environment, teaches tolerance and problem-solving, helps practice certain situations, consider future behaviour and strengthen the intercultural skills [9], [10] – [11]. Generally, Lithuanian researchers deem communication and direct contact of cultures through which intercultural experience is gained to be the major method for developing intercultural competence [12] – [14].

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8081>

© 2024 Ausra Repeckiene, Renata Zvireliene, Karolina Janickiene. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

Measures of informal education (museums, cinema, theatre, arts, etc.) help deepen knowledge about cultural differences and similarities, facilitate the gaining of life experiences, and enable communication with people from other cultures. However, these experiences do not necessarily have to be acquired in a formal environment. When an individual does not have the opportunity to learn formally or in a real setting, they can independently learn using technological tools: discussions in forums, blogs, social networks, or just using the latest technological tools only such as virtual reality, which are tailored to the needs of each learner and encourages learning through cognitive and affective skill areas [7]. Intercultural learning based on the virtual reality technology allows for creating authentic inclusive virtual learning environment and facilitates the intercultural competence development [15].

Stories have served as carriers of knowledge and experience in the social contexts for hundreds of years, by disseminating them in certain cultural strata where they had been understood [16]. Based on lengthy intercultural competence studies, the author [10] proposed the *Story Circles* method for developing intercultural competence. It is a practical tool that nurtures intercultural competence through experiential learning, where participants engage emotionally, and information conveyed with emotions is absorbed more easily. When applying this method, active listening is crucial [10], [17] – [18]. This is a prerequisite – listening to participants' stories without interruption or expressing one's opinion, which enhances skills of empathy, awareness, and respect for others [18]. By listening to the stories, participants hear examples of real-life intercultural experiences, can compare them with their own experiences, perceive differences, and critically evaluate their behaviour and the storyteller's behaviour in various situations [10]. Understanding occurs through reflection, which is essential for each participant of the story circle, strengthening their critical thinking and interpersonal relationships. Thus, *Story Circles* integrate formal and informal education, aiming to improve intercultural competence [18].

One of the biggest challenges in applying this method refers to the participants' willingness to engage in the process, i.e. the extent of their interest and motivation to develop their intercultural competence. The key is to understand that this method is based on two assumptions: 1) We are all interconnected through human rights. 2) Each person has inherent dignity and worth [10]. This implies respect and openness, determining a higher level of intercultural competence.

Object of the study – development of intercultural competence of managers.

Aim of the study – to assess the development of intercultural competence of managers of small manufacturing enterprises.

II. MATERIALS AND METHODS

Nowadays, intercultural competence of employees is crucial for all companies and especially those, which cooperate with foreign counterparts. Attainment of the possibly highest level of intercultural competence requires its constant development. The present study is aimed at empirical

assessment of managers' intercultural competence development in small manufacturing companies.

The study is based on two methodological approaches: the framework of intercultural competence includes knowledge, attitudes, skills (interpreting and connecting, discovering and interacting), critical awareness, language proficiency [1] – [2]; intercultural competence is developed through formal, non-formal, and informal methods, using specific tools and measures [10].

Qualitative research was selected seeking to understand the intercultural experience of the participants, delving into their perspectives and reflections on experiences expressed during interviews. A structured interview method was applied in which participants answered specific questions, shared their intercultural experiences and personal views on intercultural competence and its development. Data analysis was conducted following the steps of qualitative content analysis: data preparation for analysis and data analysis [19].

Research participants were provided 15 open-ended questions that are interrelated and correspond to the diagnostic areas and criteria of the research (intercultural competence expression: knowledge, skills, attitudes, awareness, and foreign language proficiency level; intercultural competence development: individual and organisational levels).

For the research, employees of small and medium-sized clothing manufacturing companies belonging to reference [20] were selected. These companies produce and export their articles to foreign markets. According to the data as of 2022, from 112 member companies, 22 (7 small and 15 medium-sized) were involved in production (sewing clothing) and exporting their products [20]. The participants in the study were managers from these manufacturing companies who directly interact with foreign clients, suppliers, and customers.

Employees holding executive and/or sales manager's positions and performing functions ascribed to these positions and associated with commercial activities (sales) in foreign markets or directly working with foreign clients were invited to the interview. Executives and sales managers were required to meet the following selection criteria for research participants:

- a) Employees work in companies exporting to or operating in more than 2 foreign markets.
- b) Employees work in companies operating for more than 5 years.
- c) Employees deal with foreign clients in the company for more than 3 years.

The study involved a total of 5 participants, including 4 senior sales managers working in small/medium-sized companies and 1 head of a small company. All participants worked in companies operating for more than 10 years, with experience in export encompassing more than 10 years. The interviews were conducted remotely using the Zoom platform for organisation of remote meetings and video conferences, with each conversation recorded after obtaining the participant's consent at the beginning of the interview. The interview with the head of the company was conducted personally, at the company. Remote interviews lasted for approximately 40 min. on average, whereas the personal interview took 60 min. The research was carried out in October 2022.

During the research, ethical principles were observed, ensuring the anonymity, confidentiality, and data protection of the participants. Participants were informed about their right to refuse participation in the study and to refrain from answering the questions they found unacceptable. Additionally, participants were provided with information about the purpose of the research, its process, and the generalised use of the results.

The data (in the form of audio records) were transcribed into textual format, with each line of the text numbered and printed. Then, text printouts were read and re-read numerous times searching for key meanings, phrases and their similarities seeking to ascribe them to meaning sub-categories and categories and to base them on coded statements of informants. When analysing the research findings, informants were ascribed codes representing their responses.

The first interview participant, representing a small manufacturing company and holding the position of senior sales manager for more than 5 years, with over 20 years of experience in the export field, was assigned code A. The participant of the study who represented a medium-sized manufacturing company, has been working with foreign clients for more than 10 years, and has been in the position of senior sales manager for more than 3 years, was assigned code B. The participant representing a small company, holding the position of senior sales manager for about 6 years, with over 15 years of experience in the export market, was assigned code C. The participant with the code D represented a small manufacturing company, holding the position of senior sales manager for more than 5 years. The last interview participant, assigned the code E, was the head of a small company, leading the company and working with foreign clients, with over 30 years of experience in the export field.

A qualitative content analysis method was chosen to process the texts and analyze the research data. The qualitative content analysis method was used to code and categorize certain meaningful examples (N) of empirical indicators (statements) from interview texts that reflect the experiences and attitudes of the informants in relation to the research questions.

III. RESULTS AND DISCUSSION

Intercultural competence expression

The content analysis of the interview data resulted in 4 categories, the content of which reveals employees' intercultural experience.

The first category *Cultural awareness and understanding* are crucial when interacting with representatives of another culture. Applying the qualitative content analysis method, four subcategories of intercultural knowledge were identified and presented in Fig 1.

The analysis of informants' intercultural experiences revealed that the majority had limited knowledge about other cultures at the beginning of their work, leading to distrust, which was further intensified by the language barrier: "I couldn't communicate freely and was afraid to speak" [D; 2].

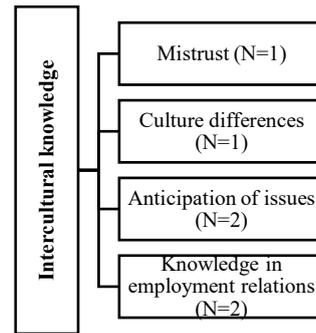


Fig. 1. Elements of intercultural knowledge.

A foreign language could be mastered the most effectively by "<.>directly interacting with foreigners" [C; 3], and "<.> constant communication helps understand how to present specific information" [D; 6]. Intercultural knowledge is crucial in professional activities too, helping to anticipate and identify obstacles when working with representatives of other cultures: "You know the deadlines, know the cultures whose representatives are prone to always being late" [C; 2], and "you can anticipate certain actions and behaviour" [E; 3]. According to the research participants, the acquired experience depends on the culture whose representatives they work with: "Europe differs significantly from Eastern countries. <.> it is always more challenging with people of the East because of their non-European way of thinking" [A; 4]. Different understanding of the work specifics inherent to another culture as well as a lack of experience can result in the loss of clients: "<.> at the beginning of our activities, we lost more than one client" [E; 5].

The second category *Attitude and behaviour* are crucial for establishing and maintaining long-term relationships with representatives of other cultures. When encountering representatives of different cultures, certain attitudes and behaviours should not become obstacles to achieving common business goals. The prevailing opinion among the informants was that the attitude changed significantly after getting to know another culture, even though there were certain preconceptions at the beginning of communication (Fig. 2).

Interview participants emphasised that in relationships with representatives of another culture, the degree of similarity between the cultures was crucial.

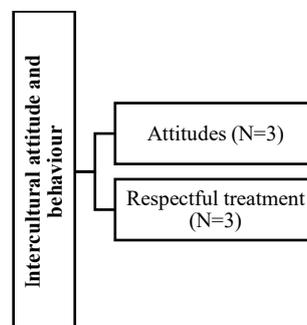


Fig. 2. Elements of intercultural attitude and behaviour.

"My attitude underwent significant changes; as we worked with the Japanese, the romanticism disappeared" [E; 1], "the attitude changes more when working with those not similar to us" [B; 2]. Proper treatment of representatives

of another culture is essential for long-term collaboration and can be achieved through respect and tactfulness, as “in communication, there are situations when one can say something using phrases or tone inappropriate to that specific culture” [C; 4].

The third category *Intercultural communication skills* are crucial allowing for a better understanding of that culture when working in international market. Continuous improvement of communication skills helps achieve a high level of intercultural competence; hence, it is essential to understand what contributes to their enhancement. During qualitative analysis, three subcategories of intercultural communication skills were identified (Fig. 3).

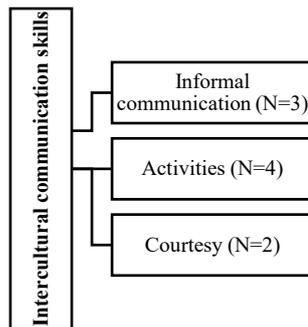


Fig. 3. Elements of intercultural communication skills.

Informants noted that deepening their understanding of other cultures is possible through traveling, reading books, or listening to the experiences of people who already have experience with representatives of other cultures. As the interview results suggested, intercultural knowledge is best acquired through experience. Most often, “live meetings <.>” [A; 8], where direct communication takes place, are helpful. Informal settings that involve conversations such as “<.> during lunch <.>” [D; 3] and touching on personal, life-related topics [A; 3] encourage getting to know representatives of other cultures. According to informants, better understanding and acquaintance with another culture can be achieved in “<.> routine work situations” [C; 1] when looking for “ways to solve various situations <.>” [B; 3].

In order to achieve a high level of intercultural communication skills, polite and large-minded communication is essential. According to the informants, understanding that angry and impolite communication is not the foundation for establishing long-term relationships with representatives of another culture is crucial.

Another important aspect that improves communication skills is continuous communication “<.> with the most diverse cultures” [D; 3].

The fourth category *Intercultural awareness* is one of important dimensions of intercultural competence in order to understand the way cultural differences and similarities affect relationships in work and communication with representatives of other cultures. Two subcategories have been identified under this category (Fig. 4).

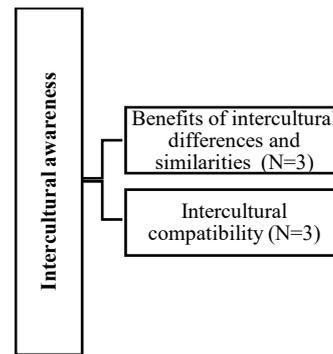


Fig. 4. Elements of intercultural awareness.

Interview participants emphasised more the impact of intercultural differences on intercultural communication. According to them, the advantage of intercultural differences is that they help to better understand another culture or change perspectives, increasing understanding not only in the work environment but also in true-life situations. Moreover, intercultural differences encourage the search for compromises, “<.> gently pressing” as opinions may not align; “<.> it's hard to prove that I am right,” or realizing that behaviour in situations may differ from expectations, requiring adaptation. Despite reaching an agreement posing a significant challenge, the search for compromises “provides motivation to work,” encouraging suppliers and clients to collaborate more effectively.

Intercultural competence development expression

The development of intercultural competence is a continuous process carried out at both individual and organisational levels, utilising various methods and tools. The qualitative content analysis identified 2 categories: individual level and organisational level of intercultural competence development. The first category, *Individual-level intercultural competence development*, is composed of 4 sub-categories (Fig. 5).

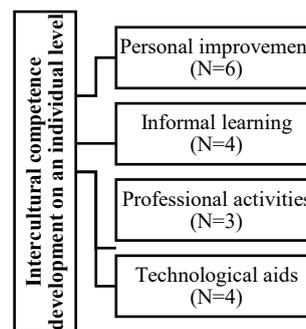


Fig. 5. Elements of intercultural competence development on the individual level.

Informants invoke traditional and informal educational tools such as documentaries, books, films in foreign languages, and travel for the development of intercultural competence. According to them, technological tools “<.> are not that much essential <.>” [C.; 4] for intercultural competence development but are useful for maintaining contacts and intercultural relationships. Participants of the study believed that the best way to develop intercultural competence was through individual, experiential learning, constant communication with representatives of different countries, and reflecting on their experiences.

The second category *Intercultural competence development on the organisational level* reflects that intercultural competence can be developed at the organisational level. Companies should be interested in fostering intercultural competence among their employees. Qualitative content analysis identified 2 subcategories for intercultural competence development at the organisational level (Fig. 6).

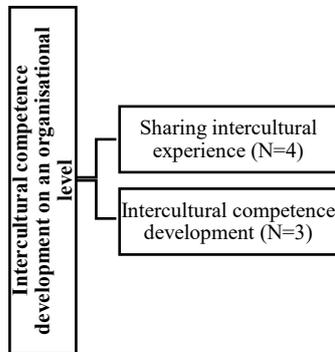


Fig. 6. Elements of intercultural competence development on the organisational level.

According to informants, sharing international experience with colleagues or executives represents an inherent element of their work, seeing that sharing “<.> helps when solving intercultural problems <.>” [D.; 3] in different situations. When telling about their experiences with other cultures, research participants reflect on their own experience and “you start thinking how you would act in other situation or another” [B; 2].

Generally, sharing intercultural experiences as a method of learning was positively evaluated by the informants. In their opinion, it could be an excellent tool, especially helping to develop the intercultural competence of new employees “<.> when extensive intercultural experience, knowledge, and skills have not yet been accumulated” [C; 5]. Nonetheless, the process should be genuine, with “<.> no secrets left” [E; 3].

However, the opinions of informants on internal trainings with the moderator (external lecturer) differed. Some stated that they would see it as beneficial “<.> I would evaluate [it] positively <.>” [C; 6], “<.> there are no doubts <.>” [D; 4], especially when the lecturer is not part of the organisation and “<.> as an impartial individual, perhaps he would see things differently and bring more considerable benefit” [B; 4]. According to some others, it would be better if the trainings were to be organised by the member of the company (executive or manager) and the lecturer “<.> was not necessary <.>” [E; 3], “<.> I am not certain if <.> it would be somehow beneficial for us” [A; 4], “<.> for me that is a big matter of question <.>” [D; 4].

The responses of the informants predominantly conveyed the attitude that companies did not contribute in any way to the organisation of intercultural competence development for their employees.

Guidelines for intercultural competence development of managers

The empirical study revealed that in small manufacturing companies, insufficient attention was given

to the development of managers' intercultural competence. Informants typically developed intercultural competence by learning from their own and others' experiences. This is an informal learning approach focused on personal improvement that relies on individual initiative [21]. The selected informal method for developing intercultural competence aligns with the principles of the educational tool *Story Circles* [10].

An assumption is made that *Story Circles* methodology could be a suitable tool for developing intercultural competence among managers working in small manufacturing companies. Since the application of the method does not require significant financial and administrative resources, and the rules of the method are simple, employees could achieve a higher level of intercultural competence by integrating the following guidelines for intercultural competence development in the companies:

- analysis of the need for intercultural competence development of employees.
- preparation of themes for intercultural competence development based on the directions of the company's activities.
- selection of development methods including the *Story Circles*.
- principles for organisation of *Story Circles* for small and medium companies:
 - a) anticipation of the frequency use of method in training.
 - b) familiarisation of employees with the development method.
 - c) employee training moderated by the lecturer.
 - d) employee training moderated by CEO or senior manager together with the lecturer.
 - e) reflection of sales managers and feedback analysis after the training, moderated by the lecturer.
- additional means for intercultural competence development:
 - a) audio and video resource collections about specific cultures.
 - b) stories of invited guests who have had experience or who have lived or worked in foreign countries.
 - c) participation in exhibitions, cultural events of customers, suppliers or clients.

V. CONCLUSIONS

The qualitative research findings revealed that *intercultural competence expression* of managers of small manufacturing and exporting companies was primarily reflected in the *knowledge and understanding of other cultures* and it manifested through experience of interaction with representatives of different cultures. Knowledge of a foreign language and knowledge about cultures and their differences allow for better understanding of other cultures, resulting in building, maintaining and expanding successful business relations with customers and suppliers. Representatives of small business companies perceived *intercultural attitude and behaviour* through the ability not to have preconceptions, their respect and empathy for other

cultures, resulting in a higher level of intercultural competence. The respondents associated *intercultural communication skills* with polite and tolerant interaction both in formal and informal surroundings. Moreover, the business community also expressed the need for constant communication with business representatives of different cultures, thus promoting both respect for other cultures and enhancing the business partnerships in the future. Furthermore, the research revealed that the intercultural competence of business representatives was affected by their *intercultural awareness* manifesting through the ability to get to know and understanding the similarities and differences of cultures, resulting in a higher level of intercultural competence and ensuring successful intercultural cooperation and communication.

Employee *intercultural competence development on individual and organisational levels* is important for the companies striving to strengthen their partnerships with business representatives of other cultures. The study revealed that managers of small manufacturing and exporting companies primarily developed intercultural competence through informal learning, interaction with foreign customers and suppliers. It was determined that the main barrier to intercultural communication was the insufficient proficiency of managers in foreign languages. Although the work environment was conducive to enhancing intercultural competence, companies did not directly contribute to the development of managers' intercultural competence. Managers independently explored the cultures they work with, maintained commercial relationships, and shared intercultural experiences, especially when facing specific intercultural challenges or operating in unfamiliar or unexpected cultural environments. It can be stated that *Story Circles* is a suitable method for cultivating intercultural competence among managers in small manufacturing and export-oriented companies, with limited financial and human resources.

REFERENCES

- [1] M. Byram, B. Gribkova and H. Starkey, "Developing the intercultural dimension in language teaching: A practical introduction for teachers," Language Policy Division, Directorate of School, Out-of-School and Higher Education, Council of Europe, 2002. [Online]. Available: <https://discovery.ucl.ac.uk>. [Accessed Jan. 16, 2023].
- [2] A. E. Fantini, "Intercultural Communicative Competence: A Necessary Ability for All," 2021. [Online]. Available: <https://digitalcollections.sit.edu>. [Accessed Jan. 13, 2023].
- [3] K. L. Liu, "Teaching and assessing intercultural communicative competence (ICC): experience with student-authored critical incidents," Taiwan Journal of TESOL, vol. 18, no. 1, pp. 1-27, 2021. [Online]. Available: ERIC, <https://eric.ed.gov/?id=EJ1288991>. [Accessed Nov 15, 2022].
- [4] J. Dabravalskytė and J. Vveinhardt, "Lietuvos mažų ir vidutinių įmonių internacionalizacijos ir tarpkultūrinės kompetencijos integracija," Organizacijų vadyba: sisteminiai tyrimai, vol. 73, pp. 27-47, 2015. [Online]. Available: Lituaniatika database, <https://etalpykla.lituaniatika.lt>, [Accessed Feb. 17, 2024], <https://www.vdu.lt/cris/entities/publication/efd9a7ae-d799-45ca-bbbe-2b42631ce237>
- [5] T. Hantsiuk, K. Vintoniv, N. Opar and B. Hryvnak, "Developing intercultural competence through design thinking," European Integration Studies, vol. 15, pp. 9-21, 2021. [Online]. Available: KTU, <https://eis.ktu.lt/index.php/EIS/article/view/28930>, [Accessed Nov 15, 2022], <https://doi.org/10.5755/j.01.eis.1.15.28930>
- [6] B. W. Haas, "Enhancing the Intercultural Competence of College Students: A Consideration of Applied Teaching Techniques," International Journal of Multicultural Education, vol. 21, no. 2, pp. 81-96, 2019. [Online]. Available: <https://ijme-journal.org>. [Accessed Dec. 12, 2022], <https://doi.org/10.18251/ijme.v21i2.1696>
- [7] M. Akdere, K. Acheson, and Y. Jiang, "An examination of the effectiveness of virtual reality technology for intercultural competence development," International Journal of Intercultural Relations, vol. 82, pp. 109-120, 2021. [Online]. Available: ScienceDirect, <https://par.nsf.gov>. [Accessed Nov. 25, 2022], <https://doi.org/10.1016/j.ijintrel.2021.03.009>
- [8] P. Sharma and Z. Wu, "Consumer ethnocentrism vs. intercultural competence as moderators in intercultural service encounters," Journal of Services Marketing, vol. 29, no. 2, pp. 93-102, 2015. [Online]. Available: Emerald Insight, <https://www.emerald.com/insight/publication/issn/0887-6045>. [Accessed Feb 12, 2023].
- [9] K. Leung, S. Ang and M. L. Tan, "Intercultural competence," The Annual Review of Organizational Psychology and Organizational Behavior, vol. 1, no. 1, pp. 489-519, 2014. [Online]. Available: <https://www.annualreviews.org/content/journals/orgpsych>. [Accessed Feb 12, 2023]. DOI: 10.1146/annurev-orgpsych-031413-091229
- [10] D. K. Deardorff, "Manual for developing intercultural competencies: Story circles," Routledge Focus: 2020. [Online]. [Available: UNESCO Open Access Repository, <https://library.oapen.org>. [Accessed Nov 25, 2022], <https://library.oapen.org/bitstream/handle/20.500.12657/76006/1/9780429521348.pdf>
- [11] G. Rață and E. M. Samfira, "Intercultural Development through Intercultural Awareness and Cultural Briefing," New Trends and Issues Proceedings on Humanities and Social Sciences, vol. 4, no. 1, pp. 61-67, 2017. [Online]. Available: academia.edu. [Accessed Sept. 15, 2022], <https://doi.org/10.18844/prosoc.v4i1.2053>
- [12] G. Paurienė, "Tarpkultūrinė kompetencija ir jos ugdymas pareigūnų rengime," Public Security and Public Order, vol. 5, pp. 114-128, 2011. [Online]. Available: <https://ojs.mruni.eu/ojs/vsvt/article/view/6157>. [Accessed Sept 26, 2022].
- [13] E. Gerulaitienė, "Patirtinio mokymosi kitame kultūriname kontekste ugdymo praktikos, plėtojant tarpkultūrinę kompetenciją, ypatumų analizė," Jaunųjų mokslininkų darbai, vol. 1, pp. 25-31, 2013. [Online]. Available: epublications.vu.lt. [Accessed Sept 26, 2022].
- [14] S. Kairė, "Būti priimtam ar būti matomam: kultūrinio susidūrimo kompleksiskumas vykdant tarpkultūrinį ugdymą," Acta paedagogica Vilnensia, vol. 34, pp. 9-19, 2015. [Online]. Available: <https://epublications.vu.lt/object/elaba:6097569/>. [Accessed Sept 26, 2022].
- [15] R. Shadiev, X. Wang and Y. M. Huang, "Promoting intercultural competence in a learning activity supported by virtual reality technology," International Review of Research in Open and Distributed Learning, vol. 21, no. 3, pp. 157-174, 2020. [Online]. Available: ERIC, <https://files.eric.ed.gov/fulltext/EJ1267463.pdf>. [Accessed Jan 10, 2024].
- [16] J. Sell, "Storytelling for intercultural understanding and intercultural sensitivity development," in Beyond storytelling: Narrative Ansätze und die Arbeit mit Geschichten in Organisationen, J. Chlopczyk, Ed. Wiesbaden: Springer Gabler, 2017, pp. 223-249.
- [17] V. M. Gabinus, "The use of Story Circles to promote intercultural competence and thereby benefit PhD students in their research" [Master's thesis]. Høgskolen i Østfold, 2020. [Online]. Available: <https://hiob.brage.unit.no>. [Accessed Jul 25, 2022].
- [18] I. Gheorghiu and C. Antonita, "The Unesco Story, The Circle Method-Creating Bridges Among People," in Teachers And Students In Multicultural Environments, Ed. M. Iorga, Iași: Editura Universității Alexandru Ioan Cuza, 2021, pp. 337-368. [Online]. Available: <https://increase.grant.umfiasi.ro>. [Accessed Sept 26, 2022].
- [19] I. Gaižauskaitė and N. Valavičienė, "Socialinių tyrimų metodai: kokybinis interviu: vadovėlis". Vilnius: Registrų centras, 2016. [Online]. Available: <https://cris.mruni.eu>. [Accessed Sept. 12, 2022].
- [20] LATIA Association of Lithuanian Clothing and Textile Companies. [Online]. Available: <https://latia.lt/>. [Accessed Sept 12, 2022].
- [21] G. Paurienė, "Savaiminio (informaliojo) mokymosi sampratos analizė," Public Security and Public Order, vol. 10, pp. 181-197, 2013. [Online]. Available: <https://www3.mruni.eu>. [Accessed Aug 10, 2022].

The Experience of Developing Social Responsibility in the Next Generation of Engineers at Ukrainian Universities

Nataliia Saienko

*Department of Foreign Languages
Kharkiv National Automobile and
Highway University
Kharkiv, Ukraine
saienkonv@ukr.net*

Olena Iliencko

*Department of Foreign Philology and
Translation
O.M. Beketov National University of
Urban Economy, Ukraine
Kharkiv, Ukraine
lenailienko@yahoo.com*

Tetiana Solodovnyk

*Department of Pedagogy and
Psychology of Social Systems
Management
National Technical University
"Kharkiv Polytechnic Institute",
Ukraine
Kharkiv, Ukraine
tetiana.solodovnyk@khp.edu.ua*

Anastasiia Ptushka

*Department of Foreign Languages
Kharkiv National Automobile and
Highway University
Kharkiv, Ukraine
metodengl@gmail.com*

Zhanna Bogdan

*Department of Psychology and
Sociology
Simon Kuznets Kharkiv National
University of Economics, Ukraine
Kharkiv, Ukraine
janna.bogdan1979@gmail.com*

Abstract. The development of social responsibility of future engineers, who must be able to predict and evaluate the results of their professional activities is a relevant aspect of training specialists at a technical university. The problem is becoming increasingly acute due to the rapid penetration of artificial intelligence into many areas of the socio-economic life of society, in which many researchers and entrepreneurs see not only benefits for mankind, but also threats due to fears of artificial intelligence getting out of human control.

Although there are some disciplines at Ukrainian universities that in varying degrees deal with ethical issues of engineering, many higher schools do not typically consider professional ethics as a compulsory course, so it seems necessary to look for additional methods and techniques for the formation of engineering ethics and social responsibility as its key element in various types of activities.

In 2021–2023, a pedagogical experiment was conducted at Kharkiv National Automobile and Highway University with the aim of selecting and testing a set of methods for developing future engineers' social responsibility. To this end, an

experimental group was formed from students of different specialities (122 students), in which a variety of pedagogical methods were used while studying various disciplines in the format of formal education (discussions, debates, solving dilemmas, projects, case studies, simulations, etc.), informal (round tables, conferences, contests, publishing results of research), and informal education (volunteering, involvement in civil activities), and a control group (120 people), in which these methods were not used.

The following criteria and indicators for assessing the level of development of social responsibility were chosen: 1) a value-based criterion (awareness of social responsibility as a key feature of an engineer's professionalism; 2) pragmatic (skills to navigate in a variety of professional situations and make responsible decisions); 3) reflective (ability to make evaluative judgments, self-esteem).

In the study, we applied a mixture of quantitative and qualitative methods to evaluate the results of the experimental work by the chosen criteria and indicators. The positive impact of the tried-and-tested methods on the development of social responsibility in the next generation of engineers was experimentally proved.

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8070>

© 2024 Nataliia Saienko, Olena Iliencko, Tetiana Solodovnyk, Anastasiia Ptushka, Zhanna Bogdan.

Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

Promising for further scientific research is the improvement of pedagogical support of ethical skills' formation in technical specialists, as well as a set of methods for diagnosing the socially significant characteristics of technical students.

Keywords: development, future engineer, pedagogical experiment, social responsibility.

I. INTRODUCTION

An important task of higher education institutions that train specialists in technical specialities is the development of social responsibility (SR) in students, which will encourage them in the future to act in the interests of society, predict and evaluate the results and consequences of their actions.

Technology is an integral part of modern culture and civilization, and the traditional technical training has always been largely targeted at the cultivation of the technocratic attitude to the world. But taking into account the bitter experience of the recent past, there is a need to re-evaluate the engineering education from the new, ethical positions, to search for more humane forms of interaction between man and technology as uncontrollability of technology poses great threats to the safety and well-being of humans. One can recall engineering-related failures that resulted in injuries or death of countless people, e.g., levee failures in New Orleans, Chernobyl disaster, Deepwater Horizon oil rig spill, Montana asbestos contamination, Minamata mercury poisoning, Jilin chemical plant explosion, Seveso disaster, interstate bridge collapse in Minnesota. These and many other tragedies undermine confidence in engineers and raise the question of strengthening their SR.

Lately, humanity has faced such a new threat as artificial intelligence, the rapid development of which causes increasing concern among the best minds of the planet, who warn about the possible existential risks that this technology poses. Among the biggest dangers with AI are fraught with the experts mention job losses due to automation, lack of AI transparency and explainability, wealth inequality, social surveillance with AI technology, lack of data privacy, autonomous weapons powered by AI, AI acting beyond humans' control and in a possibly malicious manner [1].

Not long ago, an open letter signed by more than a thousand experts and entrepreneurs came to light, calling for the development of AI technologies, which are already difficult to control, to be put on hold until robust security protocols are developed. It is also worrying that the leading tech giants (Microsoft, Meta, Tesla) involved in AI development are cutting teams that ensure responsible development of their products, although it is precisely these teams that help developers anticipate and eliminate potential risks and problems of a new technology, before new products are in the hands of users [2].

We are unlikely to want to use medicines, vehicles or civil structures if they are made by irresponsible people. As Einstein believed many years ago, the fate of scientific and technical progress depends on the moral principles of its creators, and the ethical and humanistic approach is a priority criterion for this progress.

One cannot but agree with Rapp's point of view [3], that technology is based on the mechanisms of human culture and values, so the problems of engineering can be solved by improving society, social institutions, democratic mechanisms of control, and education.

II. MATERIALS AND METHODS

Engineering ethics regulates engineering activity through a certain system of norms and values and is formed in students primarily as a result of mastering the content of the subject of professional ethics and gaining an experience of professional morality in a situational learning [4].

In many developed countries, there is an extensive ethical infrastructure, the core of which is ethics committees that work in all spheres of economic and social life, and the costs of creating and maintaining this ethical infrastructure are quickly paid off in the market when interacting with counterparties who want to cooperate with a reliable partner [5].

Leading institutions in the field of professional ethics are presented by the Canadian Centre for Ethics and Corporate Policy, Edmond & Lily Safra Center for Ethics at Harvard University, the Erasmus Centre of Behavioural Ethics at the University of Rotterdam (Netherlands) and the Center for Ethics at the Open University (Great Britain), The Hague Institute for Global Justice, Netherlands, etc. They deal with theoretical issues of professional ethics, hold various events involving businesses, participate in the accreditation of universities, their representatives are included in commissions that approve curricula and courses. The experience of these institutions is worth studying and adopting as common efforts of all countries should be applied to improve the system of ethical education.

The key concept of ethics, both professional and engineering, is responsibility. At present in the literature the term "corporate social responsibility" (CSR) or social responsibility of business is increasingly being used. The social responsibility of business involves the obligation of companies to protect the interests of society, and not just to care for profit [6].

It should be noted that the present war with Russia has a significant impact on the role and development of SR of business in Ukraine. According to a survey [7], about 67% of Ukrainian enterprises have restructured their budgets and added SR as a separate item of the balance sheet budget, thereby ensuring support for the state and the Armed Forces of Ukraine.

Researchers express their views that the development of SR should be fully integrated into the curricula at all levels of engineering education, which will allow informing students about various social and ethical aspects and consequences of their future activities. Some Western universities have already introduced such courses as business and society, business ethics, environmental management, corporate social responsibility, and corporate citizenship. In addition to special courses, such educational tools are used as the introduction of additional modules, holding seminars, conferences, other special events, etc. [8].

But it does not seem to be enough. Among 180 engineering educators in the study by Romkey [9], the average implementation of “I encourage students to consider the potential environmental impact of technology” was 2.49 (where 2 = sometimes and 3 = often on a 1–4 scale).

As Akay claims, it is clear that engineering must go beyond pure technology and address matters that are imbedded in the social and economic fabric of society [10]. Engineering courses should integrate sustainability and socially responsible design agendas throughout the four-year undergraduate curriculum and develop awareness and understanding of socially responsible design and behaviour in the next generation of engineers [11].

In order to form SR in technical students, a pedagogical experiment was conducted at Kharkiv National Automobile and Highway University in 2021–2023 with involving 242 students of different specialities who were divided into two groups, the experimental group (EG, 122 persons) and control group (CG, 120 persons), and 27 teachers of various disciplines. Besides, students and teachers from other Kharkiv universities – O.M. Beketov National University of Urban Economy, National Technical University “Kharkiv Polytechnic Institute” were invited to participate in a number of extracurricular events.

The tasks of the experimental work were 1) to select and test methods to form SR in students within the framework of formal, non-formal and informal education, 2) to compare the indicators of SR of the students from the EG who were exposed to the methods of pedagogical influence, and the CG where no experimental methods were used.

The results of diagnostic measures (surveys, interviews, observations) showed that the understanding of the concept of SR by the students is vague and mostly at an intuitive level. The students themselves explained this by an insufficient attention to ethical issues in the course of studies.

An analysis of more than 40 programmes in various technical specialities [12] showed that they did not practically include disciplines directly related to engineering ethics, though some ethical issues could be raised in the course of studying such programme disciplines as ethics of business relations, ecology, civil defence, labour protection, man-machine interaction, philosophy of engineering and technology, social concepts of sustainable development of transport, traffic safety audit, basics of academic integrity and academic writing and some others.

None of these disciplines offered a holistic approach to the formation of SR of a future specialist, but they might become a favourable basis for the development of this quality if they were supplemented with appropriate content and taught by appropriate methods that we did during the experiment.

Taking into account the features of SR in engineering (fair operating practices, care for environment, accountability, transparency, ethical behaviour, respect for the rule of law, etc.) the following criteria and

indicators for assessing its levels were chosen: 1) value-based (awareness of social responsibility as an important indicator of an engineer’s professionalism; 2) pragmatic (the formed skills to navigate in a variety of professional situations and make responsible decisions); 3) reflective (the ability to make evaluative judgments, self-esteem).

We distinguished the following levels of awareness of SR: full awareness (students understand the importance of an engineer’s SR, have a clear idea of a professional duty); partial awareness (have a vague idea of the norms of engineering ethics and the social role of the engineering profession; lack of awareness (there is no awareness of the need for responsible performance of professional duties).

The levels of skills necessary for making responsible decisions were defined as: high (a student has fully mastered all groups of skills necessary for socially responsible professional activity; average (a student requires assistance in making responsible decisions); low (a student has not mastered the skills necessary to demonstrate SR in professional activity).

The levels of reflexivity of behaviour were determined as follows: high (a student constantly reflects on his/her own behaviour in the aspect of SR; they are able to adequately analyse professional and ethical situations); average (a student is not always able to adequately analyse professional and ethical situations and make responsible decisions); low (a student does not reflect on his/her own behaviour in terms of SR).

To assess awareness of SR as an important component of the professionalism, responses to open questions of a questionnaire developed by Yemelyanova [13] were used. The formation of professional and ethical skills was revealed with the help of special tasks at the level of recognition, reconstruction, production and creativity, which contained the entire range of possible human patterns of behaviour and were expressed quantitatively [14], [15]. The indicator of reflexivity of behaviour was established using Rotter’s questionnaire for determining the level of subjective control [16] that characterizes a person’s tendency to attribute responsibility for events in life to external forces or to their own abilities and efforts.

In the experimental work we tried and tested numerous methods and techniques of active learning, which contributed to the formation of professionally responsible engineer [17].

In modern pedagogical literature, three types of education are distinguished – formal, non-formal and informal, each in its own way affects the process of organizing education and self-learning. Formal education is regulated by the programs of educational institutions, non-formal education covers various alternative measures and resources additional to the system of formal education, informal education is the least structured and organized by people themselves according to their plans.

Within the framework of formal education, SR was developed in students of the EG during lectures and practical hours while discussing issues of responsibility for the environment, the country, the results of professional activity, etc., e.g. What is a professional

duty? What is professional integrity?, Responsible people: what they are like, What can be done to improve the behaviour of road users? What are the dangers of driving under drugs or alcohol? What is more effective, advertising campaigns or stricter laws? What can be done to help people understand the risks and develop safer habits?

The students were shown videos on acute environmental problems, such as *The Human Element* (2019), *Before the Flood* (2016), *Chasing Coral* (2017), *Racing Extinction* (2015), *The Ivory Game* (2016), *Life after people* (2010), *Catching the Sun* (2015), *Home* (2009), *Extinction: the Facts* (2020), *The Day after Tomorrow* (2004), etc. The students were also suggested to watch *Oppenheimer* (2023) – a biopic about an atomic bomb pioneer Robert Oppenheimer. After watching the films, the students were asked to discuss the issues raised from the point of view of SR of technical specialists, analyse social values and destructive consequences of irresponsible attitude to the planet and its inhabitants.

The following legal and ethical questions about artificial intelligence (AI) could start highly controversial and even philosophic discussions: At what point is a machine truly intelligent? If an AI injures or kills a human, who is to blame? The manufacturer, the owner, or the AI itself? Would you be comfortable seeing an “AI Doctor” or an “AI Nurse”? Would you feel safe in a plane that was being piloted by an AI-powered system? What are the geopolitical implications of AI? etc.

Critical thinking skills were developed while solving ethical dilemmas of the robotic future: Robots in upbringing and education: parents or machine? Drones: protection or surveillance? Robots and personal affection: is it possible? Determining the boundaries of the machine responsibility: who is responsible for the accident? Privacy: to trust or not to trust our personal data to AI? Medicine: who is more likely to cure?

The students were suggested to perform an online “Environmental awareness quiz” [18] with a subsequent discussion which included the following multiple choice questions: What is the cause of climate change? How much waste do humans produce every year? What’s the most effective way to reduce CO₂ emissions? Whose responsibility is it to make sure we reduce the amount of energy used?, etc.

In order to teach students to make a moral choice, a business game “Technique for eliminating deadlock situations” was held to help students to find new ethically acceptable decisions.

The students were divided into several “road construction companies”, which had to lay a road, taking into account a number of factors: the topography of the area, the location of settlements, possible deductions to the local budget, damage to the environment. After the “companies” made their decisions, the teacher deliberately drew a card with a set of “force majeure circumstances” and announced some unexpected event, e.g., a flood destroyed a bridge, and one of the companies must urgently repair it. The affected “companies” were forced to make amendments to their calculations and

choose priorities – profit, people, environment, that required students' critical thinking responsive solutions.

The students carried out a project that involved analysing the advantages and disadvantages of different modes of transportation, assessing factors such as safety, pollution, congestion, noise, health and community well-being.

The advantage of the case study method is that students learn to work in a team, analyse various life situations and look for the most suitable solutions. An example is the case study developed by Raicu (2018), which we adapted to our conditions [19]: the students had to decide whether their company/team should enter into a contract with the city to create a controversial product by analysing what ethical issues its designers/developers need to address, and what moral values potentially conflict with each other.

Another efficient tool to accustom students to responsible behaviour is the training practice, which enables students to feel involvement in the real professional activity by performing the duties of a specialist's assistant and to realize their social role.

As part of non-formal education, such events as essay contests, round tables, conferences, and the publication of the results of research were organized. Topics for essays included the following: What are the biggest challenges in mechanical engineering? The city of the future. What scares you the most about AI? What are the potential benefits of AI? List as many as ways or applications of AI as you can. What are some future uses of AI? etc. A “Road safety” video competition was held to encourage students to conduct surveys of local roads and proposed measures to improve road safety (for example, road markings, installation of speed cameras, regular police patrols).

Round tables as a form of public discussion of some problems were held on the following topics: The city of the future; Alternative energy sources; Will virtual reality become a primary form of entertainment and communication in the future?; What kind of regulations should be in place to control the development of AI?; The jobs that can't be automated; How long will it be before self-driving cars are common on the roads?

A student conference is an annual event organized by almost all universities of Ukraine. The students of the EG presented the results of their mini-research acquiring the skills of public presentation on various urgent topics: The pros and cons of AI's effects on jobs; Does technology make society lazy?; What is the future of transportation?; The Internet to learn English; Will the increasing dependence on technology lead to a loss of critical thinking skills in individuals? etc. Even in war conditions the students continued to take an active part in research work. The best reports were published in the collection of students' scientific papers “Students. Science. Foreign language”, which since 2008 has been published annually at the university.

Informal education includes, firstly, student self-government, which deepens the initiative of student groups in the organization of various types of activities. An important direction of student self-government today

is volunteering, which during the full-scale war in Ukraine has taken various forms and contributed to the national resistance to the Russian invaders in different ways [20]. In particular, many volunteers are helping the Ukrainian military, providing important support in the form of weapons, special equipment, transport, means of communication, training, etc.

The students-volunteers from the EG also took part in collecting donations to support military and humanitarian organizations that provided assistance to those affected by the conflict, in particular, internally displaced persons. This aid included food, clothing, shelter, medical care and other essentials. They met with the participants in the hostilities – war heroes, took part in the celebration of "Day of the Defender of Ukraine", "Day of the Ukrainian Cossacks", etc.

III. RESULTS AND DISCUSSION

At the control stage of the experiment we determined the indicators of the dynamics of SR development by the specified criteria. The successful formation of SR in students is largely determined by the awareness of social responsibility as an important component of the professionalism of a modern engineer. Therefore, we

consider a significant increase in the number of students in the EG, who have a high level of awareness of the importance of SR an important result of the experimental work (Table I).

We believe that such changes occurred due to extensive work by teachers of social, humanitarian and special disciplines, and organizers of training practice as they provided an opportunity for each student to check their readiness for a responsible attitude to functional duties, the degree of professional competence, identify shortcomings and outline ways of professional self-improvement.

The formation of the skills of socially responsible behaviour was achieved thanks to supplementing the content of social and humanitarian disciplines with knowledge of a professional and moral nature, active and interactive forms and methods of learning (round table, discussion of ethical situations, solutions of moral dilemmas, brainstorming, case analysis; simulation of professional situations, etc.). The dynamics of development of SR skills is shown in Table II.

Based on [16], we also determined the indicators of the dynamics of future engineers' reflexivity (Fig. 1).

TABLE I DYNAMICS OF AWARENESS OF SOCIAL RESPONSIBILITY (%)

Feature	E (122)		C (120)	
	Before experiment	After experiment	Ascertaining data	Control data
Full awareness	11.0	83.2	15.9	19.0
Partial awareness	60.0	14.8	43.8	71.4
Lack of awareness	29.0	2.0	40.3	9.6

TABLE II DYNAMICS OF FORMATION OF SOCIALLY RESPONSIBLE SKILLS(%)

Level of development	E (122)		C (120)	
	Before experiment	After experiment	Ascertaining data	Control data
High	5.9	62.0	4.4	23.1
Average	61.5	37.5	59.1	63.8
Low	32.6	0.5	36.5	13.1

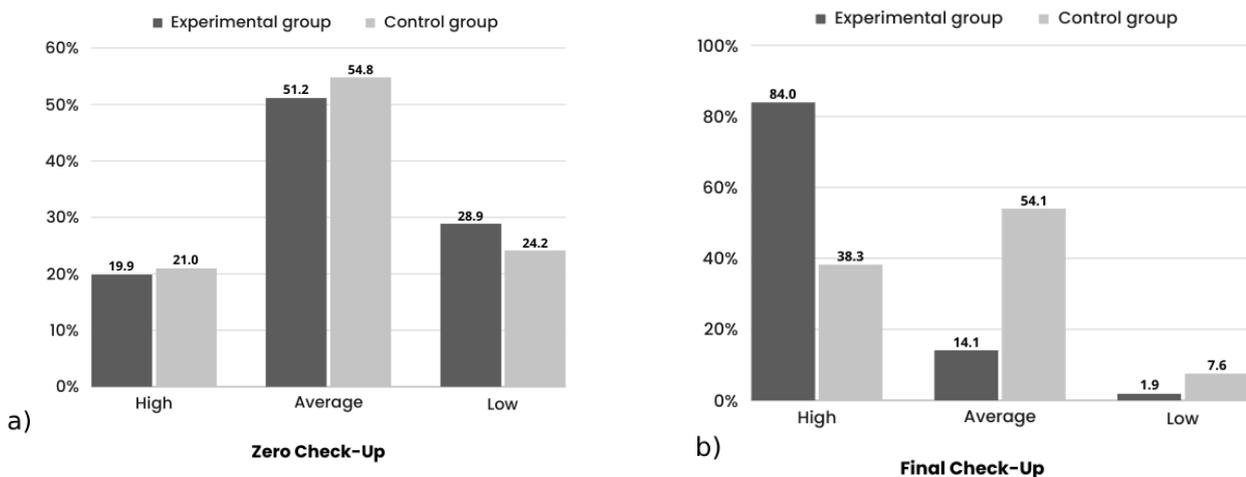


Fig. 1 Trends in the development of the reflexive behaviour

In the course of the experiment with the regular involvement of students in various practices of the ethical nature (participation in contests of essays on ethical topics, round tables, discussions of acute socio-ethical problems, case studies, etc.), the following results were obtained: the number of students with a high level of reflexive behaviour increased by 64.1% (EG), compared to 17.3% (CG), which indicates a significant impact of the applied methods on the students' ability to analyse professional situations and make responsible judgments.

The reliability of the results of the experimental work was proved by the means of mathematical statistics (the change in the statistical characteristics of the experimental and control samples was analysed by the criteria of significance) [21], which confirmed that changes in the levels of indicators of future engineers' SR are statistically significant.

In general, by the set of indicators we would divide all the students into those who demonstrate a willingness to take responsibility for their actions, act in extreme conditions, look for new ways of solving educational and professional tasks, emotional stability, stress resistance, endurance, a high degree of self-control; those who are characterized by readiness to perform tasks, but only according to the pattern, they negatively evaluate production situations in which their behaviour is not clearly regulated by normative documents; and those who are characterized by uncertainty of their social and professional position, indifferent attitude to the fulfilment of their future professional duties; formal compliance with requirements, instructions and rules of conduct. We found out that the first group of students can be quantitatively and qualitatively improved when students are suggested to consider real-life scenarios or emergency situations that teach them responsibility and develop a high level of understanding of issues of sustainable community development.

We support the idea of the need to develop holistic engineers who are able to solve the complex social problems of the future that calls for a rethinking of engineering education to include greater interaction with the public and industrial partners, more diverse teaching methods, and increased attention to engineering problems.

At the same time, we experienced a lack of a systematic approach to the development of SR in students, a clear inventory of methods and techniques that can be used within specific disciplines, a description of practical experience in this area of engineering education, therefore we believe promising for further scientific research is the development of methodological support for the formation of ethical skills of future engineers, as well as a set of methods for diagnosing the socially significant characteristics of technical students.

CONCLUSIONS

The development of technology and especially such a field as artificial intelligence makes new demands on the morality of a scientist and engineer. Almost every

day we learn about the emergence of new computer programs that surpass the mental abilities and creative capabilities of humans: they generate texts, sing, draw, and make medical diagnoses.

The improvement of technology and smart machines is inevitable, as is the fact of their undeniable impact on society, economy and relationships between people in the future. Therefore, more and more urgent calls are heard to consider the ethical principles of engineering and AI development, making sure that technology is developed in a direction that is safe for people.

These problems pose significant challenges for higher education institutions of a technical profile, because they are the ones that can and should train responsible engineers of the future, who will be ready to take responsibility for their actions, strive to improve production, be aware of the interests and needs of society.

The experience of Ukrainian universities shows that the regular involvement of students in activities that improve their organizational, evaluative, analytical abilities and affect their emotional sphere contributes to the development of their moral qualities and forms responsible engineers of the future generation.

REFERENCES

- [1] M. Cheng-Tek Tai, "The impact of artificial intelligence on human society and bioethics" *Tzu Chi Medical Journal*, vol. 32(4), pp. 339-343, Aug. 2020, doi: 10.4103/tcmj.tcmj_71_20
- [2] V. Glinka, "Artificial intelligence as a threat" [Штучний інтелект як загроза]. *Forbes Digital*. April 2023 [Online]. Available: <https://forbes.ua/innovations/shtuchniy-intelekt-yak-sira-zona-problemi-ta-rishennya-regulyuvannya-instrumentiv-na-osnovi-shi-03042023-12810>. [Accessed: September 16, 2023].
- [3] G. Ya. Mamalui, *Philosophical alternatives of the 20th century: Lectures on the course "History of Philosophy"* [Філософські альтернативи ХХ століття: Лекції по курсу "Історія філософії"]. Kharkiv: KhDAK, 2002.
- [4] O. M. Lapuzina, "Formation of professional ethics in future engineers based on situational learning," [Формування професійної етики у майбутніх інженерів на основі ситуаційного навчання], PhD thesis, Vinnitsia: VDPU, 2006.
- [5] P. Brey, "Research Ethics Guidelines for the Engineering Sciences and Computer and Information Sciences," in *The International Library of Ethics, Law and Technology*, Vol. 23, K. Laas, M. Davis, and E. Hildt Eds., Springer, 2022, pp. 15-34. https://doi.org/10.1007/978-3-030-86201-5_2
- [6] D. S. Bukreeva and K. V. Denisenko, "Social responsibility of business as a basis for ensuring business activity of enterprises: European integration aspect [Соціальна відповідальність бізнесу як основа забезпечення ділової активності підприємств: євроінтеграційний аспект], *Economy and society*, vol. 38, 2022 [Online]. Available: <https://economyandsociety.in.ua/index.php/journal/article/view/1316>. [Accessed: Oct., 4, 2023], <https://doi.org/10.32782/2524-0072/2022-38-52>
- [7] E. P. Buryi and G. P. Zhaldak, "Corporate social responsibility in war conditions [Корпоративна соціальна відповідальність в умовах війни], IV International scientific and practical conference Business, Innovations, Management: Problems and Trends, April 23, 2023, Kyiv: NTU "Kyiv Polytechnic Institute".
- [8] P. Adamek, "Corporate Social Responsibility Education in the Czech Republic," *Procedia – Social and Behavioral Sciences*, vol. 106, pp. 730-738, 2013.
- [9] L. Romkey, "Engineering, society and the environment in the teaching goals and practices of engineering instructors. *Proc. of*

- the American Society for Engineering Education (ASEE) Annual Conference and Exposition, June 14-17, 2015, Seattle: WA, 2015.
- [10] A. Akay, "The renaissance engineer: educating engineers in a post-9/11 world," *European Journal of Engineering Education*, vol. 28(2), pp. 145-150, 2003.
- [11] I. De Vere, K. Bissett Johnson and C. Thong, *Educating the responsible engineer: socially responsible design and sustainability in the curriculum*. International conference on engineering and product design education, September 10-11, 2009, University of Brighton, UK, 2009.
- [12] Catalog of educational programs [Каталог освітніх програм], 2021 [Online]. Available: <https://www.khadi.kharkov.ua/education/katalog-osvitnikh-program/>. [Accessed: Oct. 25, 2021].
- [13] T. P. Emelianova, Professional responsibility in the everyday consciousness of energy engineering students [Професійна відповідальність в об'язковому свідомості студентів-енергетиків]. *Information humanitarian portal "Knowledge. Understanding. Skills"*, vol. 2, 2013 [Online]. Available: http://www.zpu-journal.ru/e-zpu/2013/2/Emelianova_Professional-Responsibility-Students/. [Accessed: June 14, 2021].
- [14] S. Philbin, *Engineering Education: Research and Professional Skills Development*. American Society for Engineering Management (ASEM) International Annual Conference. Oct. 5-8, 2022, American Society for Engineering Management, Tampa, FL, 2022.
- [15] N. E. Adams, "Bloom's taxonomy of cognitive learning objectives," *Journal of the Medical Library Association*, vol. 103(3), pp. 152-153, 2015.
- [16] J. Rotter, "Generalized expectancies for internal versus external control of reinforcement," *Psychological Monographs*, vol. 80 (1), pp. 1-28, 1966. [Online]. Available: <https://pubmed.ncbi.nlm.nih.gov/5340840/>. [Accessed: November 13, 2021].
- [17] G. S. Sozykina, O. V. Popova and N. V. Saienko, *Social responsibility of future engineers in the automobile and road industry: pedagogical aspect: monograph* [Соціальна відповідальність майбутніх інженерів автомобільно-дорожньої галузі: педагогічний аспект: монографія]. Kharkiv: KhNAHU, 2020.
- [18] Environmental awareness quiz [Online]. Available: <https://www.ideagen.com/solutions/elearning-content/workrite/environmental-awareness-quiz>. [Accessed: March 18, 2022].
- [19] I. Raicu, *Surveillance, Safety, and Smart Cities. An Ethics Case Study*, 2018 [Online]. Available: <https://www.scu.edu/ethics-in-technology-practice/case-studies/surveillance-safety-and-smart-cities/>. [Accessed : Jan. 14, 2022].
- [20] O. Reznik, *Involvement of Ukrainians in volunteer activities during a full-scale war* [Залученість українців до волонтерської діяльності під час повномасштабної війни]. Iiko Kucheriv Foundation for Democratic Initiatives, April 26, 2023. [Online]. Available: <https://dif.org.ua/article/oleksandr-reznik-zaluchenist-ukraintiv-do-volonterskoi-diyalnosti-pid-chas-povnomasshtabnoi-viyni>. [Accessed: Nov. 15, 2023].
- [21] T. G. Kryvorot, "Non-parametric methods of mathematical statistics for evaluating the effectiveness of pedagogical innovations [Непараметричні методи математичної статистики для оцінювання ефективності педагогічних нововведень]," *Pedagogy of creative personality formation in higher and secondary schools*, vol. 32, pp. 288-295, 2013.

Readiness of The Future Preschool and Primary Education Specialists to form the Foundations of Children's Cyber Security

Oleksandra Shykyrynska

*Valentina Voloshyna Faculty of
Preschool and Primary Education
Vinnytsia Mykhailo Kotsiubynsky
State Pedagogical University,
Vinnytsia, Ukraine
o.v.shikirinska@gmail.com*

Valentyna Liapunova

*Educational and Scientific
Institute of Social-Pedagogical
and Artistic Education.
Bogdan Khmelnytsky Melitopol
State Pedagogical University
Melitopol, Ukraine
lapunova001@gmail.com*

Olha Melnykova

*Faculty of Preschool and Special
Education
Pavlo Tychnya Uman State
Pedagogical University
Uman, Ukraine
olga@maistruk.com*

Kateryna Mnyshenko

*Valentina Voloshyna Faculty of
Preschool and Primary
Education
Vinnytsia Mykhailo
Kotsiubynsky State Pedagogical
University, Vinnytsia, Ukraine
katerinamazur7@gmail.com*

Tetiana Petryshyna

*Valentina Voloshyna Faculty of
Preschool and Primary Education
Vinnytsia Mykhailo Kotsiubynsky
State Pedagogical University,
Vinnytsia, Ukraine
tetanapetrisina21@gmail.com*

Abstract. In connection with the digitization of the educational process, the need for the development of critical thinking of children of senior preschool and junior school age, the development of the ability to use information in any form, to communicate, and to be aware of the consequences of interaction in the digital world is increasing. The article found out that the training of the future preschool and primary education specialists should include the formation and development of methodological competence of students in order to develop in children of preschool and junior school age the ability to protect themselves, their information and privacy on the Internet, the ability to be friendly and brave on the Internet, formation of serious attitude to privacy and security. The experimental research has been conducted, the respondents of which were bachelor's degree students of the specialty 012 Preschool Education and 013 Primary Education of Vinnytsia Mykhailo Kotsiubynsky State Pedagogical University. The following approaches and technologies for forming the ability of the future preschool and primary education specialists to form the basics of cyber security for preschool and primary school children

have been highlighted: the problem-based approach, BYOD technology ("bring your own device"), the method of "flipped learning". The results of the approbation with bachelor's degree students of the speciality 012 Preschool Education and 013 Primary Education of the educational guide on children's security on the Internet, developed by Google in cooperation with The Net Safety Collaborative and the Internet Keep Safe Coalition and evaluated by the Scientific Center "Crimes Against Children" of the University of New Hampshire, have been given.

Keywords: *educational process of primary school, junior schoolchildren, educational process of preschool education institution, media literacy, information culture, innovative BYOD technology.*

I. INTRODUCTION

Children get acquainted with digital devices at an early age. They see that parents and relatives use such devices. Imitating their parents, children start using a tablet, touch phone, and laptop from an early age. Therefore, it is necessary to start familiarizing children with possible threats on the Internet from the youngest age, to form the ability to use gadgets safely. Another

Print ISSN 1691-5402
Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8087>

© 2024 Oleksandra Shykyrynska, Valentyna Liapunova, Olha Melnykova, Kateryna Mnyshenko, Tetiana Petryshyna.
Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

problem is that many parents do not understand the importance of forming the foundations of children's information culture and cyber security. Parents use tablets and a phones so that the children do not disturb them at home. Another problem is that parents do not know the basics of their own information security. Various threats await the child on the Internet, such as sexual content, communication with strangers, revealing personal and parents' data.

In connection with the digitalization of the educational process (Ciarko, M., & Paluch-Dybek, A. (2021); Otterborn, A., Sundberg, B., & Schönborn, K. (2024)), the need to develop critical thinking of children of senior preschool and junior school age is increasing Choiriyah, C. (2021). It is necessary to develop the ability to use information in any form, to communicate, to be aware of the consequences of interaction in the digital world Martin, F., Gezer, T., Anderson, J., Polly, D., & Wang, W. (2021). On the one hand, digital devices create more opportunities for children's learning, and on the other hand, the use of mobile apps, touch phones and tablets for entertainment can affect their safety in the digital world (Chassiakos et al., 2016). Another threat is intimidation on the Internet, social media, cyberbullying and other threats and addictions (Li, 2006). The use of mobile devices and tablets by children under the age of 7 without adult supervision is a problem, because children do not have critical thinking, do not know how to make independent decisions and cannot predict their own actions (Sziron & Hildt, 2018).

We found a contradiction between the speed of development of digital technologies and fraudulent activities on the Internet and the training of preschool and primary education specialists.

II. MATERIALS AND METHODS

In the course of this research, we used the following methods: theoretical: analysis of scientific sources to determine the state of research on the formation of the readiness of the future preschool and primary education specialists for children's cyber security, synthesis, systematization and generalization of the theoretical provisions of the problem; empirical: pedagogical observation of the activities of children in preschool education institutions, conversations with students about knowledge of the basics of cyber security, conversations with educators of preschool education institutions regarding the conduct of classes or games on children's cyber security, questionnaires of the future preschool and primary education specialists of Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University.

III. RESULTS AND DISCUSSION

The research was conducted in the period from September to December 2023. 73 full-time bachelor's degree students and 22 part-time bachelor's degree students of the 3rd year of study of the Faculty of Preschool and Primary Education named after Valentyna Voloshyna, specialty 012 Preschool Education of Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University (Vinnytsia, Ukraine) took part in the survey.

The online survey was distributed through personal connections of the researchers. The researchers shared the results of the online survey on social media and email. The survey window was open for 6 months from September 2023 to January 2024. Participation in the online survey was voluntary.

The objective of this survey was to find out the current level of readiness of the future preschool and primary education specialists for the formation of the basics of cyber security of children of preschool and primary school age. For this, appropriate criteria have been developed and their indicators determined: motivational (need for professional and personal growth; desire for new knowledge in the field of cyber security); cognitive (knowledge about threats and addictions on the Internet); activity (the ability to distinguish between threats and addictions on the Internet and to form the foundations of children's cyber security).

Three levels of readiness of the future preschool and primary education specialists to implement the basics of children's security have also been characterized.

High – expressed motivation for continuous self-development and improvement in the field of children's cyber security with readiness to implement advanced pedagogical approaches; deep knowledge and understanding of threats and dependencies on the Internet; the ability to apply practical experience in the basics of cyber security in professional activities.

Sufficient – growing awareness of the importance of professional and personal development in the field of children's cyber security, active self-assessment and identification of gaps for self-improvement; understanding of the range of methods and technologies of manipulations, threats, dependencies on the Internet; the ability to apply knowledge about children's cyber security on the Internet in practical situations;

Low – insufficient understanding of the importance of professional and personal development in the field of children's cyber security; basic knowledge of the theoretical foundations of the formation of children's cyber security; limited readiness to use knowledge in practical activities.

The respondents were offered a survey in Google Forms, which included three blocks of questions, according to selected criteria.

We used the following two questions to find out the levels of readiness of the future preschool and primary education specialists for the formation of the basics of children's cyber security based on the motivational criterion. The first was the following question: "How important is it for an educator to engage in self-education in the field of digital security?" Justify your opinion. Give at least three reasons for justification. If the student mentioned three or more good reasons, then this is a high level, if only one – it is sufficient, if he or she did not mention any or this reason was insignificant, then it is low. According to the results of the answer to this question, the level of 18 students is high, 45 students have sufficient, and 32 – low level of readiness.

In order to find out whether the future specialists use the given arguments in their own lives, we proposed the

second question: “What courses have you taken in the last six months on information culture?” If the respondent named at least two courses, it was a high level, if one – sufficient, if none – low. Thus, 15 students have a high level, 37 have a sufficient level, and 43 have a low level. Based on the results of two questions, we can determine the levels of readiness of the future preschool and primary education specialists according to the motivational criterion: high 17, sufficient 41, low – 37.

The next block of questions was aimed at identifying the levels of readiness of the future preschool and primary education specialists for the formation of the basics of children’s cyber security according to the cognitive criterion. The first question was: “Which of the submitted can be fake: fact, news, computer, antivirus, video, photo, piece of information, theorem, site, account, program?” If the student chose more than three correct answers it was a high level, at least three – a sufficient level, one or none – a low level. The results are as follows: high – 27, sufficient – 39, low – 29.

The future preschool and primary education specialist should be well aware of all the threats and addictions that await an unprepared user on the network. The next question was to find out such knowledge. We offered a list of threats and addictions: happy slapping, “dancing pigs”, “fb shower”, “phubbing”, scams, voyeurism, greed for information, selfies, tablet zombies. The respondent had to place them in two categories: category one – threats, category two – addictions. If the student made one mistake during placing, this is a high level, if two to four it is sufficient, more than four – low. Results: high – 20 students, sufficient – 32 students, low – 43. The generalized data according to the cognitive criterion are as follows: high – 24, sufficient – 36, low – 35.

In order to familiarize children with the basics of cyber security, the future preschool and primary education specialist must have the ability to verify information himself or herself. The next block of questions is aimed at identifying the levels of readiness of the future specialists for the formation of the basics of cyber security of children of preschool and younger school age according to operational criteria. The first question was: “How to check if the information is fake?” Students indicated that they need to check all events, names, processes listed in the information on at least three different sites. The results should be the same. If we cannot find the name of a famous person mentioned in the information or we notice other discrepancies, most likely, this information is fake, that is, untrue. In order to check this, students were asked to check whether such information is true. Information. Once every five years, the awarding ceremony of one of the world’s main art prizes is held. This is happening in the homeland of outstanding painters: Michelangelo, Caravaggio and Raphael – in Italy. All these five years, their respected descendants carefully follow the talents of the brush from all over the planet, in order to discover the most gifted and skilled. Therefore, it is especially pleasant that this time the experts chose an artist – a young and talented, and from now on, an artist recognized by the world – Mykola Bezkorovainyi. “We are all extremely impressed

by the simplicity and at the same time the power of the artistic expressions of this young artist”, said the curator of the prize, Gert Jan Jansen. “I have not seen anyone more gifted and at the same time wise and modest. So I am sure: we should be proud of such an artist”. Students who indicated all three signs that the information is fake – high level, only one – sufficient, those who said that the information is true – low level. Results: high level – 16 students, sufficient – 56, low – 36.

The next question is: “How important do you think it is to talk about building the basics of children’s cyber security with parents of preschool children? Justify your opinion”. If the student gave three or more arguments, this is a high level, if one – it is sufficient, if there were no arguments, it is low. Results: high – 35 students, sufficient – 44 students, low – 16. As we can see, in the answer to this question there are the most students of high and sufficient levels. In our opinion, this is caused by the specifics of the pedagogical institution in which the future preschool and primary education specialists receive their education. Generalized data on the readiness of the future preschool and primary education specialists to form the basics of children’s cyber security according to operational criteria: high – 26, sufficient – 50, low – 19. Generalized data according to three criteria can be seen in Table 1.

TABLE 1. LEVELS OF READINESS OF THE FUTURE PRESCHOOL AND PRIMARY EDUCATION SPECIALISTS FOR THE FORMATION OF THE BASICS OF CHILDREN’S CYBER SECURITY

	High	Sufficient	Low	Total
motivational	17	41	37	95
cognitive	24	36	35	95
operational	26	50	19	95

We also observed the educational process in 14 preschool education institutions in the city of Vinnytsia. The results of the observation are as follows: in 10 kindergartens, educators do not conduct activities on children’s cyber security. The reason was found out in personal conversations with educators. Since children are not allowed to use gadgets in kindergarten, they consider cyber security work to be the parents’ business. In four other kindergartens, educators conduct special discussions, games, and quests with the aim of children’s cyber security.

To increase the level of knowledge of the future preschool and primary education specialists in the basics of children’s cyber security, we offer students selective disciplines “Media education and formation of information culture of preschool and primary school children”, “Formation of the basics of cyber security of preschool and primary school children”. In the course of teaching these disciplines, we emphasize the interaction of the educator of the preschool education institution with parents regarding the formation of the basics of cyber security for children of preschool and primary school age.

We also used the educational guide on children’s security on the Internet during two academic years, namely: 2021-2022 and 2022-2023. The guide was developed by Google in cooperation with The Net Safety

Collaborative and Internet Keep Safe Coalition. In cooperation with the non-profit organization Committee for Children, the authors created new social-emotional educational activities that will help children in their travels through the digital world. The guide on children's security on the Internet has been evaluated by the University of New Hampshire's Crimes Against Children Research Centre. Based on the results of the research conducted by the centre, this is the first guide on children's security on the Internet that has been proven to have a positive impact on teaching children about online security and digital citizenship. The guide on children's security on the Internet is a self-contained resource. All practical tasks can be completed without special professional skills, with minimal training and without special equipment or other learning resources. In addition, the material learned at the lessons can be put into practice in a fun and interesting way thanks to the online adventure game Interland. The guide covers five fundamental topics on digital citizenship and security: share wisely (digital footprint and responsible communication); don't be fooled (phishing, scams and trusted sources); keep your secrets (online security and passwords); it's cool to be friendly! (combating negative behaviour on the Internet); do you doubt? Ask! (doubtful content and scripts).

This guide is designed for grades 2-6, but the lessons will be useful for teachers of both older and younger children, including sections on terms, class discussions and games. We encourage you to experiment and choose the program that works best for your pupils. For example, you can go through the entire program from start to finish, or you can focus on a few lessons that your pupils need most. In addition, you can use resources for teachers and parents: ready-made slides, printables, a manual and tips for families to use at home. International Society for Technology in Education (ISTE) conducted an independent audit of the guide on children's security on the Internet and recognized it as a resource that helps prepare pupils for the ISTE 2021 Standards and awarded with the Seal of Alignment for Readiness.

While working with this guide, we used the following approaches and technologies of the formation of the future preschool and primary education specialists in the ability to form the basics of cyber security of children of preschool and junior school age: problem-based approach, BYOD technology ("bring your own device"), the method of "flipped learning". At the beginning of each practical lesson, before explaining a new topic, we asked students problematic questions. For example, during the study of the topic "I don't mean it" (module 1, lesson 3), students were asked whether they encountered the phenomenon of non-understanding or misunderstanding of certain information by others. Such a problematic question prompted students to be motivated in perceiving a new topic. Since students and teachers of Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University work remotely during martial law, they used BYOD technology ("bring your own device") during

practical classes, giving students the task of finding certain information using their own devices. The method of "flipped learning" was also used. For this, on the eve of the practical lesson, information was posted for familiarization in the virtual environment of Google Classroom. This material was discussed directly with the students in the form of a conversation during the practical lesson. We also noticed that this approach contributes to a stronger memorization of the material.

ACKNOWLEDGMENTS

We express our gratitude to the teachers and students of the Department of Pre-school Education of the Mykhailo Kotsiubynskyi Vinnytsia State Pedagogical University, to the teachers of Pre-school Education Institution No. 30 and 27 in the city of Vinnytsia

CONCLUSIONS

In the article, the authors made an attempt to actualize the problem of readiness of the future preschool and primary education specialists to form the foundations of children's cyber security. In connection with the increase of threats on the Internet and the use of gadgets by children from an early age, it is necessary to develop children's ability to use the Internet safely, to be conscious citizens of the digital world. In this regard, it is necessary to train the future preschool and primary education specialists.

The following approaches and technologies for forming the ability of the future preschool and primary education specialists to form the foundations of cyber security of preschool and primary school children have been highlighted: problem-based approach, BYOD technology ("bring your own device"), the method of "flipped learning".

The conducted research does not cover all aspects of the problem under consideration. The question of forming the motivation of preschool and primary education specialists for independent continuous professional development in the field of cyber security requires further research.

REFERENCES

- [1] A. Ciarko, and A.Paluch-Dybek, (2021). The importance of digitalization in the education process. In *E3S Web of Conferences* (Vol. 307, p. 06002). EDP Sciences.
- [2] A.Otterborn, B. Sundberg, and K. Schönborn, (2024). The impact of digital and analog approaches on a multidimensional preschool science education. *Research in science education*, 54(2), 185-203.
- [3] C. Choiriyah, (2021). Science literacy in early childhood: Development of learning programs in the classroom. *Indonesian Journal of Early Childhood Education Studies*, 10(2), 136-142.
- [4] Y. L. R. Chassiakos, J. Radesky, D. Christakis, M.A. Moreno, and C. Cross, (2016). Children and adolescents and digital media. *Pediatrics*, 138(5), e20162593. <https://doi.org/10.1542/peds.2016-2593>
- [5] F.Martin, T. Gezer, J. Anderson, D. Polly, and W. Wang, (2021). Examining parents perception on elementary school children digital safety. *Educational Media International*, 58(1), 60-77.
- [6] Q. Li, (2006). Cyberbullying in schools: A research of gender differences. *School Psychology International*, 27(2), 157-170. <https://doi.org/10.1177/0143034306064547>

Application of Upcycling Technology in the Project Activity of Future Teachers of Labor Education and Technology

Iryna Shymkova

Department of Fine and Decorative Arts,
technologies and safety of life
Vinnytsia Mykhailo Kotsiubynskiy State Pedagogical University
Vinnytsia, Ukraine
irina.shym22@gmail.com

Svitlana Tsvilyk

Department of Fine and Decorative Arts,
technologies and safety of life
Vinnytsia Mykhailo Kotsiubynskiy State Pedagogical University
Vinnytsia, Ukraine
tsvilyksv@gmail.com

Oksana Marushchak

Department of Fine and Decorative Arts,
technologies and safety of life
Vinnytsia Mykhailo Kotsiubynskiy State Pedagogical University
Vinnytsia, Ukraine
ksanamar77@gmail.com

Vitaliy Hlukhaniuk

Department of Fine and Decorative Arts,
technologies and safety of life
Vinnytsia Mykhailo Kotsiubynskiy State Pedagogical University
Vinnytsia, Ukraine
hluhanukvit@gmail.com

Volodymyr Harkushevskiy

Department of Fine and Decorative Arts,
technologies and safety of life
Vinnytsia Mykhailo Kotsiubynskiy State Pedagogical University
Vinnytsia, Ukraine
garkushevskiy1952@gmail.com

Abstract.–The aim of this article is to justify the potential of technologies for processing secondary raw materials and to investigate the effectiveness of developing professional competences in future teachers of labor education and technology through the utilization of upcycling technology in the design of eco-bags.

Project activity focuses on fostering critical thinking and portrays the pedagogical process as a system based on the theory of universal human values, humanization, a person-oriented approach, and the priority of subject-subject relations. It proves to be effective in shaping the personality of future teachers. The main features of the process of designing eco-bags using upcycling technology are determined to be interdisciplinary, communicative, and dynamic, facilitated by the use of information services of social networks. The process emphasizes environmental friendliness under the conditions of recycling secondary raw materials and involves creative project and practical activities.

Pedagogical conditions for project activity in eco-bag upcycling are defined through provisions such as structuring the project and its stages, setting educational goals and tasks, implementing an integrated program of technological activity, developing a criterion basis for determining the levels of educational achievements, and creating information-subject and material-technical support

for the educational process. Collaboration among teachers of general and professional training cycles is highlighted for content coordination, organization of training, and improvement of educational, methodological, and software training for processing secondary raw materials.

The work employs methods of theoretical and empirical research, including analysis and synthesis to clarify main concepts and categories of learning technologies for processing secondary raw materials for future teachers of labor education and technology. It also involves the study of psychological-pedagogical and scientific-methodical literature and advanced pedagogical experiences related to learning technologies in higher education institutions, enabling the identification of regularities and formulation of conclusions on the investigated problem.

Keywords: pedagogical conditions of professional training for teachers of labor education and technology, Pinterest social network, project activity, upcycling.

I. INTRODUCTION

Social development puts on the agenda the requirement of forming a creative personality that orients itself, chooses a path, and acts using new approaches,

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8076>

© 2024 Iryna Shymkova, Svitlana Tsvilyk, Oksana Marushchak, Vitalii Hlukhaniuk, Volodymyr Harkushevskiy.

Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

ideas, and solutions. The individual realizes oneself and adapts to society, utilizing one's own potential on the basis of effective, productive knowledge, and creative opportunities.

The problem of training a teacher in labor education and technology, capable of shaping the creative personality of a student in a general secondary education institution (GSEI), is currently being emphasized. Future teachers should be knowledgeable and practically prepared for project-based learning, utilizing innovative techniques and materials processing technologies that are engaging for students.

In the concept of "New Ukrainian School" [1] it is emphasized that the development and formation of a creative, comprehensively developed personality is a strategic task of GSEI. The educational process should be dynamic and aimed at improving existing methods and developing new, effective approaches to foster the creative personality through the use of innovative technologies.

The process of forming professional competences and developing the creative personality of a future teacher of labor education and technology utilizing cloud services for mastering original processing technologies is effective, as evidenced by certain of our studies [2]. We view the learning of upcycling technology through the implementation of eco-bag projects with the involvement of social network services as an innovative pedagogical approach for shaping the technological competences of future teachers capable of creative activity [3]. This approach necessitates an interdisciplinary approach [4].

II. MATERIALS AND METHODS

A number of works by researchers and practicing teachers are devoted to the problem of professional training for teachers in labor education and technology, emphasizing the increasing role of innovative learning systems using cloud services and the necessity for their development, advancement, and implementation in the educational field. For example, V. Steshenko and D. Kilderov propose a systematic approach to the formation of professional competencies of a teacher of labor training and technology [5]. The authors of the collective monograph (A. Gedzik, et al.) noted that competence reflects the practical orientation of the educational process, implying effective activity and a high final result [6]. V. Sydorenko substantiated the concept of "competence" as the ability to effectively use knowledge and skills, the presence of personal qualities to achieve results at a specific workplace [7].

We agree with S. Tkachuk's interpretation regarding the peculiarity of forming the professional and pedagogical competence of a teacher in labor training and technology. This involves mastery of technological culture, with components such as project competence (subject knowledge and skills related to the design of educational activities) and technological competence (cognitive, emotional, valuable, and creative aspects reflected in a humanistic attitude towards professional activity) [8].

The state standard of secondary education in Ukraine defines the priority goal of the technological field as the realization of the student's creative potential, the formation of critical and technical thinking, readiness to safely alter the natural environment through modern technologies and design, the ability for entrepreneurship and innovative activity, partnership interaction, and the utilization of equipment and technologies for the satisfaction of one's own needs, cultural, and national self-expression [9].

The unfolding of personal potential, the development of abilities, the formation of the ability to independently search for the necessary information to solve the tasks, to creatively approach the creation and manufacture of an aesthetic and technically complete occur through the involvement of GSEI students in creative technological activities during labor training and extracurricular time.

Modern educators are convinced that the educational space of the New Ukrainian School (NUS) should evolve into a comfortable learning environment characterized by trust and valuable discussions. Within this space, students are shaped as competent, creative personalities, and conscious, responsible citizens. Notably, V. Sukhomlynskyi regarded creativity as an activity that reveals the spiritual world of the individual, referring to creativity as the essence of life in the world of knowledge and beauty [10]. In light of this, the educational and cognitive activity of students in primary and secondary schools, emphasizing a creative aspect, necessitates their mastery of project technology. From the perspective of the personal-activity approach, scientists believe that abilities are "...individual psychological features of a person that are manifested in activity and will be a condition for its successful performance" [11]. V. Kremen believes that creativity is the apogee of human existence, when a person acquires the ability to transform the reality (relationships, norms, values) in which he performs life activities [12].

An important aspect of developing the creative abilities of secondary school students is creative pedagogical activity, which significantly influences the effectiveness of this process. Thus, S. Sysoeva justifies that the object and result of pedagogical creativity is the creation of a personality, not an image (as in art) or a mechanism (as in technology) [13].

In the integrated scientific interpretation, the creative personality is considered as a complete human individuality, which shows developed creative abilities and motivation, creative skills that provide it with the ability to generate qualitatively new materials, technologies and spiritual values that, to a greater or lesser extent, change a person's life for the better [14]. It is also worth agreeing with Yu. Koptiloi's opinion that the effective formation of the creative personality of a student of secondary school requires the creation of certain pedagogical conditions for the implementation of a personality-oriented approach; ensuring in-depth individualization of the educational process; cooperation between participants of the educational space; pedagogical patronage of the self-development of a creative personality [15].

Currently, project technologies are widely used in various fields of knowledge, in the teaching of various disciplines, increasing educational motivation, developing cognitive interest and creative abilities. Project activity is focused not only on the implementation of the project, but also on personal changes in the subjects of this activity, when the project culture of the learner is formed - a complex, multi-level, dynamic system of technological qualities.

Studying the opinions of scientists gives us reason to consider the process of project activity as a symbiosis of the development of creative potential and creative technological activity of an individual. In view of this, the purpose of our research is to substantiate the possibilities of upcycling technology and to study the effectiveness of the formation of professional competences and creative abilities of future teachers of labor education and technology in the design of eco-bags.

Note that upcycling is a method of transforming used things into new products in order to reduce the negative man-made and social impact on the environment. It's a process sometimes interpreted as "upcycling", defined by upcyclethat.com as: "The act of taking something that's no longer used and giving it a second life and a new function. At the same time, the finished product often becomes more practical, more valuable and more beautiful than the one that was before" [16].

The rapid development of technology has turned humanity into consumers of natural resources, which has caused an ecological crisis. It is known that the light industry produces billions of units of clothing annually, a large part of which never reaches the consumer. At the same time, fast fashion giants throw away defective or unsold clothes, warehouses are filled with clothes without final use.

Unlike traditional recycling technologies, in which materials such as plastic and paper gradually break down and can only be recycled to a limited extent, upcycling transforms unwanted items into products of greater value. Proponents call this "closing the loop". In particular, Jamie Burdett, co-owner of the London company Worn Again, sees used material as a resource worth saving. A practical embodiment of this approach is the emergence of branded bags made from Royal Mail jackets and Virgin Group balloons [17].

Upcycling is a creative design solution for recycling materials that ensures their ecological use and gives old products a new purpose. Under the conditions of material processing, humanity can save a significant amount of water, slow down the excessive production of textiles and other materials, and reduce the mass of landfills. Design recycling moves waste items forward in the chain of useful consumption [18].

On the other hand, upcycling is a project technology both for beginners (for example, installing a clock mechanism on an old record or restoring a coffee table) and for creating your own brand of recycling clothes or household items, which requires certain experience, tools and creativity.

Upcycling technology is not only focused on environmental benefits. The process of making, refining and recycling products is actually beneficial for many in terms of rehabilitation, mental health issues and motivation for generations to come. Taking into account the research of scientists on the content of environmental training for future teachers [19; 20], we have identified the main advantages of upcycling, which can become decisive in the project activities of future teachers of labor training and technologies (Table 1).

Social networks are an integral part of today, where users have accounts to communicate and share information. Researchers believe that social networks are an effective way to expand one's personal learning network and discover resources. Under conditions of distance learning, participants in the educational process rely on certain social media as part of their daily routine. In teaching the technologies of processing used things, in addition to programs, plans, educational videos, posters, it is possible to publish creative ideas, projects and products that are related to technological activity and the formation of creative abilities.

In the network, future teachers learn not only the content of individual disciplines, but also ways and methods of working on the Internet in order to immerse themselves in the educational process, intensify participation in research projects, develop communication, draw attention to important events, own pages and share experiences.

III. RESULTS AND DISCUSSION

In the organization of project training for future teachers, we determined the search and analysis of social networks, which make it possible to increase the effectiveness of training in processing technologies, in particular, upcycling technologies. This work involved solving the following tasks: searching for popular social networks, analyzing the pages of thematic social networks, studying the possibilities of their use in creating banks of creative projects. The most famous social networks in Ukraine are Facebook, Instagram, Snapchat, etc. Their interface is clear and familiar to today's youth.

We focused our attention on the possibilities of the free social network Pinterest (with more than 200 million monthly visitors), which uses attached diaries and

TABLE 1 ADVANTAGES OF UPCYCLING

Environmental	Socio-economic	Personal
Processing of materials from landfills	Preservation and distribution of the works of ancient and modern masters	Conservation of natural resources
Reducing the volume of landfills	Support of regional industry	Formation of master skills of repair and processing
Economical use of natural resources	Reduction of production costs and losses	Creating unique things

pictures, reminders as a giant educational board. The feed shows Pins, Follows, and Users based on recent activity on Pinterest. Pins can be searched by keywords. For example, if you enter the word "Handmade" in the search bar (Fig. 1), the system immediately displays a collection of pins for selection. Pins are ideas that Pinterest users create, find and save from the web. Pinning is about saving, organizing, organizing important and useful information on your own and group boards on your Pinterest profile.

The profile contains long-term saved foams, created boards and ideas, topics (Fig. 2). It is possible to create illustrative thematic boards that talk about what network users are currently doing (drawing, designing, manufacturing, etc.).

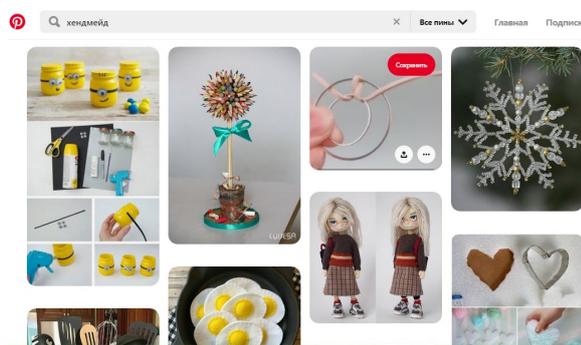


Fig. 1. Suggested pins by keyword.

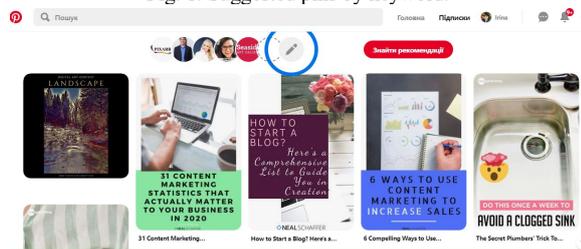


Fig. 2. An example of a subscription in your own Pinterest profile.

Teachers use personal pages for educational purposes, create thematic groups, collect educational videos, interesting information with links, create galleries of works, etc. Teachers create their own boards on Pinterest from various fields of knowledge, technology and pedagogical practice activities. Their boards are filled with lesson plans, activities, and general ideas for classroom improvement.

Users can connect interesting pins, find context boards, add and subtract search terms, orient relevant content. Along with boards for educational activities and ideas for creative development, you can create boards for generating ideas and new projects.

In particular, on the topic of our research, there are more than 1000 pins related to the processing of used jeans into various products: bags, rugs, jewelry, interior items, etc. An important aspect is the dosage and selection of information from social networks. A structural approach, identification of network leaders, contextual search, dosage, processing and generalization of information is effective in this process.

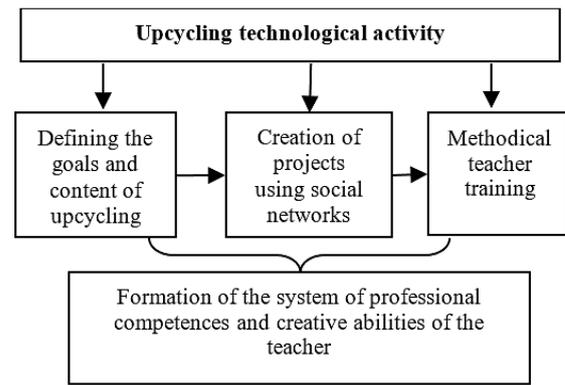


Fig. 3. Priority directions and goals of technological activity for the upcycling of the future teacher of labor education and technologies.

We have determined the priority directions and goals of technological activity on upcycling using the possibilities of social networks of the future teacher of labor education and technologies (Fig. 3).

We have worked out a number of organizational and pedagogical conditions for project activity on the upcycling of future teachers of labor training and technologies, namely: definition of structural elements and stages of the project; determination of educational goals and objectives, implementation of an integrated program of project and technological activities of the participants; determination of the stages of formation of professional competences and development of abilities of future teachers in project activity, which is based on the formation of experience of creative activity; development of a criterion basis for determining the levels of educational achievements of students in the implementation of eco-bag projects; use of opportunities and improvement of information-subject and material-technical support of the educational process; modeling of systems of interdisciplinary connections in technology education; constant cooperation of teachers of various subjects regarding the content, organization of training, development of educational and methodological and software support for teaching technologies.

We assume that the observance of these organizational and pedagogical conditions will ensure the formation of the readiness of the future teacher of labor education and technology to learn upcycling technology and the development of creative abilities of students of primary and secondary schools.

In the implementation and determination of the effectiveness of the organizational and pedagogical conditions of project activities on upcycling with the involvement of information arrays of the Pinterest social network regarding the formation of professional competences and creative abilities of future teachers of labor education and technology, we carried out a pedagogical study of the educational process at the Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, which was carried out in three stages (2020-2023): *ascertaining experiment* - a preliminary slice of knowledge (the levels of formed professional competences of future teachers were determined); *formative experiment* - the organization of learning technologies for making eco-bags by the upcycling

method with the involvement of information arrays of the Pinterest social network and the formulation of organizational and pedagogical conditions of project activity; *control and generalization stage* – analysis, processing of research results using statistical methods, formulation of theoretical-experimental conclusions and recommendations.

Control (K) and experimental (E) groups were selected for the experiment. The average level of previous knowledge was almost the same in the groups. The one in which the established level of knowledge was higher was chosen as the control group.

In order to establish the effectiveness of the organizational and pedagogical conditions of project activities on upcycling with the involvement of information arrays of the Pinterest social network, control measures were carried out in 2 groups of higher education institutions: implementation and protection of eco-bag projects.

The K-group students worked according to the method of individual execution of products for various purposes, the E-group students worked in small groups on the production of eco-bag projects using the upcycling method with the involvement of social network services aimed at developing the system of professional competences and creative abilities.

In evaluating the results of the participants of both groups, an integral criterion for the development of technological and creative abilities was the determination of harmony, aesthetics, unity, and the quality of artistic, design, and technological solutions. Teachers of professional disciplines evaluated the achievements of students in designing eco-bags on a four-point scale: high (5 points), sufficient (4 points), average (3 points), low (2 points). Students' project activities were observed, collective discussions and individual conversations were held. We evaluated the progress of students according to the degree of formation of professional competences, levels of mastery of project activities; a manifestation of creativity and independence, quality and flexibility in the implementation of projects.

We chose the ecological and technological direction, when students used upcycling technology in the design and manufacture of eco-bags. Important aspects of these projects are as follows:

- interdisciplinary character, when knowledge of natural and mathematical, technical and humanitarian fields is used to solve practical problems.
- involvement of cloud services and social networks with the possibilities of visualization, dynamism, mobility and integration;
- the use of used things, which is important in the use of secondary raw materials and the saving of material resources;
- application of ecological technologies without the generation of harmful waste;
- creative project-technological activity aimed at creating original, beautiful and useful things;

- development of creative and technological abilities and formation of professional competences of students.

In the development of the upcycling application method, we involved students in contextual search, discussion of the accumulated information, its generalization and definition of the content of the project activity on the processing of fibrous materials. Students together with teachers chose the topic of the project "Making an eco-bag from used items".

The possibilities of access to the use of significant volumes of interesting information about eco-bags gave students the opportunity to enrich their worldview, use a certain style of creative activity or choose their own. At the planning stage, an analysis of the types of author's eco-bags made from secondary raw materials, created by designers, craftsmen and displayed on the social network Pinterest, which were liked by the forms, design and availability of production, was carried out.

To develop the idea and its practical implementation, the main requirements for the project were defined, namely: originality and uniqueness of execution; compliance of manufacturing technology with ecological criteria. At this stage, students familiarized themselves with the types of eco-bags with decoration (formation of a bank of ideas) (Fig. 4), the technology of their creation, determined the time and resources needed to complete the project.

To achieve aesthetic goals, special attention in the analysis of prototype models is given to style, distinguishing characteristic features and execution of product sketches. Students noted the elements of shape, size, decoration and additional details of the composition.

The material of the product is used jeans, made of dense fabric, which has good operational properties and good appearance. Equipment and materials are selected for sewing the bag (sewing machine, needles, threads, scissors, etc.), for the artistic decoration of the product - ribbons for embroidery, beads, scraps of fabric, muslin, iris (to choose according to the model).

The technological stage of creating an eco-bag is a creative process from the manufacture of basic parts to decoration, where creative and technological skills are used. We have determined the technological sequence of sewing an eco-bag according to a certain algorithm: cutting off the worn bottom of jeans and cutting out the front and back panels; folding panels face to face and equalizing the width; stitching of all sections, cutting out the lining and its processing; sewing the patch pocket to the lining; sewing the side corners of the bag; making and covering bag handles; artistic decoration of the bag; connection of the lining with the main fabric.

During the defense of creative projects, students emphasized that the eco-bag is an ergonomic, ecological, technologically powerful, and original work. They also highlighted that upcycling is an accessible activity providing an opportunity to showcase and realize oneself as a creative person.



Fig. 4. Creating a bank of ideas.



Fig. 5. Artistic decoration of the product: a – ribbon embroidery, b – patchwork decoration, c – smooth embroidery.

Errors made by students in the design, manufacture, and decoration of products were identified and analyzed. These included issues such as disproportionality and excessive complexity of elements in form and composition, unsuccessful placement of additional and decorative parts, misalignment of the composition center, violation of proportions between main and secondary elements, and oversaturation of the product surface with decorative elements, among others.

Eco-bags of female students of specialty 014.10 Secondary education (Labor training and technologies) using upcycling technology are presented in Fig. 5.

The achievements of project participants were determined in relation to: the use of physical, technological, operational, and aesthetic properties of materials; ecologically responsible consumption of things; precise technological production and artistic design of products; compliance with the decoration of the product to its functional purpose; creative novelty and development of style; use of modern and regional traditions.

The analysis of the results of the implementation of eco-bag projects using the upcycling technology allows us to draw the following conclusions: the quality indicators (QI) of the implementation of control measures were, respectively, in the experimental and control groups: QI = 76%, QI = 56%, which revealed a mostly high and sufficient level of knowledge acquisition and formed competences and creative abilities in the E-group and a sufficient and average level - in the K-group (Table 2). The obtained results are displayed graphically in Fig. 6.

TABLE 2 LEVELS OF STUDENTS' ACHIEVEMENTS IN DESIGNING ECO-BAGS

Groups	Achievement levels in points				QI, %	Overall success, %
	5	4	3	2		
E	44	70	35	1	76	99,3
K	26	58	56	10	56	93,3

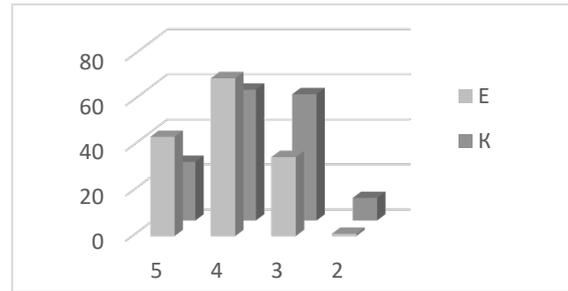


Fig. 6. Frequency diagram of grades received by students during control measures.

To confirm the reliability of the obtained results, the null hypothesis was put forward that the level of professional competences and creative abilities of future teachers formed during the design of eco-bags using the upcycling method in the control and experimental groups is the same or that the discrepancy in success is accidental and not due to the effectiveness of the experimental teaching methods.

TABLE 3 LEVELS OF PROFESSIONAL COMPETENCES AND CREATIVE ABILITIES OF STUDENTS

Groups	Levels of professional competences and creative abilities, %				Qualitative indicator, %	Quantitative indicator, %
	high	sufficient	average	low		
E	36	56	8	0	88	100
K	12	40	40	8	52	100

Students were previously tested to determine the levels of professional competences and creative abilities, the results of which are presented in the Table 3.

The degree of difference in success in two types of groups was assessed by the agreement Pearson χ^2 criterion. We determined the calculated ($\chi^2=22$) and permissible ($\chi_0^2=16.27$) value according to the table given in [21]. Comparison of the table value with the calculated value revealed that it is smaller. Under these conditions, the null hypothesis is rejected.

CONCLUSIONS

The pedagogical result of the effectiveness of the organizational and pedagogical conditions of the project activity on the upcycling of future teachers of labor education and technology is positive. This gives reason to assert that the introduction of eco-product manufacturing projects into the educational process is an important factor in the formation of professional competences and creative abilities of future teachers of labor education and technology, and the technology of upcycling is an effective means of involving future teachers in project activities in the teaching of technologies of students of primary and secondary schools.

We correlated the stages of students' creative activity according to the requirements of project technology (organizational-preparatory, design, technological, final), during which we observed, studied, designed and adjusted the educational process.

It has been established that upcycling as a processing technology is an effective means of forming the personality of future teachers of labor education and technology, when they develop the abilities of creative, technological and ecological thinking and problem solving. An important aspect of increasing the efficiency of this process is the involvement of social network services, which ensures educational mobility, group cooperation of teachers and students, active communication, discussion and teamwork of participants.

A special factor of effective activity using upcycling technology is the combination of information and communication technologies and handmade, which allows students to use the acquired knowledge, demonstrate technological abilities, and demonstrate creative abilities in the manufacture of eco-bags.

The upcycling of eco-bags reflects the idea of the integrity of the pedagogical process as a system of universal values, humanization, a person-oriented approach, and the priority of subject-subject relations. We have determined the main features of the process of designing eco-bags using upcycling technology - interdisciplinary, communicative and dynamism through the use of information services of social networks, environmental friendliness under the conditions of recycling of secondary raw materials; creative and practical activities that can be provided under certain organizational and pedagogical conditions.

ACKNOWLEDGMENTS

We express our sincere gratitude to the staff of Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University for providing the opportunity to conduct research on the educational process using innovative technologies. We envision further exploration in the development of distance learning methods, with a focus on enhancing the teacher's information and communication competence in upcycling technology. Additionally, we aim to involve student youth in participating in clubs, studios, sections, electives, exhibitions of creative works, and other related activities.

REFERENCES

- [1] Concept "New Ukrainian School" [Kontsepsiia "Nova Ukrainska shkola"]. [Online]. Available: <https://osvita.ua/doc/files/news/520/52062/new-school.pdf> [Accessed: Sept. 4, 2023]
- [2] S. D. Tsvilyk, I. V. Shymkova, E.Iu. Pedorenko, N. I. Tkachuk, "Methods of applying technologies of secondary processing of raw materials in the training of students of vocational education institutions" [Metodyka zastosuvannia tekhnologii vtorynnoi pererobky syrovyny v navchanni uchniv zakladiv profesiinoi osvity]. Modern scientific research: achievements, innovations and development prospects. Proceedings of the 12th International scientific and practical conference, pp. 394-401, May 22-24, 2022. [Online]. Available: <https://sci-conf.com.ua/xii-mezhdunarodnaya-nauchno-prakticheskaya-konferentsiya-modern-scientific-research-achievements-innovations-and-development-prospects-22-24-maya-2022-goda-berlin-germaniya-arhiv/> [Accessed: Sept. 22, 2023]
- [3] I.V. Shymkova, S.D. Tsvilyk, V.S. Harkushevskiy, "Modernization of professional and technological training of future teachers in the context of the development of STEAM education" [Modernizatsiia profesiinoi i tekhnolohichnoi pidhotovky maibutnikh pedahohiv u konteksti rozvytku STEAM-osvity]. Problemy pidhotovky suchasnogo vchytelia: zbirnyk naukovykh prats Umanskoho derzhavnogo pedahohichnogo universytetu imeni Pavla Tychyny. Uman, vol. 1(19), pp. 152-159, 2019.
- [4] D. Shulikin, "STEM education: preparing for innovation" [STEM-osvita: hotuvaty do innovatsii]. Osvita Ukrainy (ofitsiine vydannia Ministerstva osvity i nauky Ukrainy). № 26 (1437), pp. 8-9, 2015.
- [5] V.V. Steshenko, D.E. Kilderov, "System of special (professional) competences of a teacher of labor training and technology" [Systema spetsialnykh (fakhovykh) kompetentnosti vchytelia trudovoho navchannia ta tekhnolohii]. Naukovyi chasopys natsionalnogo pedahohichnogo universytetu im. M.P. Drahomanova. Seria №13. Problemy trudovoi ta profesiinoi pidhotovky: zb. nauk. prats. K.: Vyd-vo NPU im. Drahomanova. Vol. 8, pp. 99-105, 2017.
- [6] A.M. Hedzyk, et al. "Competency approach in professional training of future technology teachers" [Kompetentnisnyi pidkhid u profesiinii pidhotovtsi maibutnikh uchyteliv tekhnolohii]: kolektyvna monohr. Uman: Vydavets «Sotsynskiy M. M.», pp. 280, 2017.
- [7] V. Sydorenko, "Essential characteristics of professional competence. Labor training in educational institutions" [Sutnisni kharakterystyky profesiinoi kompetentnosti]. Trudova pidhotovka v zakladakh osvity. № 5. pp. 3-7. 2010.
- [8] S.I. Tkachuk, "Teoriia i metodyka pidhotovky maibutnogo vchytelia trudovoho navchannia do formuvannia v uchniv tekhnolohichnoi kultury" [The theory and methodology of training the future teacher of labor education for the formation of technological culture in students]: The theory and methodology of training the future teacher of labor education for the formation of technological culture in students. Kyiv. p. 38, 2012.
- [9] "State standard of complete general secondary education" [Derzhavnyi standart povnoi zahalnoi serednoi osvity]. Postanova KМУ №898 vid 30.09.2020 r. [Online]. Available: https://osvita.ua/legislation/Ser_osv/76886/ [Accessed: Sept. 4, 2023]
- [10] V. O. Sukhomlynskyi, "Mental education and education of a teenager" [Rozumove vykhovannia i osvita pidlitka]. K.: Radianska shkola. T. 3, 1977.
- [11] O. Stepanov, "Psychological encyclopedia" [Psykholohichna entsyklopediia]. K.: Akademydav, p. 424, 2006.
- [12] V. H. Kremen, "Transformations of personality in the educational space of modern civilization" [Transformatsii osobystosti v osvitnomu prostori suchasnoi tsyvilizatsii]. Pedahohika i psykholohiia. №2 (59), pp. 5-14, 2008.
- [13] S. O. Sysoieva, "The basics of pedagogical creativity" [Osnovy pedahohichnoi tvorchosti]: pidruchnyk. Kyiv: Milenium, p. 346, 2006.
- [14] "Creative personality is the main goal of education" [Tvorchia osobystist – holovna meta vykhovannia]. [Online]. Available: <https://osvita.ua/school/method/upbring/1476/> [Accessed: Sept. 4, 2023]
- [15] Yu. M. Koptila, "Development of a student's creative personality in the modern educational space of a general secondary education institution" [Rozvytok tvorchoi osobystosti uchnia v suchasnomu osvitnomu prostori zakladu zahalnoi serednoi osvity] [Online]. Available: https://www.narodnaosvita.kiev.ua/?page_id=5810 [Accessed: Sept. 22, 2023]
- [16] N.V. Chuprin, M.B. Susuk, "Upcycling and its definition as a direction of eco-design in the modern fashion industry" [Apsaiklinh ta yoho vyznachennia yak napriamu ekodyzainu v suchasniyi industrii mody]. Visnyk Kharkivskoi derzhavnoi akademii dyzainu i mystetstv. № 3, pp. 38-41, 2014.
- [17] Gardiner Beth, "Upcycling Evolves From Recycling". Energy & Environment. November, 2010. [Online]. Available: <https://www.nytimes.com/2010/11/04/business/energy-environment/04iht-rbogup.html> [Accessed: Sept. 4, 2023]
- [18] McMurdo Max, "The upside to upcycling". Environment Journal. February, 2017. URL: <https://environmentjournal.online/waste/the-upside-to-upcycling/> [Accessed: Sept. 4, 2023]
- [19] L. O. Chystiakova, "Ecoculture of future teachers of labor education and technology: theory and practice" [Ekokultura

maibutnikh uchyteliv trudovoho navchannia ta tekhnolohii: teoriia i praktyka]. Dnipro: Seredniak T. K., p. 372, 2020.

- [20] H. V. Varkholyk, "Education of student youth in the context of ecological culture" [Vykhovannia studentskoi molodi v konteksti ekolohichnoi kultury]. Mizhnarodnyi naukovyi visnyk. №2 (9).

Uzhhorod, pp. 324–331, 2014.

- [21] P. M. Volovyk, "Probability theory and mathematical statistics in pedagogy" [Teoriia imovirnosti i matematychna statystyka v pedahohitsi]. Kyiv: Radianska shkola, 1969.

Multimedia Technologies as Tools for Fostering Digital Literacy in Education

Nataliia Sorokolit

Department of Theory and Methods
of Physical Culture
Ivan Bobersky Lviv State University
of Physical Culture
Lviv, Ukraine
sorokolit21@gmail.com

Olha Rymar

Department of Theory and Methods
of Physical Culture
Ivan Bobersky Lviv State University
of Physical Culture
Lviv, Ukraine
okopiy@ukr.net

Ivanna Bodnar

Department of Theory and Methods
of Physical Culture
Ivan Bobersky Lviv State University
of Physical Culture
Lviv, Ukraine
ivannabodnar@ukr.net

Olena Khanikiants

Department of Theory and Methods
of Physical Culture
Ivan Bobersky Lviv State University
of Physical Culture
Lviv, Ukraine
olena07lviv@gmail.com

Alla Solovey

Department of Theory and Methods
of Physical Culture
Ivan Bobersky Lviv State University
of Physical Culture
Lviv, Ukraine
alla_sol@ukr.net

Abstract. This study explores the integration of multimedia technologies into the educational landscape of physical education in Ukraine, considering various forms of education such as face-to-face, mixed, and distance learning, especially under martial law.

The purpose of the study is to reveal the attitude of physical education teachers towards the use of MT during physical education, to determine the level of digital literacy of physical education specialists and to outline the ways to improve it.

Methodology involves analysis and synthesis of literary sources, surveys conducted among physical education teachers using Google Forms, mathematical data processing, and a pedagogical experiment. Survey results underscore the necessity of integrating multimedia technologies into physical education, with most teachers acknowledging their positive impact on teaching quality but expressing a need for enhanced digital skills. The observed digital literacy level aligns with the basic standard, prompting the development of a program utilizing multimedia technologies to shape the digital literacy of physical education teachers.

Digital literacy evaluation employs the Digital Competence Framework for Citizens rooted in UNESCO documents, categorizing competence levels as basic, independent, and professional. The resultant program for nurturing digital literacy among physical education teachers comprises theoretical-organizational, operational, methodical, and assessment components. Experimental testing confirms the program's efficacy, revealing an improvement in digital literacy from basic to independent user levels and, in some cases, professional competence.

In conclusion, this research highlights the positive impact of the program on enhancing the knowledge, skills, and professional aptitude of physical education teachers, poised to improve the effectiveness of physical education in Ukraine and address contemporary educational challenges. Furthermore, the program serves as a foundational framework for advancing multimedia support in the field.

Keywords: digital literacy, multimedia technologies, physical education.

I. INTRODUCTION

Multimedia technologies (MT) in education are one of the promising directions in informatization of educational process. They integrate powerful educational resources that are able to support an educational environment for the formation and development of key competencies, which primarily include information and communication ones.

MT are a system of complex interaction of visual and audio effects under the guidance of interactive software using modern digital technical and software tools. They combine text, sound, graphics, photos, videos, etc. into a single digital representation.

The application of MT in educational process has a number of advantages, namely visualisation and formation of higher interest in learning. Lessons using MT allow you to visually demonstrate the capabilities of software and save time by intensifying the study of

Print ISSN 1691-5402
Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8077>

© 2024 Nataliia Sorokolit, Olha Rymar, Ivanna Bodnar, Olena Khanikiants, Alla Solovey.
Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

educational material, as well as to strengthen the motivation of students and boost their cognitive activity through interactivity.

Ukrainian and foreign scientists have paid considerable attention in their scientific research to the problems of using MT, digital applications, and multimedia programmes in educational process lately. Scientists considered the conditions for the formation of digital literacy of a teacher in postgraduate studies [1], created an ICT model of a teacher [2], made methodological guidelines for information and communication competence of students [3] and searched for ways of their implementation [4], researched the framework of digital competences of teachers [6], [7], [8], the formation of digital competence in education [9], [10], [11], [12], the development of a valid toolkit for measuring the informational and communicative competence of primary school teachers [13], considered the structure of digital competences [14], as well as the relationship between a role model process and digital literacy of physical education teachers [15]. Despite such significant interest of Ukrainian and foreign scientists in the problem of using MT and digital applications in educational process, we believe that the issue of using various multimedia technologies, programmes and applications in physical education is not covered enough. A number of contradictions have arisen that require an urgent solution. These include contradictions between today's requirements for application of MT and devices into the practice of physical education and the digital literacy of modern teachers; between the need to introduce digital literacy during professional development courses and the desire of teachers themselves to increase their own level of mastery of MT; between the digitalization of Ukrainian society and the material and technical provision of physical education in secondary education institutions, which have enabled to formulate the purpose of this study.

The purpose of the study is to reveal the attitude of physical education teachers towards the use of MT during physical education, to determine the level of digital literacy of physical education specialists and to outline the ways to improve it.

II. MATERIALS AND METHODS

The research was conducted during 2022-2023. The level of digital literacy of physical education teachers was studied and the effectiveness of the application of the special course on the formation of digital literacy within retraining programme was experimentally verified.

The following methods of scientific research were applied: analysis and generalization of literary sources, surveys of physical education teachers, a pedagogical experiment and methods of mathematical processing of research results. The analysis and generalization of literary sources made it possible to reveal the arsenal of multimedia technologies used in education. The surveys of 248 physical education teachers revealed the peculiarities of the use of MT in educational process of physical education, the advantages and difficulties of their application in this domain were highlighted. The

pedagogical experiment included ascertaining and formative parts. During the ascertaining part, on the basis of entrance testing, the levels of digital literacy of teachers were determined in accordance with the European Digital Competence Framework (DigComp 2.1) for teachers. The formative part was aimed at increasing the level of digital literacy of physical education teachers after applying the authorial programme methods. The experimental testing helped to monitor the digital literacy of teachers during the experiment using mathematical calculations and to determine the effectiveness of the authorial programme.

Fifty-one physical education teachers of secondary schools took part in the pedagogical experiment.

III. RESULTS AND DISCUSSION

Currently, the Ministry of Youth and Sports of Ukraine develops a separate digital direction. As a result sports startups have begun to be actively implemented, for example "RunAn" (a sports tracker that allows you to reduce injuries and increase the efficiency of running, due to the control of running technique); "Gymcerebrum" (AI platform with unique computer vision, which is to function in a fitness club as a virtual trainer); "TenniRobo" (an innovative table tennis robot that functions as a professional coach controlled by a mobile application); "12Climb" (an interactive climbing wall with thousands of tracks controlled by a smartphone, as well as an application with the ability to track your training); "Real Talk Sport" (CRM web-system for administration of martial arts competitions and activities of sports federations); "Unior F" (sports platform for children, schools and scouts) [16].

Digital transformation in the field of physical education and sports in the world and in Ukraine in particular is implemented through a variety of software (mobile) applications that allow you to monitor the number of calories consumed, daily routine, training, calculate total physical activity during the day, thus creating the optimal content of training and activities taking into account the individual characteristics and needs of a specific person on the basis of the data obtained ("Runtastic", "Heart Graph", Google Fit, "Yoga Breathing Exercises", "HealthKit", "Yazio Calorie Counter", "MyFitnessPal", "Fatsecret, Dialife", "Fitbit", "RunKeeper", "Endomondo Sport Tracker", "Health", etc.).

Based on the Internet sources analysis, N. Grabyk and I. Grubar [17] found out that the most common multimedia resources used by physical education teachers during the lessons are:

- application programmes (MS Word, MS PowerPoint, MS Excel, web browsers, cloud technology tools);
- web servers for creating interactive tests, quizzes, discussions, surveys, educational games: LearningApps, StudyStack, EDpuzzle, Kahoot, Quizziz, Quizalize, Triventy, Plickers, Google Form, Mentimeter, ClassMarker, Master test;

– means of electronic synchronous (chats, messengers, video conferences) and asynchronous (e-mail, forums, educational groups in social networks) communication (Zoom, Google Meet, Google Classrooms, ClassDojo, Skype, Instagram, Facebook, Telegram, Viber and others);

– online learning platforms (Prometheus, Educational Era, “Na Urok”, “Osvitioria”, “Vseosvita”, LearningApps.org) that allows to get informal education, master modern trends and news, without spending excessive resources;

– software (mobile) applications intended for monitoring: daily activity (number of steps, speed, distance covered, etc.), heart rate, breathing, energy expenditure (Google Fit, Health, HealthKit, Nike Plus Running, MyFitnessPal, Samsung Health, Fitbit, RunKeeper, Endomondo Sport Tracker, Runtastic); physical condition (“Digifit i Cardio”, “Heart Graph”, “Google fit”, “Yoga Breathing Exercises”, “Breathe”, “BackExercises”); body water balance (Waterbalance, Watercheck, Water Drink Reminder, Water Your Body, Watermania, Hydro, WaterLogged); body weight, calorie content of foods, a balanced diet (Calorie table, Lifesum, Fatsecret, Myfitnesspal (Calorie Counter), Yazio Calorie Counter, Dialife, LoseIt, Eat Slower);

– video motion analysis systems and complex computer simulator complexes for tracking and capturing movements (Expert Vision Analysis, Motion Analysis Corp., Vicon, Oxford Metrics CODA, Charnwood Dynamics, BioVideo, Kinovea, Dartfish);

– web servers for creating multimedia posters (Thinglink, Glogster);

– web servers for creating memory cards, mind maps (Mindomo, Mindmeister, Spiderscribe);

– web platforms for creating animated videos, interactive infographics, presentations and video scribing (Powtoon.com, SparkolVideoScribe, PearDeck, Nearpod).

I. Vorotnikova notes that each of these levels is considered according to 5 aspects: understanding of MT in educational policy, curriculum and assessment, pedagogy, application of digital skills, organization and management, and professional training of teachers [1].

For the citizens of Ukraine European framework of digital competences is used as the basis for the formation of knowledge, abilities and skills in the use of MT in education. This tool is designed to improve digital literacy. This framework was adapted by Ukrainian experts and is based on the relevant The Digital Competence Framework for Citizens of the European Union (DigComp 2.1) and other recommendations on the formation of digital literacy from European and international institutions. The recommendations are adapted to the national, cultural, educational and economic characteristics of Ukraine (Table 1).

TABLE 1 CHARACTERISTICS OF DIGITAL LITERACY LEVELS CATEGORIES OF THE TEACHER

Category	Characteristics	Short description
Beginner (A1)	Awareness (knowledge acquisition level)	Understanding of basic concepts and terms related to multimedia and digital technologies. Ability to use simple programmes and applications. Ability to perform basic tasks on the Internet
Explorer (A2)	Exploration (knowledge acquisition level)	Ability to use various programmes and services. Ability to find and evaluate information on the Internet
Integrator (B1)	Integration (knowledge deepening level)	Ability to work with a huge amount of information. Ability to use specialized programmes and tools. Understanding the principles of Internet security
Expert (B2)	Expertise (knowledge deepening level)	Thorough understanding of digital technologies and their capabilities. Ability to solve complex tasks and problems using MT. Ability to analyze and critically evaluate information
Leader (C1)	Government and Management (knowledge creation level)	Ability to design and implement innovative solutions. Ability to promote digital transformation in education. Leadership in the digital environment
Innovator (C2)	Innovations (knowledge creation level)	Deep knowledge in specific areas of digital technologies. Ability to solve complex tasks and problems in education using multimedia and digital technologies. Ability to teach others

The survey of physical education teachers makes it possible to assert that the introduction of MT in physical education is essential. Most survey participants have positive attitude towards the use of MT: 30.0% of teachers have been using MT for the last three years; 34.6% of teachers use them systematically in a remote mode and occasionally in a face-to-face mode; 81.22% of the surveyed teachers note that MT allow students to immerse themselves more deeply in the educational material; 75.49% are convinced that MT increase the quality of the lesson; 45.6% of teachers indicate that they need training on improving digital skills. In addition, 47.6% note that professional development courses allow to increase your own level of digital literacy. That data became the basis for developing a special course for the formation of digital literacy within the retraining course programme, which comprises theoretical-organizational, operational, methodical, and a control block for assessing training effectiveness (Fig. 1).

Before the introduction of the retraining programme on the formation of digital literacy, we offered physical education teachers to evaluate their own level of MT proficiency.

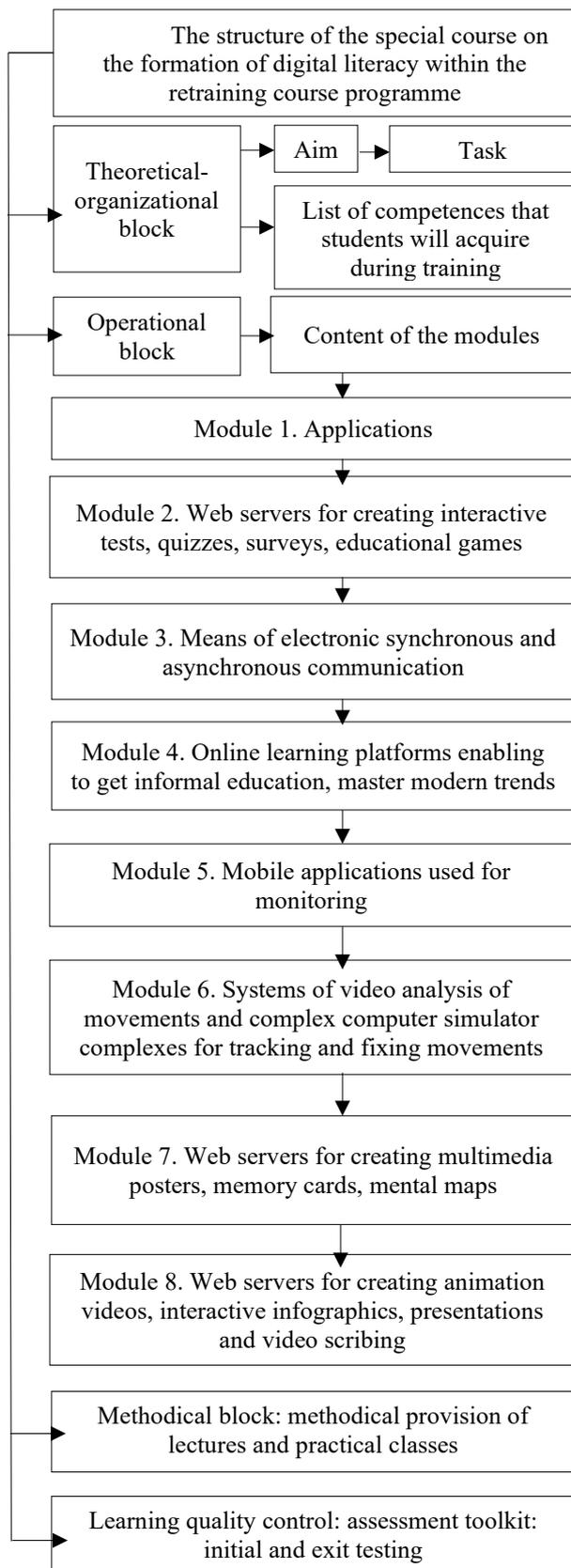


Fig. 1. Schematic representation of the special course within the retraining course programme.

It was established that before the start of the training courses, 20.5% of teachers believed that they knew no more than how to use digital applications during a physical education lesson. They realize that the use of MT

and devices during a physical education lesson can positively affect the improvement of pedagogical and professional practice. However, they do not have the practice of introducing multimedia devices in classes, and mainly use text editors to prepare the lesson, which help them to ensure organizational communications. To improve their own digital literacy skills, they need guidance and encouragement to expand their knowledge and skills and apply them in their own teaching experience. Such characteristics correspond to the first level of digital literacy “Beginner” (A1).

It was also found out that 26.9% of the teachers at the courses were not only aware of the potential of MT, but were also interested in studying digital applications to improve pedagogical and professional practice. They claimed that they sometimes used MT, devices and applications during physical education lessons, but with no systematic and consistent approach. They are convinced that they need motivation to master MT and encouragement, understanding and inspiration. To deepen digital literacy, they need the example of colleagues, involvement in the exchange of practical experience. Such characteristics indicate that 26.9% of physical education teachers defined their own level as “Explorer” (A2), which corresponds to the second level of digital literacy.

A slightly higher percentage (38.2%) of the teachers stated they were able to experiment with various MT to achieve different goals of physical education and introduce digital devices into their professional activities. They creatively use them for effective professional activity. They seek to increase the number of IT tools and their practical usage. However, they are still trying to determine which tools work best in different pedagogical situations, trying to generalize which MT contribute to the implementation of various pedagogical strategies and methods. However, they complain about the lack of time for experimentation. These characteristics indicate that almost every third participant of the courses considered his/her own level of digital literacy as “Integrator” (B1), because compared to others, they possess a level of in-depth knowledge and are able to search and experiment with the necessary digital information.

For 6.4% of physical education teachers claimed there is no difficulty to confidently use MT during various forms of physical education. They creatively and critically raise the level of their professional use by recording their own videos and placing them on the Internet. They purposefully select MT for specific situations, determine the advantages and disadvantages of various digital strategies. However, they are open to new ideas, knowing that they have not yet tried many things. They use experiments as a means of expanding, structuring and consolidating a list of their own pedagogical practice. Since all innovations, including digital applications, are the main driving force in the organization of the educational process for them, they are open to the introduction of innovative practices into their own pedagogical experience. These indicate that 6.4% of the course participants are believed to have digital

literacy at the fourth level of competence (“Expert” (B2)).

It was established that 5.2% of physical education teachers stated they mentor other teachers and willingly share knowledge and practical skills of using MT in the physical education of students with their colleagues. They have a consistent and integrated approach to the use of MT to increase the level of professionalism, and they are confident that they have a wide range of digital strategies from which they know how to choose the most suitable ones for a specific situation. They are constantly analyzing, synthesizing and implementing new digital practices, organizing the exchange of ideas with colleagues, constantly inform about new events, ideas, resources. They are convinced that they are a source of inspiration for those to whom they impart their knowledge. This characteristic corresponds to the fifth level of digital literacy (“Leader” (C1)).

A small percentage of teachers (2.8%) are said to question the adequacy of modern digital pedagogical practices and the possibility of their use during the physical education lesson, although they themselves are leaders. They are concerned about the limitations or shortcomings of these practices and are open to innovation to improve resources and tools. They note that they are in a systematic search for new digital applications, constantly experimenting with highly innovative and complex MT. They claim that a large number of colleagues take an example from them. This characteristic corresponds to the highest level of mastery of MT (“Innovator” (C2)).

The introduction of the special course within the retraining programme has contributed to improving the level of digital literacy of teachers, updating their skills and providing access to current IT tools in the educational process. After the introduction of the programme, each of the levels of digital literacy has undergone significant changes. In particular, the “Beginner” level got decreased by 18.1%, while the indicators of other levels of MT proficiency have improved significantly: “Explorer” - by 8.5%; “Integrator” - by 5.9%; “Expert” - by 4.1%; “Leader” - by 2.4%, which proves the effectiveness of our programme (Fig. 2).

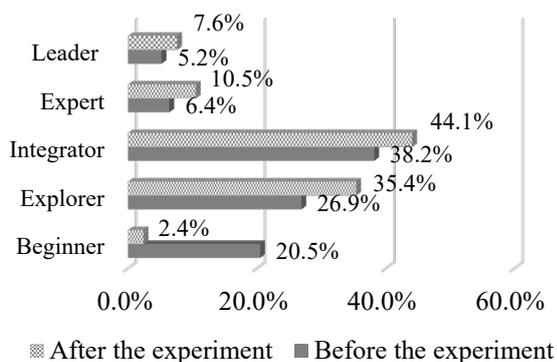


Fig. 2. Dynamics of changes in the digital literacy levels of physical education teachers during the experiment.

IV. CONCLUSIONS

The conducted research makes it possible to state that the problem of MT introduction in education is an important and urgent issue. The positive attitude of physical education teachers to the use of MT, programmes and digital applications in physical education was established. Respondents claim that over the past three years they have started to use MT more often in their own pedagogical practice (30.0% of teachers have been using MT over the past three years; 34.6% of teachers use it systematically in a remote mode and occasionally in a face-to-face mode of learning; 81.22% of the surveyed teachers note that MT allows students to immerse themselves more deeply in the educational material; 75.49% are convinced that MTs increase the quality of the lesson; 45.6% of teachers indicate that they need training on improving digital skills. In addition, 47.6% note that advanced training courses allow them to improve their own level of literacy. Our designed programme of the special retraining course on the formation of digital literacy significantly improved the level of mastery of MT, programmes and digital applications. All levels of the Digital Literacy Framework, except for the “Beginner” level, have increased. The “Beginner” level decreased by 18.1%. Other levels indicators improved as follows: “Explorer” by 8.5%, “Integrator” by 5.9%, “Expert” by 4.1%, and “Leader” by 2.4%, which proves the effectiveness of our program.

REFERENCES

- [1] I. P. Vorotnikova, "Conditions for the formation of a teacher's digital competence in postgraduate education, " in Open educational e-environment of modern University, Vol. 6, 2019, pp. 101-118.
- [2] N. V. Morse and I. P. Vorotnikova, "ICT model of teachers' competence, " in ScienceRise: Pedagogical Education, Vol. 10 (6), 2016, pp. 4-9.
- [3] O. V. Ovcharuk, "The Digital Competence Framework for Citizens: A European Strategy for Determining the Level of Digital Competence, " in Pedagogy and psychology. Bulletin of the National Academy of Pedagogical Sciences of Ukraine, Vol. 1(98), 2018, pp. 31-38.
- [4] N. S. Sorokolit, "Methodical methods of formation of informational and communicative competence of students by means of physical education, " in Actual issues of physical culture, sports and ergometry: coll. theses III International science and sport cong. Chernivtsi National University named after Yu. Fedkovicha, Chernivtsi, 2019, pp. 36–38.
- [5] N. S. Sorokolit, "Ways of implementing mathematical and informational and communicative competences in physical education of schoolchildren, " in Innovative pedagogy, Vol. 44(3), 2022, pp. 54-57. DOI: <https://doi.org/10.32843/2663-6085/2022/44/3.11>
- [6] DigComp 2.1: The Digital Competence Framework for Citizens, Update Phase 1: the Conceptual Reference Model, Luxembourg: Publications Office of the European Union, 2017. DOI:10.2760/38842. [Online]. Available: [http://publications.jrc.ec.europa.eu/repository/bitstream/JRC106281/web-digcomp2.1pdf_\(online\).pdf](http://publications.jrc.ec.europa.eu/repository/bitstream/JRC106281/web-digcomp2.1pdf_(online).pdf) [Accessed: Aug. 18, 2023].
- [7] M. Kelentrić, K. Helland and A. T. Arstorp, "Professional Digital Competence Framework for Teachers in Norway, " [Online]. Available: <https://www.udir.no/in-english/professional-digital-competence-framework-for-teacher> [Accessed: 13 Apr. 2023].

- [8] S. Kluzer, L. P. Priego, DigComp into action: Get inspired, make it happen. A user guide to the European Digital Competence Framework. Joint Research Centre (Seville site), 2018. DOI : [10.2760/112945](https://doi.org/10.2760/112945)
- [9] R. J. Krumsvik, "Teacher educators' digital competence, " in *Scandinavian Journal of Educational Research*, Vol. 58(3), 2014, pp. 269-280.
- [10] O. Megarr, and A. Mcdonagh, "Digital Competence in Teacher Education, " [Online]. Available: https://www.researchgate.net/publication/331487411_Digital_Compentence_in_Teacher_Education [Accessed: 13 Nov. 2023].
- [11] Fanny Pettersson, "Digitally Competent School Organizations-Developing Supportive Organizational Infrastructures, " Vol. 14, 2018, pp.132-143.
- [12] L. Starkey, "A review of research exploring teacher preparation for the digital age, " in *Cambridge Journal of Education*, Vol. 50(1), 2020, pp. 37-56.
- [13] J.Tondeur, K. Aesaert, B. Pynoo, N. Fraeyman and O. Erstad, "Developing a validated instrument to measure preservice teachers' ICT competencies: Meeting the demands of the 21st century, " in *British Journal of Educational Technology*, 2016. DOI : <https://doi.org/10.1111/bjet.12380>
- [14] R. Vuorikari, Y. Punie, Gomez S. Carretero and G. Van den Brande, "DigComp 2.0: The Digital Competence Framework for Citizens. Update Phase 1: The Conceptual Reference Model, " in Luxembourg Publication Office of the European Union, 2016. DOI: [10.2791/11517](https://doi.org/10.2791/11517).
- [15] O. Wohlfart, M. Mödinger and I. Wagner, "Information and communication technologies in physical education: Exploring the association between role modeling and digital literacy, " in *European Physical Education Review*, 2023. DOI : <https://doi.org/10.1177/1356336X231193556>
- [16] Three Ukrainian sports startups received a free one-year membership subscription to The Global Sports Innovation Center powered by Microsoft. Ministry of Youth and Sports of Ukraine. [Online]. Available: [URL:https://mms.gov.ua/news/try-ukrainski-sportyvni-startapy-otrymaly-bezkoshtovno-richnu-pidpysku-nachlenstvo-uorhanizatsii-the-global-sports-innovation-center-powered-by-microsoft-gsic](https://mms.gov.ua/news/try-ukrainski-sportyvni-startapy-otrymaly-bezkoshtovno-richnu-pidpysku-nachlenstvo-uorhanizatsii-the-global-sports-innovation-center-powered-by-microsoft-gsic). [Accessed: Nov. 22, 2023].
- [17] N. Grabyk and I. Hrubyk, "The modern educational space requires a pedagogical worker to master the latest approaches based on digital technologies, to create and operate a proper high-tech and high-quality information and educational environment. Digital technologies in the training of physical education teachers, " in *Modern digital technologies and innovative teaching methods: experience, trends, " in prospects: IX International science-practice Internet Conf. (Ternopil, April 28, 2022). Ternopil: TNPU named after V. Hnatyuka, 2022, pp. 87–90.*

The Application of Process Simulation Software FlexSim in Textile Study Program

Eugenija Strazdiene, Aiste Laiskonyte
Department of Fashion Design
Vilnius University of Applied Sciences
Vilnius, Lithuania
e.strazdiene@mtf.viko.lt

Abstract. Nowadays simulation is becoming a common tool for various processes analysis, whether it is a video game, local weather forecast, or any other area of daily life. FlexSim software provides virtual environment with the ability to simulate any process with as much information as the user needs. FlexSim simulations are commonly applied in areas such as manufacturing, warehousing, distribution of goods and products, materials processing etc. The aim of this presentation is to show how FlexSim software can be integrated into textile orientated study programs and to illustrate its application possibilities in the analysis of garment production process. Also, to take measures to increase the efficiency of production flow by eliminating its bottlenecks.

Keywords: simulation software, garment manufacturing, bottlenecks, efficiency, production flows

I. INTRODUCTION

Nowadays simulation is becoming a common tool for various processes analysis, whether it's a video game, local weather forecast, or any other area of daily life. Animated scripts are usually simulated in virtual environments that correspond to a real situations, processes or data flows. FlexSim program provides virtual environment with the ability to simulate any process with as much information as the user needs FlexSim simulations are commonly applied in areas such as manufacturing [1], warehousing [2] distribution of goods and products, materials processing [3], etc. They can also be easily adapted to simulate human resource logistics, e. g. in healthcare [4] or other service areas, due to their flexible and virtual design. Often, simulation models are quite abstract, because they are projected to answer a specific question or solve a specific problem.

The aim of this presentation is to show how FlexSim software can be integrated into textile orientated study programs. Parallely to illustrate its application possibilities performing the analysis of garment

manufacturing process by taking certain measures to eliminate bottlenecks and to increase the efficiency of production flow. The presentation shows how FlexSim software can be used by educators, students, and researchers as a learning resource in the classroom, or as a research tool.

II. METHODS

Layout of manufacturing workplaces can be modelled using traditional or digital methods. Traditional methods are static, time consuming and usually lead manufacturing industries to real time problems, e.g. like unpredicted presence of bottlenecks. Meantime, FlexSim is a simulation software used to model, to visualize, and to analyze the production flow with real-time situations.

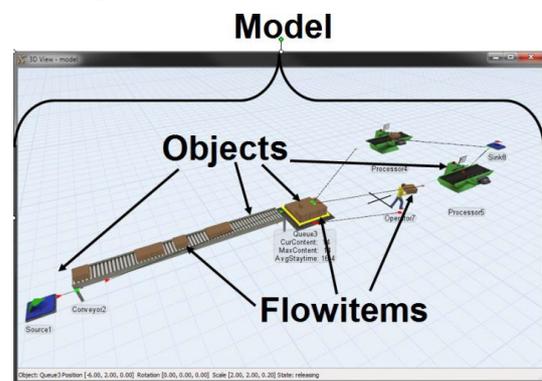


Fig. 1. The sample of FlexSim model, composed of objects, flowitems and input-output port connections [5]

FlexSim simulation model consists of objects and flowitems [5]. Objects: *Queue*, *Processor*, *Conveyor* are the basis of simulated model. They are stationary blocks with predefined attributes, variables, e.g. processing time, and visual properties. Meantime flowitems are semi-finished products that travel from one workplace to another, e.g. from one processor to the other. Objects are

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8099>

© 2024 Eugenija Strazdiene, Aiste Laiskonyte. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

also considered as fixed resources, which send and receive flowitems. For example, the *Source* introduces flowitems into the simulation model, the *Queue* stores them; the *Processor* processes and at the end flowitems leave the model through the *Sink* (Fig. 1).

Specific parameters must set for each fixed resource. In this case of garment manufacturing process for the *Source* ‘arrival schedule’ style was selected and it was indicated that semi-products of all 800 garments were provided at the start of production (Fig. 2a). For *Queue*, which in real garment manufacturing production represents trolley, maximum capacity was limited up to 800 garments (Fig. 2b) and for each *Processor* individual processing times were set, e.g. 138 seconds (Fig. 2c).

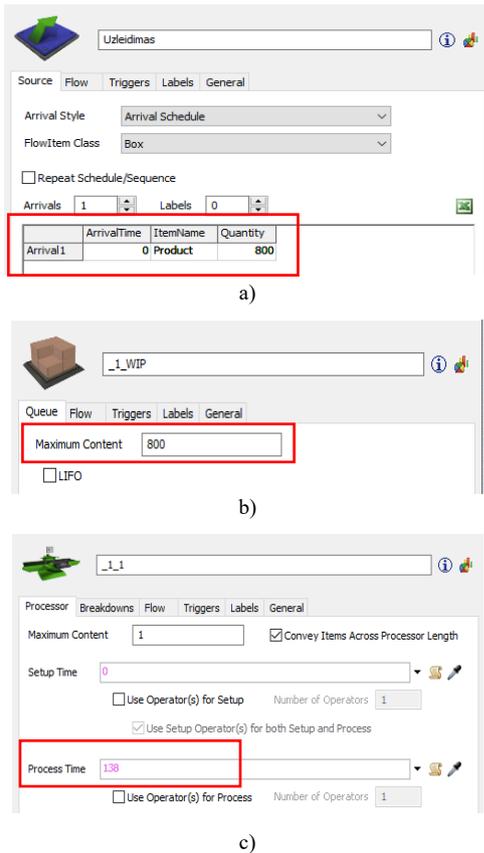


Fig. 2. Configuration of fixed resources: a) *Source*; b) *Queue* and c) *Processor*

At the start for training and aiming to provide initial skills to work with FlexSim software simple tasks with little number of objects and flowitems are provided for students. For example, it may be the task related to the efficiency of customer service in the store, e.g. buyers arrive every 120 s and only 25 buyers can wait in line at the store at the same time. There are two cash registers with a service time of 45 s each, the store's working hours are 8 h (28800 s). Unserved customers are directed away (Fig. 3). At the second step of training the task becomes more complex in such a way that it is necessary to find means and to model new situation so that there would be no unserved buyers.

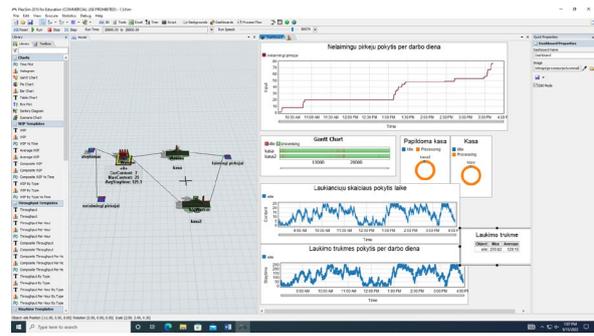


Fig. 3. The sample of FlexSim model, composed of objects, flowitems and input-output port connections

By modelling and simulating the above-mentioned situations, students simultaneously learn to use the analysis tools integrated in the software, i.e. various forms of graphs and charts that illustrate system changes in real time (Fig. 3). After acquiring initial knowledge and skills in Flexim, the students are moving towards more complex tasks. In this case - the analysis of the garment manufacturing process, which is described in the next section.

III. RESULTS AND DISUSSIONS

Garment production management starts with product specification - the document, in which the information about particular garment is collected, i.e. its type, collection, season, size range, etc. Usually it includes technical sketch, brief description and specific manufacturing instructions.

The sample of a textile student work, which is presented below, started with the specification of women’s shirt-style dress: a) Technical sketch (Fig. 4), b) Description and c) Making plan (Table 1), i.e. technological sequence of shirt dress making (sewing) operations.

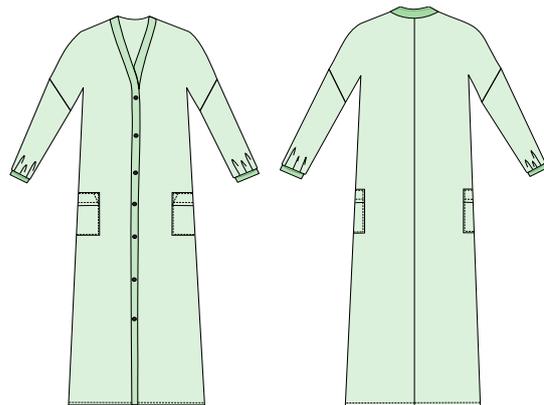


Fig. 4. Technical sketch of women’s shirt-style dress

The Description of the product is as follows: oversized shirt-style dress the length of which is below the knees. The shoulder line of the garment is lowered and soft. The dress is fastened with seven buttons. Sleeves are single-stitched, with ruffles and cuffs. On the sides of the dress there are deep pockets with decorative flaps.

TABLE 1 THE SAMPLE OF WOMEN'S SHIRT MAKING PLAN

Op. No.	Making operation description	Work type	Time t , s	Equipment
1.	to fuse cuffs, stand and collar	P*	35	ironing bar
2.	to sew cuff details together; seam width 1,0 cm	M**	364	universal sewing machine
35.
Total making time:			2365 s	

NOTE: P* - hot pressing work; M** - machine work.

In traditional textile studies garment manufacturing efficiency and production flow planning are performed on the basis of theoretical calculations the data for which is: process capacity (PC); process tact (τ); total making time of a garment ($T_{garment}$); number of employees (D). In this task process capacity PC was 800 shirt dresses per shift. Total making time of a shirt dress $T_{garment}$ was 2365 s. Duration of a work shift T_{shift} 8 hours (28800 s). Process tact τ (the average time of organizational operation) is calculated using equation (1) and the number of required employees D - using equation (2):

$$\tau = T_{shift}/PC = 28800/800 = 36s \quad (1)$$

$$D = T_{garment}/\tau = 2365/36 = 65,6, \text{ i.e. } D = 66 \quad (2)$$

During the next step 35 making operations from Making plan (Table 1) must be grouped into organizational operations so that their duration is equal to or a multiple of the tact τ , which is 36 seconds. However, to group making operations by following this rule is practically impossible. Therefore, 15% deviations from the tact are allowed for non-conveyor processes. Thus, the duration of organizational operations is calculated by considering these limits:

$$\tau_{min} = 0,85 * 36s = 31s \quad (3)$$

$$\tau_{max} = 1,15 * 36s = 41s \quad (4)$$

The sample of making plan division for 66 employees by grouping 35 making operations into 18 organisational operations is presented in Table 2.

Using synchronization chart of women's shirt production flow, it is possible to analyse theoretically the employee efficiency by comparing the compatibility of the durations of organizational operations with the tact τ of the process. The time of each organizational operation must be equal to or a multiple of τ , which is 36 s. However, due to the allowable 15% deviations, the limits of the correct time are between 31 and 41 seconds (Fig. 5). Columns marked in yellow represent workplaces with occupancy below the permitted limits, while red columns represent workplaces with occupancy above the tact τ and the permitted deviation (Fig. 5).

From this synchronization chart theoretical prediction can be made that the most problematic workplace will be no.12 as the biggest bottleneck will appear here and certain organization measures must be considered before starting the manufacturing process. Still this is theoretical assumption that by solving the problem of workplace no. 12, 800 garments will be successfully produced in one shift of 8 hours.

TABLE 2 THE SAMPLE OF ORGANISATIONAL OPERATIONS PLAN

Op. No.	Description	Time t , s	Number of employees		Employee efficiency, %
			Theoretical	Actual	
1.	1. to fuse cuffs, stand and collar	35			
	3. to iron the seam to the inside	20			
	4. to fold the top edge of the pocket by 1 cm	10			
	5. to iron the sides and bottom of the pocket by 4 cm	40			
	6. to fold the cuffs in half, to flatten another 1 cm from one edge	90			
			195	5,4	5
2.	7. Sew the sleeve piece to the base	60			
		60	1,67	2	83,3
18.
In total:		2365 s		66	

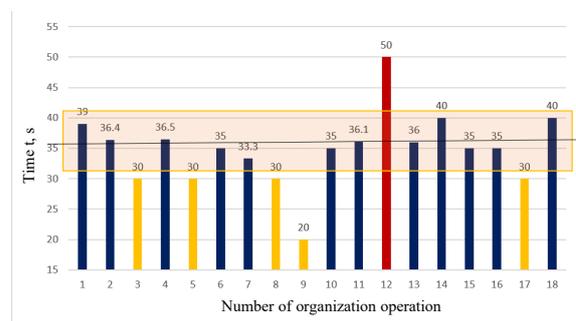


Fig. 5. Synchronization chart of women's shirt production flow

Actual situation, which was simulated by student with the help of FlexSim software, appeared to be different. The model of the process is presented in Figure 5 and it shows that after 8 hours (28800 s) only 525 shirt dresses were finished and it will take much more time to finalize the whole order of 800 garments.

Also, work efficiency graphs were generated with FlexSim simulation software, which indicate workplaces loaded at maximum during the entire shift: no.1 (100%), no.2 (92.15%), no.4 (91.56%) and no.12 (93.94%) (Fig. 6). It corresponds to theoretical data presented in synchronization graph (Fig. 5), as the time of these organizational operations exceeds process tact of 36 s. It can be also noticed that operational time at workplace no.14 and no.18 are also higher than 36 s (40 s), but their efficiency is very low due to the bottleneck at workplace no.12, because of which they were not receiving garments.

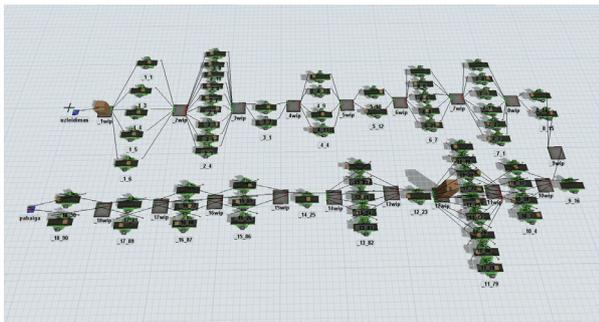


Fig. 6. FlexSim simulation model of women's shirt production flow with bottlenecks

Analysis of simulation results allowed to make the conclusion that making operations must be grouped into operational seeking to get their duration equal or a bit less than process takt τ at the very start of the production flow in order not to form bottlenecks and not to stop the work at the following workplaces. In the analysed case 60 garments were stuck at the workplace no.1 and were not started to be processed even at the end of the shift, i.e. after 8 hours. The difference between process takt τ (36 s) and operational time at workplace no.1 (39 s) is only 3 seconds, but it was enough for the bottleneck to form at the start of manufacturing process.

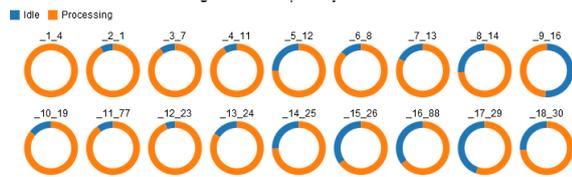


Fig. 7. Efficiency of work stations in women's shirt production line simulated by FlexSim software

The second bottleneck of 152 garments was formed at the workplace no.12 - in the ironing zone. A rational way of solving this problem is to plan a return operation, i.e. transfer part of the products to the workplace no.9, e.g. by trolleys, because this workplace is also equipped with an iron. In this way, the occupations of both workplaces would be balanced and the problem of workplace no.9 - too low work efficiency, which was only 49%, will be solved.

Thus, it is evident that virtual modelling of garment manufacturing processes and the ability to simulate them

in real time provides significant added value to the study process by developing a wider skill of students, as the knowledge of production process planning is not limited only with theoretical calculations.

IV. CONCLUSIONS

Nowadays textile and clothing companies are different in terms of innovations, knowledge generation, experience and competences. In order to accelerate the transformation of fashion industry into intelligent and digital, it is necessary to educate specialists by providing knowledge and practical skills to analyse, research and solve the problems of product development and production processes based on their digital simulation and virtualization. FlexSim software provides a powerful real-time simulation tool which makes it possible not only to check different solutions for the elimination of bottlenecks, which may appear in production flows due to the deviations in the synchronization of production operations, but also to check them through the whole virtual production period. Virtual modelling of garment manufacturing processes and the ability to simulate them in real time provides added value to the study process by developing a wider skill of students, as the knowledge of production process planning is not limited with theoretical calculations, but deepened by real time simulations.

REFERENCES

- [1] N.Y. Shivraj. Productivity Improvement in a Windows Manufacturing Layout Using FlexSim Simulation Software. *International Journal of Research in Advent Technology*, 3 (9), 86-90, 2015.
- [2] E. Szczepański, R. Jachimowski, M. Izdebski, I. Jacyna-Golda. Warehouse Location Problem in Supply Chain Designing: a Simulation Analysis. *Archives of Transport*, 50 (2), 101-110, 2019.
- [3] W. Shuangping, X. Anjun, S. Wei, L. Xiuping. Structural Optimization of the Production Process in Steel Plants Based on FlexSim Simulation. *Steel Research International*. 90 (10), 1-21, 2020.
- [4] P. Amaliaa, N. Cahyatia. Queue Analysis of Public Healthcare System to Reduce Waiting Time Using FlexSim 6.0 Software. *International Journal of Industrial Optimization*. 1 (2), 101-110, 2020.
- [5] FlexSim Tutorial. Available from Internet: https://www.academia.edu/36666441/TUTORIAL_FLEXSIM [accessed 27 April 2022].

Algorithm for Implementing Quest Technologies in Research Work with Preschool and Primary School Children

Tetiana Vasiutina

Department of Primary Education
and Innovative Pedagogy
Dragomanov Ukrainian State
University, Faculty of Pedagogy,
Department of Primary Education
and Innovative Pedagogy
Kiev, Ukraine

Yulia Bondar

Department of Primary Education
Vinnytsia Mykhailo Kotsiubynskyi
State Pedagogical University
Vinnytsia, Ukraine

Liudmyla Ishchenko

Department of artistic disciplines,
preschool and elementary education
Vinnytsia Mykhailo Kotsiubynskyi
State Pedagogical University
Vinnytsia, Ukraine

Anna Khilya

Department of Primary Education
Vinnytsia Mykhailo Kotsiubynskyi
State Pedagogical University
Calp, Spain
anika.line@gmail.com

Halyna Kit

Department of Primary Education
Vinnytsia Mykhailo Kotsiubynskyi
State Pedagogical University
Vinnytsia, Ukraine

Abstract. The origin of the definition "quest" and the use of quest technologies in traditional education have been well theoretically analysed and substantiated. In particular, a quest could be a type of collective creative work, scientific/educational competitions or excursions in the traditional form of organising educational activities. However, with the transition to digital education, the implementation of quest technology has changed. It continues to be seen as a motivational tool for learning, a creative form of work in the educational programme. But, according to our observations, this type of work is declining in the online format. We will discuss the reasons for this and options for replacing quest technologies in this description.

It is worth noting that in order to achieve the goal of our study, we turned to the basic requirements for organising a Web Quest, recommendations for its design, convenience according to the age category of children, clarity of instructions, etc. The next step was to compare online education technologies that had similar characteristics to the quest (computer games, educational applications and platforms, RPGs, video quests, VR audiences, etc.) This allowed us to draw a conclusion about their common roots and concepts, as well as to understand the reasons for the decline in scientific interest in the topic of the quest itself.

After analysing the available open access publications, we concluded that this is not enough to understand the reasons

for the decline in interest in this form of online work. After all, street quests are still popular. That is why we interviewed students specialising in preschool and primary education who had the opportunity to create Web Quests and participated in them. The feedback from future specialists on the implementation of quest technology in online and offline formats directed us to describe the reasons for refusing this technology in the online format of the educational process and allowed us to confirm the list of possible substitutions for quests for the research activities of preschool and primary school students suggested above.

Keywords: higher education, preschool education, primary education quest, teacher training, WebQuest.

I. INTRODUCTION

Nowadays, there is a wide range of proposals for online activities in education that replicate, imitate or adapt the forms of traditional schoolwork in a digital format. We have seen the development of synchronous and asynchronous courses in various subjects, synchronous lectures, seminars, conferences, and video lectures that can be viewed asynchronously. In addition, we have developed training exercises in core subjects (language, mathematics) and game applications for developing mathematical or reading skills, which are relevant to primary education.

Print ISSN 1691-5402
Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8089>

© 2024 Tetiana Vasiutina, Liudmyla Ishchenko, Halyna Kit, Yulia Bondar, Anna Khilya.
Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

In vocational and higher education, we can observe a gradual shift towards teaching and learning theoretical or practice-oriented information through digital applications. This does not refer to the development of programming or digital design skills, but to professions related to the real world (mechanic, teacher, lawyer, technician for system repair or installation of solar systems, for example). All these professions require knowledge and, most importantly, systematic practical training. They also require students to be involved in practical activities in a professional environment (for a mechanic at a service station, for a teacher at a school, university or any educational institution, for a lawyer in court or a practicing lawyer's office, etc.) All of this requires time and a high-quality distribution of the load between theory and practice without losing the effectiveness of each piece of information.

That is why quest technologies have attracted our attention. They are presented as a pedagogical technology that combines the ideas of the project method, problem-based and game-based learning, teamwork, and the use of information and communication technologies to develop new forms of learning content development [1].

When using the terminology inherent in the digital world, we speak of a Web Quest, understanding that this type of quest is defined as a guided research activity in which the information used comes in whole or in part from pre-selected Internet resources that focus students' attention on using the information they analyse, synthesise and evaluate [2].

This is what prompted us to search for an answer to the question of interest and practical implementation of quest technologies in the educational process. And in particular, it led to the choice of the topic of our study: an algorithm for implementing quest technologies in research work with children of preschool and primary school age.

The purpose of the study is to theoretically develop and substantiate an algorithm for research work with preschool and primary school children using quest technologies.

II. MATERIALS AND METHODS

Based on the well-known technologies in the educational process that are effective at all levels of education, we continued to work with quest technologies, setting ourselves the following tasks

- to identify the basic requirements for the organisation of a quest, in particular a Web Quest for teacher training for this activity and in the development of a quest for preschool and primary school children.
- to analyse the advantages and weaknesses of Web Quests in comparison with quests in a real environment and other virtual environments that have similar characteristics to a quest (computer games, educational applications and platforms, RPGs, video quests, VR audiences, etc.)

Thus, at the first stage of this study, we analysed existing theoretical studies on the use of quest technologies in the online format, which, in our opinion, are the closest to implementation in preschool education and primary school.

Further, we drew an analogy with the development of quests in the real environment offered by the Ukrainian educational space. Based on the developed algorithm, we analysed the results of the work of students majoring in primary education and preschool education within the framework of the Educational Hackathon on inclusive topics.

Finally, we drew an analogy between Web Quests and analogues of quests in the digital environment.

III. RESULTS AND DISCUSSION

Thus, in the course of our work, we found out that international researchers consider Web Quests, for example:

- in terms of the impact of the methodology on learning; assessing the impact on students' attitudes and perceptions; or research on the promotion of higher order thinking and research skills [2];
- in terms of the benefits of Web Quests for learning through the development of cognitive and academic skills, facilitating access to information and increasing motivation, developing problem-solving skills, improving academic performance and logical thinking, learner-centred and discovery-based learning, contextual foreign language learning, specific scenarios for learning any subject embedded in a Web Quest framework [3];
- as such that can be designed to promote autonomous learning and literacy development, improve reading comprehension in a foreign language, help in acquiring knowledge, develop communication skills, promote efficient use of time, provide motivation to learn and enhance cooperation [4].
- as a form of ensuring the effective use of technology to create new learning opportunities and promote the achievements of primary school students [5].
- as a finished product - for example, an original app designed to combine typing exercises and interactive games for primary school children [6].

The most important part of implementing a Web Quest is that participants are actively involved in an activity, situation or problem from real life, which changes passive learning into a more constructive way of learning and allows them to access new knowledge by discovering, interpreting and building this new knowledge based on their previous understanding of the experience [3].

It is also worth noting that [7] distinguishes between

- short-term Web Quests, which, according to researchers, are better suited for individual work, have time limits of up to two meetings, and the purpose of short-term Web Quests is particularly focused on developing or using lower-level thinking skills in the area of knowledge and skills learning;
- long-term Web Quests are more often used for group work, last a maximum of several meetings, and the main goals are to develop problem-solving and critical thinking skills, allowing students to analyse knowledge and show understanding of the material by creating something that others can respond to.

This approach, in our opinion, resembles a project activity. Therefore, as we continue to explore the topic of Web Quests, we have come to its structure. Thus, the structure of the quest has the following components:

- an introduction that includes background information;
- tasks that tend to inspire;
- a network of information resources needed to complete the tasks;
- an explanation of the process that students need to go through to complete the tasks;
- the actual process of completing the quest, which includes the steps that were prescribed in the task. There is a specific sub-stage of instructions on how to organise data, i.e., queries or guidelines for completing tasks, maps or diagrams;
- evaluation, which should be clearly linked to the objectives stated in the assignment or introduction;
- conclusions. A part that is similar to the closing of a story, summarising the achievements after completing the learning process - the quest. This part may also contain some final questions for reflection and additional references for in-depth study of the topic [7], [8].

If we look at the proposed structure of a Web Quest, in particular, the task page, which contains information about what the student should do, as well as links to learning resources and materials to be mastered with the help of this task [7], we move on to an educational, search or project activity that will not meet the user's (student's) request for a quest. After all, a quest is an action game that requires research, puzzles, non-standard tasks, and manipulations that will keep you in the game.

That is why, in the 2020-2021 academic year, in the process of interaction with students majoring in "013-Primary Education" and "012-Preschool Education", we offered to work in two stages.

The first stage included the actual work of students on completing a Web Quest in the speciality Inclusive Education, which was intended to both summarise the knowledge acquired in the subject and deepen students' understanding of certain elements of accessibility of the environment, materials, administrative and human resources [9], [10]. We proposed 3 phases of the quest. The first of them took place during an online meeting where we offered information about the quest, its purpose and emphasised the importance of attention in the teacher's work, which also had a significant impact on the success of the quest. Since 13 students out of 56 did not read the conditions of the 2nd stage and had to ask for a "hint from the audience". Based on the results of the "room hint", another 6 students were identified who had skipped the second stage, which affected their overall grade (as a result of their absence during the first starting interaction). This also made it possible to assess their low activity during the second stage - the development of their own Web Quest.

The second stage included the development of their own Web Quest for primary school students as part of the Educational Hackathon, which took place in teams [11].

The results of this part of the work can be found at the corresponding link in the list of references. In addition, the audience and jury members were involved in evaluating the work of the student teams, voting anonymously. However, the results can be seen in the corresponding menu list on the Educational Hackathon website. In addition, the general results of the groups were shared in the Inclusive Education social network group, which contributed to the activity of the participants and their creative approach to the second part of the tasks.

For example, during the first stage, we gave students the opportunity to participate in a Web Quest, understand its functions and components. We explained how to create materials, and at the end of the quest, we discussed the problems and difficulties that arose and that may be difficult for primary school children. It was this discussion that was key to understanding the availability of methodological materials and allowed us to consolidate the material we had learned in our own projects at the second stage. In other words, we fulfilled the tasks of the inclusive cycle disciplines and expanded the digital capabilities of students, which was in line with the issues of accessibility in the digital inclusive educational space.

Also, given such a feature of the quest as accessible sources of information and links prepared by the teacher as a facilitator of the process, we have two main advantages - students save time searching for the information they need [3] and in the game content we can check the quality of assimilation and understanding of the information offered for study. This is what we talked about above.

In our opinion, other forms of quests used in various fields are also interesting. For example, we can mention CS50 PuzzleDay, which is held annually and is being worked on by the course team, which updates the content and looks for new interesting questions and forms of interaction, expanding the range of participants through the introduction of new projects and training around the world. This project is about programming, but it gives you the opportunity to expand your knowledge on other topics that become "inspirations" for developers and help you understand the essence of Web Quests in their specific form and natural environment.

An example of a Ukrainian Web Quest was the Museum in the Dark in Kyiv, which until early 2022 was implemented as a project and had a free online part, during which anyone could try to test their senses for perception of information from the world around them using a laptop, computer or phone. Since 2022, the online format of the Web Quest has been unavailable, but in 2024 you will be able to use this programme for a fee. Thus, we have a good example of the functioning of a Web Quest project after its official completion. Of course, these are just two examples of Web Quests that have been developed by teams of specialists and continue to operate.

Other Web Quests offered by Ukrainian colleagues are usually highly specialised and static, which reduces their value as the information space is updated. In addition, as we have previously noted, turning a quest into a project or research activity reduces the interest in participation, particularly among children. After all, in this case, it becomes more interesting for children to take part in a quest

that takes place in the schoolyard, allowing them to run around in search of the truth and solve problems.

Also, if we go back to our process of working on Web Quests. As part of our introduction to virtual reality applications, we developed the Rat Race. It was implemented in the 2021-2022 academic year before the start of military aggression. This stage was implemented as part of the educational hackathon and participation in the Mentoring programme of the Media Literacy Workshop "New tool - new opportunities: meet AltspaceVR" 3.0! This event required serious preliminary preparation, taking into account the technical capacity of the Web Quest participants, additional testing of the functionality of transitions from room to room and buttons that launched the interaction of participants with quest questions, etc [12].

Each room of the virtual reality quest "Rat Race" contained information that students knew, but at the same time it was encrypted in the game space so that students demonstrated awareness of important aspects for inclusive education. That is why students who did not include all their senses, attitudes, and intellects found themselves on a desert island and had to return to the previous step in search of the "right" choice. In conclusion, there was a discussion of the issues raised in each room to assess the inclusion and understanding of the basic principles and provisions of inclusive education by students.

Despite the interesting experience of all three stages of Web Quests, we came to the conclusion that this type of work cannot replace the main educational process. After all, the process of creating, checking the functioning of transitions, buttons and correctness of answers is quite labour-intensive. Problems arise already at the preparation stage when choosing a form, applications and game platforms that would make the process of obtaining a quest key simple and the interaction with information intuitive.

That is why, after analysing the results of three stages of Web Quests based on the specialities of Primary and Preschool Education, we came to the conclusion that the difficulties in organising such activities in the online format remain quite serious for teachers. Therefore, in our opinion, Web Quests should not be used as the main technology in the educational process, but as a technology of non-formal education for in-depth study of a subject or profession in general. Also, given the extensive preliminary work on the implementation of Web Quests, it is worth considering this technology as a type of project or grant activity to achieve a quality result and the functioning of the development even after the project is completed. After all, high-quality Web Quests do not leave the audience indifferent and tend to be used not only by developers, but also by professionals or teachers who are interested in this topic.

In general, observing the upward trend in the market of gaming applications for computers and smartphones, we understand that such forms of interaction as computer games, educational applications and platforms, RPGs, video quests, VR audiences, etc. are quite common today. Both adults and children play these game variations of a search, research and exploration nature. Some applications are used by teachers, but often to achieve the goal of a particular topic or area of education that is relevant at a given time. For example, we can mention the applications Minecraft, Roboblocks, which are quite well-known today

and have dozens of variations in use by computer science teachers or children's clubs (non-formal education). Video quests are currently offered by non-formal education teachers to engage the audience and encourage participation in professional development programmes (individual teachers on the Na Urok platform, etc.). But, in fact, the share of educational content in such games, applications, and meetings is small, as we have previously noted, because it requires high-quality development and, most importantly, the availability of resources for its implementation from idea to implementation.

IV. CONCLUSIONS

We analysed the main aspects of Web Quests and their analogues in the digital world. It is also worth noting that we did not dive into the analogues of the digital world, as this is a separate research topic that requires an in-depth analysis of the educational component of the content. But, according to our observations, this segment of educational activity has a low interest in use among teachers. After all, for quest technologies in the distance education format, the availability of resources, time, and, in fact, the teacher's readiness to implement a complex Web Quest project on the subject matter are important. Its support from conception to implementation, support at all stages, checking the functionality, correctness of answers, and the actual functioning of the project upon completion of interaction with students.

REFERENCES

- [1] T. Trofimuk-Kyrylova, A. Karpiuk, & S. Chybyrak. 2022. Zastosuvannia kvest-tehnolohii u pidhotovtsi zdobuvachiv vyshchoi osvity (z dosvidu Volynskoho natsionalnoho universytetu imeni Lesi Ukrainky). HUMANITARNI STUDII: Istorii ta Pedahohika, (1), 140-154.
- [2] M. V. Martín, & J. Quintana. 2011. Las webquests en el ámbito universitario español. Digital Education Review, 2011, num. 19, p. 36-55.
- [3] S. M. Şahin, & M. H. Baturay. 2016. The effect of 5E-learning model supported with WebQuest media on students' achievement and satisfaction. E-learning and Digital Media, 13(3-4), 158-175.
- [4] Al-Shamisi, A. S. (2016). The effect of WebQuests on grade 11 reading comprehension and student perceptions of WebQuests. American International Journal of Contemporary Research, 6(1), 132-143.
- [5] A. L. A. B. A. Sofowora OLANIYI, A. S. Ayobami, & O. Adedjoja Gloria. 2013. Perceived Benefits and Attitude of Student Teachers to Web-Quest As a Motivational, Creative and Inquiry-Based Learning Tool in Education. In EdMedia+ Innovate Learning (pp. 2186-2193). Association for the Advancement of Computing in Education (AACE).
- [6] J. Kulbida, & B. Maguire. 2013. Print quest: a learning adventure. Learning & Teaching with Media & Technology, 474.
- [7] Y. Soepriyanto, I. N. S. Degeng, P. Setyosaric, & S. Ulfad. 2019. The Effect of Using WebQuest for Lower Order Thinking Skills. International Journal of Innovation, Creativity and Change, 5(4), 552-563.
- [8] P. B. Seitkazy, R. K. Toleubekova, A. K. Amanova, A. A. Tashetov, G. Iskakova, & S. S. Demissenova. 2016. A Web-Quest as a teaching and learning tool. International Electronic Journal of Mathematics Education, 11(10), 3537-3549.
- [9] WEB-Quest. The second stage. General questions.. https://docs.google.com/forms/d/1YcrIz_XKxL6zatdegM1fWH3r3-J1UY214tWxzLT4_t8/viewanalytics
- [10] Web-quest. The third stage. A difficult level. <https://docs.google.com/forms/d/1sW4ZectuSJJQv85tkFzXgJavFMxGtqANmO8nKeCRrV8/viewanalytics>
- [11] Educational Hackathon - spring 2021 <https://sites.google.com/vspu.edu.ua/web-quest-spring->

2021/%D0%B3%D0%BE%D0%BB%D0%BE%D0%B2%D0%BD%D0%B0-
%D1%81%D1%82%D0%BE%D1%80%D1%96%D0%BD%D0%BA%D0%B0

ENVIRONMENT. TECHNOLOGY. RESOURCES. Rezekne.
2023. Volume 2. 141-144.
<https://doi.org/10.17770/etr2023vol2.7268>

- [12] A. Khilya Basic Principles of Using Virtual and Augmented Reality Technologies in the Process of Teacher Training in Ukraine.

Atmosphere monitoring system for practical training of students pursuing degrees in environmental sciences

Maya Vatzkitcheva
UMG „St. Ivan Rilski”
Sofia, Bulgaria
mayavack@gmail.com

Plamen Savov
UMG „St. Ivan Rilski”
Sofia, Bulgaria
psavov@mgu.bg

Abstract. Issues related to preservation of the environment are among the most important global problems in the beginning of 21st century. These are central for the planet as a whole and also for each individual country, region and city. Solutions for said problems are discussed on various levels: legislative, judicial, economic and technical. Formation of professional ecological education is an essential task nowadays. In our teaching activities with students in the master’s program “Ecology and Environment Preservation” at University of Mining and Geology „St. Ivan Rilski“ we strive to ensure the necessary theoretical and practical competences of the future specialists – ecologists. In this paper, we present some major topics of the Atmosphere & Environment Course, as well as the system of practical training of students for field measurements.

Keywords: ecology, atmospheric aerosol, ecological education, ecological monitoring.

I. INTRODUCTION

The task of any educational establishment is producing qualified specialists, taught to think and ready for further self-development. Educational process is a closed system including students, faculty, government organizations and possible future employers. This system should provide the best possible conditions for theoretical and practical training of students.

Issues related to preservation of the environment and mitigation of anthropogenic impact thereon have been especially focal in recent years. Therefore, it is particularly important that the students studying in the “Ecology and Environment Preservation” course receive not only the necessary theoretical basis of knowledge, but also acquire specific practical skills. They will be able to use these skills as specialists in the field of environmental protection.

II. DEFINITIONS, TASKS AND GOALS OF ECOLOGY

Ecology – is a science studying the conditions of existence of live organisms and their correlations ad habitats. The term “ecology” (from Greek: oikos – home, logos – science) was first suggested by the German zoologist E. Hekkel.

Modern ecology combines in itself a number of fundamental sciences – biology, chemistry, physics, geography, sociology, geology, etc.

From scientific and practical point of view, ecology is divided into theoretical and applied science. Theoretical ecology deals with study of general order of life organization, and practical (applied) branch – with study of mechanisms causing destruction of biosphere by humans and search of methods for prevention of that process and for rational use of natural resources.

Impact on habitats is felt by organisms via so-called environmental factors, called ecological. Such factors include abiotic, biotic and anthropogenic. We shall discuss anthropogenic factors in more detail.

Anthropogenic factors are triggered by human activity causing impact on the environment (air pollution, water and soil contamination, soil erosion, decimation of forest and animal flora and fauna, etc.)

In view of the specifics of our course, we will discuss in more detail issues related to air pollution by aerosols.

Atmospheric air pollution should be perceived as any change of air composition and/or properties which might lead to negative impacts on human, animal or plant health.

There are two types of air pollution: innate– caused by natural processes (volcanic activity, weathering of rock formations, wind erosion of soils, smoke from wildfires, etc.); and anthropogenic – caused by human activity (power engineering, industry, transport, everyday activities, etc.).

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8069>

© 2024 Maya Vatzkitcheva, Plamen Savov. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

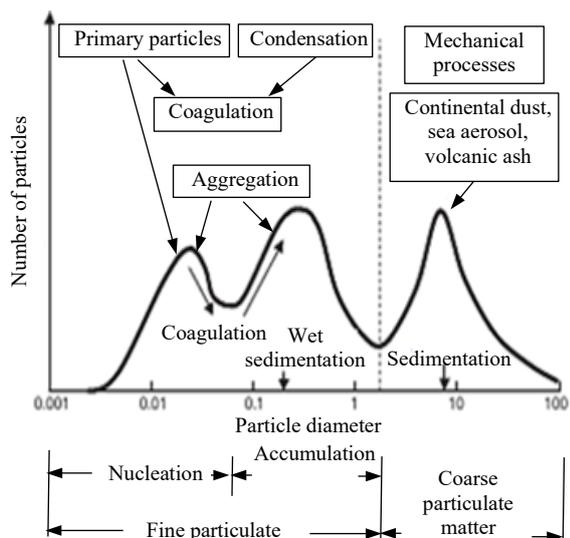


Fig. 1. Transformation processes of particles in atmosphere. Transition from fine particulate matter to coarse dispersed matter [1].

Depending on the scale of propagation these are: local, characterizing propagation of pollution in not very large areas (city, industrial zone, rural region); regional (scale of a country, island, peninsula, continent); global (affect the entire planet). According to the state of matter, harmful substances emitted to the atmosphere include: gas (sulphur, nitrogen and carbon oxides, hydrocarbons, etc.); liquid (acids, alkali, salt solutions, etc.); solid (dust of organic and inorganic origins, soot, lead and its compounds, resinous substances, etc.)

A. Main characteristics of aerosol in atmosphere

Generally, aerosols are solid or liquid admixtures suspended in gas medium. Such gas medium, in the specific case, is the atmosphere.

Aerosol particle sizes range from few nanometers (new particles created by nucleation) to hundreds of microns (particles emitted from earth surface via wind erosion or from sea and ocean surfaces). Usually, size range includes five modes: nucleation mode – where particles first emerge from gas phase; Aitken mode - named after the Scottish meteorologist John Aitken; accumulation mode - where particle mass becomes bigger via coagulation and/or condensation of particles; coarse dispersed mode – for large particles; super coarse dispersed mode – for overly large particles. Experimental observations usually record up to three modes. Nucleation and Aitken modes are clearly visible on size distribution of aerosol particles (Fig. 1). Size distribution ranges from several nm to approximately 50 nm. Accumulation mode is observed on area distribution of particles.

B. Sources of atmospheric aerosol

Air pollution sources are the places where such pollutants are emitted to the atmosphere. Pollutants are two types – innate (natural) and anthropogenic (resulting from human activity). Table I present values of annual aerosol emissions of various sources. It can be seen that the sum of all aerosol emissions on the planet per annum is approximately 5,5 bill tons.

The main source of atmospheric aerosol is the underlying planet surface. Hence, it can be of continental origins (Fig. 2), sea aerosol, urban, rural, desert, etc.

TABLE I

Annual aerosol emissions	
Source	Formation rate (10^6 t/yr)
Natural	
Primary	
Sea salt	3000
Mineral dust	1500
Volcanic dust	300
Wildfires	100
Secondary	
Sulfates	40
Nitrates	30
Hydrocarbons	20
Anthropogenic	
Primary	200
Secondary	300
Total	5490

Main source of air pollution in cities is the automobile transport. Fig. 3 presents percentage content of different fractions in exhaust gases of diesel engines, it is seen that over 40% emissions constitute carbon and its compounds, and over 30% are unused fuel and oils.

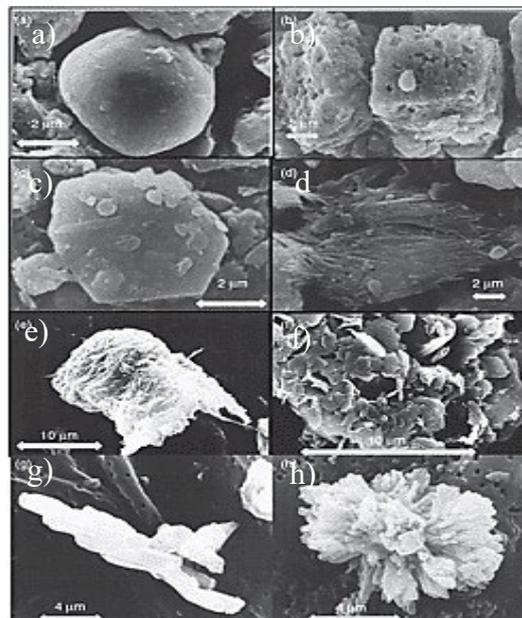


Fig. 2. Photos of particles of continental origins made by scanning electronic microscope: a – quartz; b – dolomite; c – kaolinite; d – paligorskite; e – smectite; f – ellit; g and h – gypsum [2].

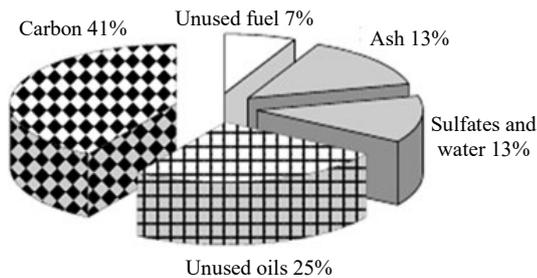


Fig. 3. Share of waste products in exhaust gases of a diesel engine [3].

C. Impact of aerosol admixtures on human health

Aerosol admixtures exert negative effect on human health depending on their concentration and chemical composition [4].

According to the definition of the World Health Organization, health is a positive state defining personality as a whole, e.g. a state of complete physical, mental and social well-being.

Fine particulate matter (FPM) affects mostly human respiratory system. Fig. 4 shows human respiratory system with its sections and the degree of penetration of aerosols of various diameters. The graph shows that the main share of the coarse dispersed matter (ca. 10 μm) is deposited in upper respiratory tract whilst mostly fine particles of diameters ca. 10 nm penetrate deep into the alveolae.

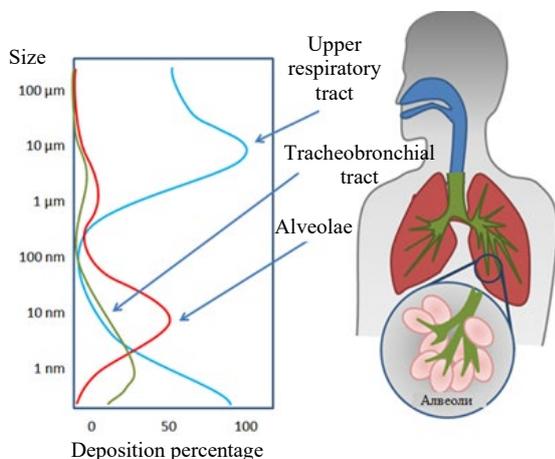


Fig. 4. Deposition percentage of aerosol particles in different sections of respiratory system during inhaling [5].

D. Ecological monitoring

One of the major activities for ecological control is the monitoring of the environment (from Latin „monitor“ – observing, reminding) which is a system of observations, assessments and prognosis of state of the environment and the degree of pollution. The main principle of monitoring is continuous observation of the core parameters of the environment.

Advanced technologies make possible creation of efficient systems for ecological monitoring with high precision measurement, quick action, low inertia of

sensors and capacity for recording large amounts of data [6].

In addition to scientific and research pursuits, said technologies (equipment and systems) should be used also for practical training of future specialists in the field of ecology. That is why we have developed such ecologic monitoring system and use it during laboratory and field experiments with students pursuing master's degree in "Ecology and Environment Preservation" at UMG „St. Ivan Rilski”.

Major instruments in the system are portable laser particle counters PC200 (TROTEC, Germany) and a multifunctional meteorological station PCE-FWS 20-1 (Fig. 5).

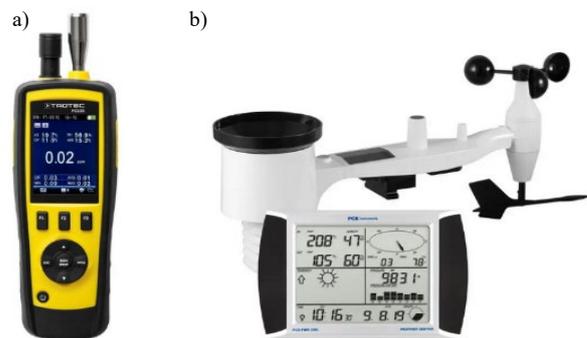


Fig. 5 Six-channel particle counter PC200 (a) and multifunctional meteorological station PCE-FWS 20-1 (b).

We use the multifunctional meteorological station for measuring wind direction and speed (with anemometer), outdoor temperature and relative air humidity (by integral thermos-hygrometer) and precipitation quantity (rain meter). Meteorological parameters are essential factor for the formation, propagation and distribution in space of fine particulate matter. Humidity influences aerosol size (especially of hygroscopic particles), and temperature and wind – generation and dispersion thereof.

There are different types of particle counters, however aerosol particle counters are used for measuring air pollution (both indoors and outdoors). They determine air quality by counting number of particles and measuring their size. The device is equipped with a small vacuum pump which draws in certain volume of air (predefined by the investigator). Particles contained in that volume pass through the ray of high energy light source – laser. Light is dissipated by the particles and registered by a photo detector. The principle of action of the particle counter is shown in Fig. 6.

The counter we use in the laboratory system is designed to work in six channels – recording particles with the following sizes: 0,3; 0,5; 1; 2,5; 5 and 10 μm . All measurements are displayed simultaneously on the device screen. There are visual (color scale) and audio signals when critical levels of FPM concentrations are reached. The device also records large amount of data in its internal memory and up to 16 GB on additional SD card.

Fig. 7 shows specific measurement made by students. Mass concentration of FPM 2,5 μm and wind direction and speed are presented.

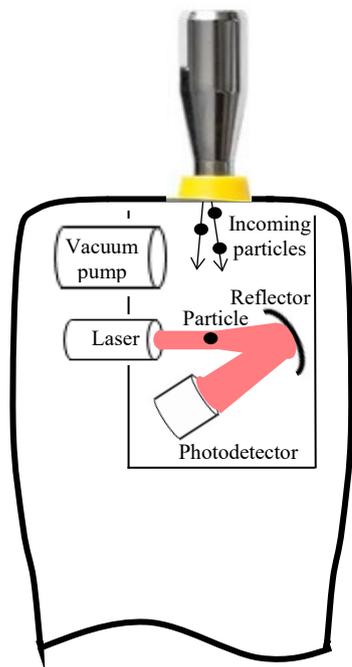


Fig. 6. Counter mode of work

The measurements were carried out in Borisov Garden in Sofia at distances of 0, 20, 50 and 100 m from Tsarigradsko Shosse Blvd. towards park interior. The purpose was to determine impact of park vegetation on the mass concentration of fine particulate matter of different sizes. Measurements were taken every thirty minutes during the first half of the day. Only hours with the highest (9:00 to 10:30) and lowest (12:00) values are shown on the graphs. The students concluded that concentration fell sharply between the boulevard and the 20th meter, and with further distance changes were already insignificant. There was no wind in the beginning of measurements. This and the peak vehicle traffic reflected in higher concentrations at 9:00 h. Later wind gusts 1-3 m/s appeared mostly slantwise from the park to the boulevard and despite intensifying traffic at times, concentrations fell.

This is a small part of the students' practical activity. They carry out similar measurements under different weather conditions for a given season and also during different seasons. The goal is to make the corresponding conclusions about the generation and distribution of atmospheric pollutants according to the relevant conditions.

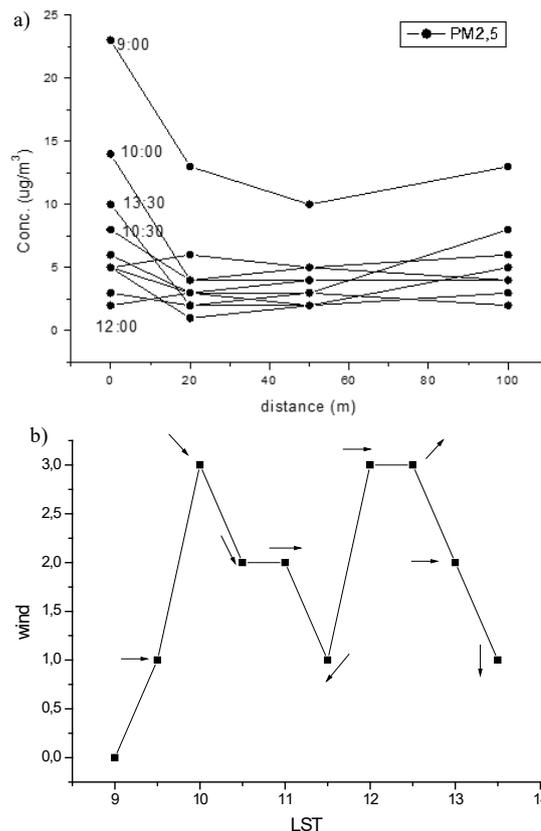


Fig. 7. FPM 2,5 μm mass concentration (a) and wind – direction and speed (according to local summer time (LST)) (b).

III. CONCLUSION

Traditional education is a conservation system that focuses predominantly on theoretical preparation of trainees. Dynamics of contemporary life and the problems it places before us requires introduction of new practices in the process of teaching and learning, to ensure not only theoretical but also good practical development of competences. We believe that an important part of such teaching is presenting to students advanced methods and equipment for work in their chosen field of future professional endeavors.

REFERENCES

- [1] D. Vallero, Fundamentals of Air pollution. Elsevier Inc., 2008.
- [2] P. Knippertz and J. Stuut, Mineral Dust. A Key Player in the Earth System, Springer Dordrecht, 2014. <https://doi.org/10.1007/978-94-017-8978-3>
- [3] J. Colls, Air pollution, CRC Press, 2002. <https://doi.org/10.4324/9780203476024>
- [4] W. Cotton and R. Pielke, Human impacts on weather and climate, Cambridge University Press, 2007. <https://doi.org/10.1017/CBO9780511808319>
- [5] J. Ayres, R. Maynard and R. Richards, "Air Pollution and Health", Air Pollution Reviews, Vol. 3, Imperial College Press, 2006.
- [6] J. Vincent, Aerosol sampling: Science, standart, instrumentation and Applications, John Wiley & Sons, 2007.

Analysis of the experience and prospects of the implementation of the Moodle platform for the organization of distance learning in Ukrainian universities

Vanda Vyshkivska
*Faculty of Pedagogy
Dragomanov Ukrainian State
University
Kyiv, Ukraine*
vivanova154@gmail.com

Yuliia Sylenko
*Faculty of Pedagogy
Dragomanov Ukrainian State
University
Kyiv, Ukraine*
silenko1yulia@gmail.com

Oksana Golikova
*Institute of Social and Humanitarian
Technologies NTU KhPI
National Technical University
"Kharkiv Polytechnic Institute"
Kharkiv, Ukraine*
golikovantu@gmail.com

Tetiana Tsehelnik
*Faculty of Pedagogy and Psychology
Volodymyr Hnatyuk Ternopil
National Pedagogical University
Khmelnitskyi, Ukraine*
sveettana@ukr.net

Oksana Patlaichuk
*Educational and scientific
humanitarian institute
Admiral Makarov National
University of Shipbuilding
Mykolaiv, Ukraine*
oksana.patlaichuk@nuos.edu.ua

Abstract. The educational process has been rapidly transformed in the last couple of years due to the global changes of the twenties of the 21st century, which significantly affect the ways of organizing the educational process both in face-to-face and online form. Learning conditions provide for a constant increase in the amount of educational information and the need to improve the quality of its use with minimal time expenditure and in non-standard conditions complicated by various factors. Accordingly, the focus of attention of teachers and students is the tools of distance learning, in particular the educational digital platform Moodle, which allows to ensure a high technological level of organization of the educational process, regardless of external circumstances, in conditions of the impossibility of visiting an educational institution.

The purpose of the article is to analyze the experience of implementing the Moodle platform in the system of higher education of Ukraine as a tool of mixed learning; determining the level of respondents' ownership of Moodle resources; development of a universal model of distance learning organization on the Moodle platform.

Through a comparative analysis of educational content management systems, it has been proven that the Moodle platform is the best adapted to the environment of higher education in Ukraine, where since 2020, due to the COVID-

19 pandemic, the format of educational institutions of various training levels has been changed from face-to-face to distance learning. The introduction of martial law in 2022 has even more actualized the problem of the development of distance learning tools, the need for teachers and students to master them.

The article analyzes the experience of introducing Moodle (LMS) as a single online platform in higher education institutions of Ukraine (the sample included 4 universities) with the aim of improving the educational process in the conditions of distance learning. In a comparative aspect, the results of the transformation study of the readiness of subjects of the educational process to use the opportunities and resources of the Moodle platform are presented. The study, organized in two stages, made it possible to analyze the work of teachers (filling electronic educational complexes, uploading test tasks) and students of education (use of the materials presented, educational activities) on the Moodle platform in 2020/2021 (Stage I) and to follow the transformation of the acquired experience during 2022/2023 (Phase II) in connection with the introduction of distance learning as the main form of obtaining higher education in the vast majority of regions of Ukraine.

A universal model for organizing the educational activities of master's students on the Moodle platform in distance

Print ISSN 1691-5402
Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8078>

© 2024 Vanda Vyshkivska, Yuliia Sylenko, Oksana Golikova, Tetiana Tsehelnik, Oksana Patlaichuk.
Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

learning conditions was developed and theoretically substantiated (using the example of studying the disciplines of the cycle of general professional training - "Psychological and pedagogical technologies", "Information systems and technologies", "Didactic systems and educational technologies in higher school").

Keywords: a universal model of the organization of educational activities, distance learning, students of higher education, the Moodle platform (LMS).

I. INTRODUCTION

As of today an active transformation of the educational process in higher educational establishments through creation of the managed information learning environment is currently on both in Ukraine and worldwide. Moodle is the most widespread among the platforms specialized in organizing online learning (ATutor, Claroline, LAMS, Dokeos, Sakai, Open) as it enables designing, creation and further management of resources of dynamic information learning environment. Provision of varied educational services, enhancement of student activity for mastering materials, optimization of asynchronous individual work, intensification of encouragement to self-knowledge and self-organization, activation of interactive convergence are ensured in the aforesaid environment, thereby resulting in formation of the individual position of students.

II. RESEARCH METHODOLOGY

Higher education students (master graduates) and teachers of 4 universities: Drahomanov Ukrainian State University represented by 107 persons, National Technical University "Kharkiv Polytechnic Institute" represented by 99 persons, Volodymyr Hnatyuk Ternopil National Pedagogical University represented by 101 persons, Admiral Makarov National University of Shipbuilding represented by 104 persons were the survey respondents. The total number of respondents was 411.

The following methods are applied in our research: theoretical (analysis; identification of literary sources in order to specify theoretical aspects of the research problem), empirical (survey of university scholars and master degree students so as to determine whether they have experience in using the Moodle platform in the educational process), methods of mathematical processing of findings (ranking method).

III. RESULTS AND DISCUSSION

Our research commenced in 2017 when a pilot experiment on organizing blended learning for full-time students through the Moodle system was launched at the Andriy Malysko Faculty of Ukrainian Philology and Literary Art and at the Faculty of Foreign Philology of the National Drahomanov Pedagogical University. The experiment was launched following acquisition of the recommendation to implement the results of the blended learning project (2016-2017) from the Prometheus platform developers in such Ukrainian higher educational establishments as the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Ivan Franko National University of Lviv, Lviv Polytechnic National University, Ukrainian Catholic University.

At that time, deployment of the Moodle platform was focused on uploading training courses (lecture materials and assignments for workshop classes) by teachers and providing students with the opportunity to process them whenever and however it seemed convenient to them. That way of using the Moodle platform complemented the knowledge mastery organizational forms which were common for teachers and students: full time studies, consultations.

However, since 2020, in connection with the spread of the acute respiratory disease COVID-19 in Ukraine, the format of activities of educational institutions of various levels of training is radically changing: distance learning using information and communication technologies is being introduced. The Moodle platform is becoming especially popular as such, as evidenced by a comparative analysis of educational content management systems, which is the best adapted to the educational environment of educational institutions of Ukraine.

TABLE 1 COMPARISON OF EDUCATIONAL CONTENT MANAGEMENT SYSTEMS

opportunities	systems				
	ATutor	LAMS	MOODLE	Open ACS	Dokeos
Multi-language interface (languages)	(>30) +	(19) +	(54) +	-	(34) +
SCORM Support	-	-	+	-	+
IMS Support	-	-	+	-	+
Testing system	+	+	+	+	+
External testing systems support	-	-	+	-	-
Accounting system	+-	+-	+	+-	+-
Ukrainian Language support	+	+-	+	-	-

While analyzing the peculiarities of organization of training through the Moodle platform, we have assumed that the remote course is a special form, which is based on the network technology, to present content of the educational subject and means to implement the educational network forms and methods.

The analysis of the informational component of the educational platform (training courses for teachers) confirmed the presence of all the necessary materials (lectures, seminar and practical tasks, criteria for evaluating educational achievements). At the same time, unsystematic updating of posted information by teachers, insufficient use of the functionality of the Moodle platform, which enables the organization of continuous interactive interaction between teachers and students through announcements, forums, feedback, chats, comments on tasks, etc., was noted.

The Moodle information environment has two types of basic elements for placing educational information: course resources (Web page, text page, note, Web link to a site or file, folder, etc.) and interactive course elements (glossary, book, lessons, task, workbook, seminar, Wiki, forum, chat, database, etc.).

Determining the level of their possession and use in organizing training on the Moodle platform was the first task of the ascertainment stage of the research and was carried out by us through the logic of determining the levels of information literacy. For this purpose, the following criteria with corresponding indicators have been developed: motivational (interest and need in mastering the Moodle resources); informative (familiarity with the Moodle resources; understanding of their essence and role in the educational process); activity (ability to independently create informational content and systematically apply the Moodle resources in educational activities).

Subject to the developed criteria, 3 levels of proficiency in the Moodle resources have been featured: the initial, technological and creative ones. Level I (initial): users have an idea of the Moodle resources, their use in the educational process; partially simulate the learning process through use of the Moodle resources to fulfill trivial assignments. Level II (technological): they know how to use various Moodle resources to a sufficient degree in order to efficiently organize the educational activities; Level III (creative): users create an innovative educational environment based on the Moodle resources, using the up-to-date information and communication tools; evaluate their own activity, efficiently implementing the information and communication tools into the subject area.

Thus, in 2020, we made a survey in order to identify the acute experience (level) of using the Moodle platform services as an auxiliary resource in arrangement of the educational process, to clarify attitudes towards the forms, technologies, resources and prospects for their use in remote learning. The survey included three blocks of questions: motivational, informational and activity ones, each consisting of 5 questions.

The first question of the motivational block "Are you interested in using the Moodle platform?" was answered affirmatively by 67% of respondents, 30% said that their interest was "partial", and 3% were not interested in using it. In response to the question "Can you say that mastering the Moodle resources is a necessary component of information technology competence", 63% of respondents answered "yes", 23.1% chose the "partial" answer, 13.9% did not answer the question. When asked whether it was convenient to navigate in the personal account of the Moodle platform, 72.5% ticked "yes", 13.5% - "partially", 14% specified that navigation was not convenient. When asked about the potentials of Moodle to implement the educational process, 13% said that they appreciated the platform, which made it possible to build an educational path in mastering the course. Meanwhile, 67% noted that they were partially interested in delivery of potentials, and

20% were not motivated by its potentials in educational activities at all. The question "Do you have a desire to continue educational activities on the Moodle platform" was answered by 64.5% of respondents affirmatively, 33.2% were "partially" interested, and 2.3% did not show any desire to use it any longer.

Diagnosis according to the information criterion included answers to the following questions: "Do you think that the Moodle platform has all the necessary resources to transfer in-person learning to a remote format?" (38% of respondents answered affirmatively, 12.3% chose "partially"; 49.7% said "no"); "Please substantiate why the Moodle platform is communicative in a dynamic educational environment" (8.78% set forth a detailed proper answer, 67% of respondents managed to give a partially proper answer, 24.22% failed to answer the question); "Do you know about an option to exchange ideas on the platform by discussing challenging issues" (68% answered "no", 20% - "partially", 12% answered affirmatively); "Do you know the social constructivism provisions underlying the Moodle platform (92% of respondents were not aware of such provisions, 6% of respondents said they were partially aware, only 2% had an expertise knowledge of such information). Accordingly, we can claim that the respondents lack understanding of the conceptual features of Moodle, particularly, creation of a personalized educational environment where the students themselves participate in structuring knowledge as a dynamic, multimodal structure. This contributes to acquisition of experience of self-replenishment of professional knowledge, development of personal responsibility for this process.

Responding to the questions of the third block, respondents noted that 11.23% were able to use the interactive elements of the course on the Moodle platform, 50.57% were partially able, 38.2% were not able at all; with regard to development of presentation materials, 26.78% noted that they had perfectly mastered the elements of development, 64.72% had partially mastered them, and 8.5% failed to master them at all. 5.03% of respondents took advantage of filling in and filling out the glossary on the Moodle platform, 28.2% had incomplete experience, and 66.77% had never used it at all. When asked about development of chats and forums for communication, 7.93% of respondents informed that they used them constantly, 14.68% had incomplete experience, and 77.39% had never used this service at all. Wiki or database resources, according to the survey, were completely ignored by 98%, and only 2% had partial experience.

Thus, the research findings show that the respondents do not sufficiently use the wide range of the Moodle multimedia resources in the educational process, which resources make it possible to create an innovative educational environment and interactive teamwork between participants. Correlation of the criteria and proficiency levels in the Moodle resources by respondents is shown in Fig. 1.

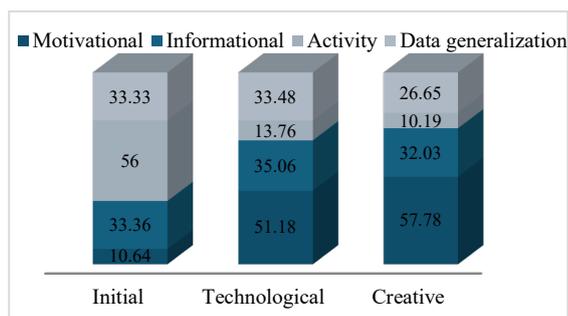


Fig. 1. Moodle resources proficiency levels according to Phase I of the research

As it follows from the research findings, the vast majority of respondents has the initial level in terms of information and activity criteria featured by a sketchy concept about the Moodle resources and primitive use thereof in the educational process, an insufficient ability to create high-quality and complex information content based on the unsystematic nature of its application in the educational process activity. Instead, the motivational criterion at all levels is predominantly characterized by an acute interest, however with an undesignated need to master the Moodle resources owing to complexity of mastering multimedia services.

It should be noted that in settings of the war, arrangement of the learning process through the Moodle platform has become the only opportunity for the teachers, who stay in the temporarily occupied territories or in the front-line territories, to continue the educational process, and for the students from extremely dangerous areas to receive high-quality educational services, since for the reasons of security and due to the technical problems they are unable to attend Zoom online classes. Thus, we have conducted the second phase of our research in the period of 2022-2023, through Google Forms (<https://forms.gle/csmeufpocxEQY4AZA>), which was targeted to establish the acute level of use of the Moodle platform as the major resource of remote learning that was introduced under the conditions of martial law in Ukraine.

The repeated survey has been conducted according to the same blocks of questions as in the first phase of the research: motivational, informational, activity. The answers have been evaluated based on the following scale: "yes" - high level, "partially" - medium, "no" - low.

Generalized analysis of the findings is given below. The affirmative answers to the motivational block questions ("Are you interested in using the Moodle platform?", "Do you think that proficiency in the Moodle resources is the essential component of the informational and technological competence?", "Are you willing to continue learning on the Moodle platform?") have grown up by 20%, 25%, 20% accordingly, which fact implies to a steady interest to use of the Moodle platform. Respondents have also been asked: "What percentage can you assign to your aptitude to use all the Moodle services in the educational process?" and the subjective answers are divided. So, 43.1% are ready for 50%, 41.2% outline their

readiness at the level of 50-75%, and 15.7% indicate that they are 75-100% ready.

Analysis of the informational block answers shows that the respondents' level of awareness of the specifics of the Moodle platform has increased. 50% more positive responses have been obtained to the question: "Do you think that the Moodle platform optimally organizes in-person learning in the distance format?" 12.3% of respondents (i.e. 3.52% more than in Phase I) give the proper answer to the question: "Why is Moodle a communicative platform in the dynamic learning environment?"

Almost the same proportion of answers is given to the question "Do you know the social constructivism provisions underlying the Moodle platform?". 81.5% respondents do not have any idea of such provisions (Phase I: 92%), 7.2% partially know about them (Phase I: 6%). 11.3% respondents have an excellent knowledge of the above information, i.e. 9.3% more than before. Thus, it can be concluded in the comparative analysis that respondents (compared to Phase I) understand, in their vast majority, the conceptual features of Moodle.

The third block of questions provides for analysis of the activity aspect. Thus, the question "Do you develop interactive components of the course on the Moodle platform?" has been answered affirmatively by 27.6% (i.e. 16.36% more than before), "partially" by 61.1% (50.57% in Phase I), 11.3% of respondents do not develop them at all (i.e. 26.9% less than before).

When asked "Do you use Moodle resources or tools to develop your presentations?", 47.3% have noted that they still do not use them; 43.2% use them partially; and 9.5% have mastered a range of services competently (indicatively, respondents have chosen H5P (7.8%), HotPot (3.9%), EJSApp (1%), etc., as such tools).

The question "Do you use the resources or tools to ensure social interaction between participants in the educational process?", 59.1% have provided a completely affirmative answer, 17.2% use them partially, 23.7% of respondents do not use any resources at all (i.e. 24.3 % less than before).

Thus, our respondents have mentioned Google Meet™ for Moodle (34.3%), feedback (20.6%), chats, forums (18.6%), etc., as the above resources (i.e. 3.92% more than in Phase I of the research).

When asked about study of the research and pedagogical literature and replenishment of the glossary, respondents have mentioned them in the following proportion: 17.8% use them on a permanent basis (5.03% in Phase I), 38.4% use them occasionally (28.2% in Phase I), and 43.8% have never taken advantage of them (i.e. 22.97% more than before).

However, the findings have remained the same with regard to the database creation tools and the use of Wiki resources, since according to the survey 98% do not use them, and only 2% have partial experience.

The research Phase II findings are shown in Fig. 2

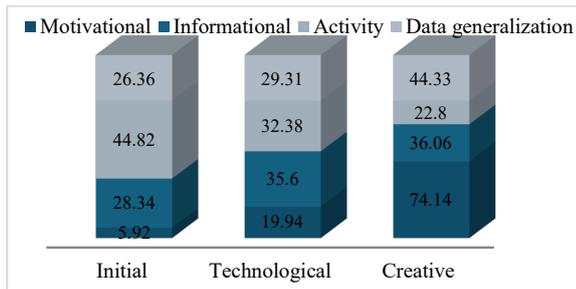


Fig. 2. Moodle resources proficiency levels based on the Phase I of the research

As it follows from the research findings, 44.33% of respondents have a creative and technological level (29.31%) that makes it possible for them to create the informational environment on the basis of creation of the multimedia educational information. However, we still observe 26.36% of respondents who have an initial level of proficiency in the Moodle services, therefore they are disabled to efficiently fulfill the whole range of potentials of the Moodle platform in their subject area.

Ranking of findings on Phases I and II of the research is shown in Fig. 3.

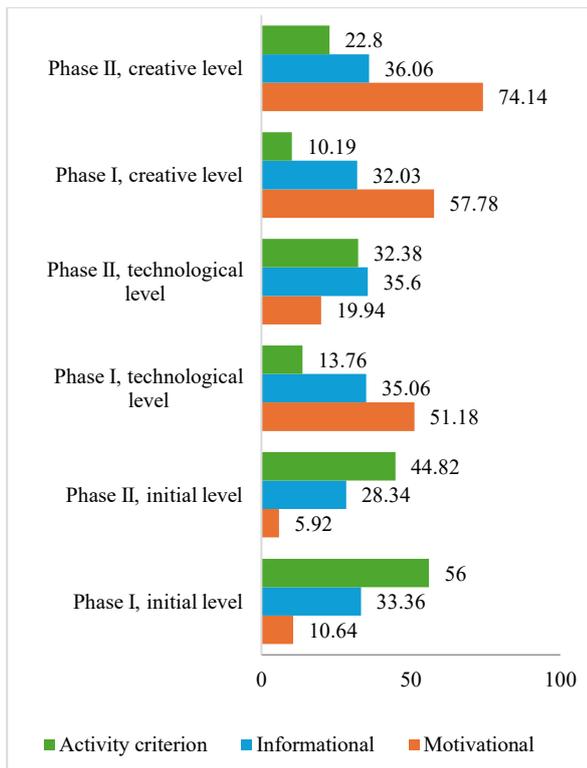


Fig. 3. Moodle resources proficiency levels by Phases I and II of the research (compared)

The obtained findings imply that the two-year experience in using the Moodle platform has made it possible to enhance interest and motivation for using it (the creative level was 57.78% in Phase I of the research, and 74.14% in Phase II); informational awareness of the platform and its potentials has increased slightly (the creative level was 32.03% in Phase I of the research, and

36.06% in Phase II). At the same time, the level of students' proficiency in the operational constituent of the Moodle resources remains insufficient, as the creative level is observed at 10.19% in Phase I of the research, and 22.8% in Phase II. Meanwhile, the low level remains consistently high (56% and 44.82%, respectively).

This conclusion provides for the necessity to develop a universal model to arrange distance learning through use of the Moodle platform in higher education institutions.

TABLE 2 MODEL TO ORGANIZE THE WORK OF MASTER DEGREE STUDENTS ON THE MOODLE PLATFORM IN THE DISTANCE LEARNING FORMAT

Block of motivation and purpose	Purpose: to optimize and intensify the organization of work of master degree students on the Moodle platform in the distance learning format			
Block of content and arrangement	Theoretical and methodological fundamentals to implement the model			
	Methodological approaches:	Didactic principles:		
	Competent Structural and systemic Personal and activity	Scientific, systematic, variability, individualization and differentiation		
Block of content and activities	Arrangement of educational process			
	Educational forms	Types of training	Moodle resources	
	Lecture classes	Recital of educational material, presentations:	- EJSApp; - HSP; - HotPot; - SCORM package;	Discussion of material: chats, forums
		Work with research literature:	- database; - Wiki; - glossary;	
	Workshops / Practical classes	Discussion of material, replenishment of knowledge, formation of practical knowledge and skills	- assignment, workshop class	
	Individual work	Completion of the assignments provided by the course program:	- database; - Wiki; - glossary;	
Material proficiency check:		- "Questionnaire"; - "Choice" feedback;		
Consultations	Clarification of problematic issues	- OpenMeetings; - Google Meet™ for Moodle;		
Block of analysis and findings	Monitoring of the Moodle platform skills formed			

As evidenced by our research, the resource potential of Moodle in the universities of Ukraine is quite limited at present. Largely, it goes about creating different categories of courses using the Moodle's own tools, choosing their structure, content [1], arrangement of test evaluation of the students' academic achievements [2], reducing the interactive multimedia as necessary to ensure the proper quality of education interaction to a minimum, in our opinion. At the same time, Avramchuk [3] and Halimon [4] claim that using the MOODLE tools in the educational process fosters responsibility of teachers and students for quality of teaching and learning, develops their independence; alongside, it does not require teachers to have special programming skills. We accept the opinion of the authors, however we consider that the professional competence of teachers requires a significant advancement, in particular in respect of its information and technological component, as well as competence in designing multimedia electronic educational resources in the Moodle system [3].

Similar conclusions are available with foreign researchers. Jalobeanu [5], Naaj [5], Martin-Blas [6], Serrano-Fernandez [6] emphasize that MOODLE contributes to improvement of comprehension of educational information by students, helps to develop motivation for learning, but requires proper training of teachers. Alongside, researchers have noted that the Moodle resources are used by a large number of participants and as a result do not always meet pedagogical needs of the teacher in all types of activities [7]. That is why technologies for implementing a personalized hybrid e-learning system are being developed (Čeponienė [7]).

Hargreaves argues that motivation and ability of students to learn independently are crucial for personalization, as they reduce dependence on the teacher and traditional classroom learning styles [8]. We believe that the training organization through the Moodle tools solves this issue in the best possible way as due to the research it implements the idea of individualization of training and differentiation of educational assignments to the fullest extent.

A number of scientists (Zaiarna [9], Kauts [10]), while examining the options of using administrative, educational and communication tools of LMS Moodle in teaching the English language students, have also determined the prospects of the above tools. Taking into account the opinion of the authors, we have developed a model of the Moodle resources used not just for studying a particular subject, but as a means to arrange the educational process in a distance format, specifying the Moodle resources depending on the training organizational forms (lecture, workshop, independent work, consultations) and types of educational works and assignments.

IV. CONCLUSIONS

Interactive resources and information delivery systems of the Moodle platform are able to ensure the appropriate level to render educational services: presentation of

educational material, impartial assessment of educational achievements, interpersonal communication and advisory support of students. In the conditions of the martial law, distance learning solves a number of security issues as well. At the same time, the operational productivity on the Moodle platform, as the main tool for implementing distance learning in most universities of Ukraine, depends on solving a number of problematic issues, including the major ones: no sufficient aptitude of most teachers to work in the informational educational environment. The developed model, in our opinion, will help increase the aptitude level for introducing a range of the platform services into the educational process with an option to create an informational educational environment with interactive multimedia support in both distance and blended learning conditions.

V. ACKNOWLEDGMENTS

We express our kind gratitude to higher education teachers and students of Drahomanov Ukrainian State University, National Technical University “Kharkiv Polytechnic Institute”, Volodymyr Hnatyuk Ternopil National Pedagogical University, Admiral Makarov National University of Shipbuilding for assistance in conducting the experimental research and direct participation therein.

REFERENCES

- [1] O.A. Shcherbyna, “Automation Of The Creation, Filling And Administration Of Course Categories On The Moodle Website”, ITLT, vol. 93, no. 1, pp. 178–198, Feb. 2023. [Online], Available: DOI, <https://doi.org/10.33407/itlt.v93i1.5117> [Accessed February 9, 2024].
- [2] N.M. Boliubash, “Organizational And Methodological Aspects Of Teaching Based On The Moodle Information Environment”, ITLT, Vol. 33, issue March 1, 2013. [Online], Available: DOI, <https://doi.org/10.33407/itlt.v33i1.761> [Accessed February 9, 2024].
- [3] A.M. Avramchuk, “A Model Of Competence Development Of A Linguist Teacher Regarding The Design Of Multimedia Electronic Educational Resources In The Moodle System”, ITLT, vol. 61, issue 5, p. 50–60, October 2017. [Online], Available: DOI, <https://doi.org/10.33407/itlt.v61i5.1810> [Accessed February 9, 2024].
- [4] I.Y. Halimon and S.I. Shevchenko. “The Role Of LMS MOODLE Educational Tests In Education Of Linguistic Profile Students”, ITLT, vol. 72, issue 4, p. 246–257, September 2019. [Online], Available: DOI, <https://doi.org/10.33407/itlt.v72i4.2455> [Accessed February 9, 2024].
- [5] M.Jalobeanu, A. Naaj, R. Dumbraveanu, C. Herman Using MOODLE platform in distance education. 2011. [Online], Available: Academia https://www.academia.edu/1125342/USING_MOODLE_PLATEFORM_IN_DISTANCE_EDUCATION [Accessed February 9, 2024].
- [6] T.Martin-Blas, A.Serrano-Fernandez. “The role of new technologies in the learning process: Moodle as a teaching tool in physics”. Computers & Education, 52, 1. p. 35-44. 2009.
- [7] L. Čeponienė, “The Collaborative Designing Of A Personalized Hybrid Lms Using A Virtual Machine In A Cloud Environment”, ITLT, vol. 98, no. 6, pp. 142–163, Dec. 2023. [Online], Available: DOI, <https://doi.org/10.33407/itlt.v98i6.5242> [Accessed February 9, 2024].
- [8] D.H. Hargreaves Personalising learning: Next steps in working laterally. London : Specialist schools Trust. 2004.
- [9] S. Zaiarna, “The Model For E-Teaching English Reasoning Writing To Law Students Based On LMS Moodle”, ITLT, vol. 76, no. 2, pp. 152–162, Apr. 2020. [Online]. Available: DOI,

<https://doi.org/10.33407/itlt.v76i2.3332> [Accessed February 9, 2024].

- [10] D.S. Kauts and Navdeep Kaur, "Effectiveness of Moodle- LMS on the Academic Achievement and Student Satisfaction among IX
- [11]

grade. Mathematics Learners," Turkish Online Journal of Qualitative Inquiry (TOJQI), 12, 3, p. 1544-1555. 2021.

Enhancing Students' Coding Skills With Bloom's Taxonomy And The Competence Approach Through Educational Game Design

Valentina Voinohovska
University of Ruse
Department of Informatics and information technologies
Ruse, Bulgaria
vvoihovska@uni-ruse.bg

Julia Doncheva
University of Ruse
Department of Pedagogy
Ruse, Bulgaria
jdoncheva@uni-ruse.bg

Abstract. This paper explores an innovative approach to enhancing students' coding skills by integrating Bloom's Taxonomy and the Competence Approach through the design and implementation of educational games. The rapid evolution of technology necessitates a dynamic pedagogical framework that not only imparts technical knowledge but also fosters higher-order thinking skills. Bloom's Taxonomy provides a structured hierarchy of cognitive skills, ranging from basic understanding to advanced synthesis and evaluation, offering a comprehensive framework for curriculum development. Concurrently, the Competence Approach emphasizes the practical application of knowledge, focusing on real-world skills and problem-solving. In this study, we propose the synthesis of these two pedagogical frameworks to create a robust and effective methodology for teaching coding to students. By aligning specific coding tasks with Bloom's Taxonomy levels and integrating real-world problem-solving scenarios using the Competence Approach, educators can develop a curriculum that caters to diverse learning styles and cognitive abilities. To implement this approach, we advocate the use of educational games as a powerful and engaging tool for active learning.

Keywords: Coding Skills, Bloom's Taxonomy, Competence Approach, Educational Game Design.

I. INTRODUCTION

In a world dictated by rapid technological advancements, the imperative to equip students with robust coding skills has become more pronounced than ever. However, the traditional methods of teaching coding often fall short in fostering the multifaceted development required for success. This paper introduces an approach to address this gap, blending the cognitive levels of Bloom's Taxonomy with the practical orientation of the Competence Approach, all within the immersive context of educational game design.

The intersection of Bloom's Taxonomy and the Competence Approach offers a framework that not only guides the acquisition of coding proficiency but also fosters the development of critical thinking and problem-solving skills. While Bloom's Taxonomy provides a structured hierarchy for cognitive skill development, ranging from basic knowledge to advanced synthesis and evaluation, the Competence Approach emphasizes the application of knowledge in real-world contexts. By integrating these two educational paradigms, we aim to create a comprehensive strategy that exceeds the traditional confines of coding education.

Recognizing the potential of educational games as powerful tools for engagement and active learning, this paper advocates for their integration into the coding curriculum [4]. These games are designed not only to teach coding concepts but also to immerse students in scenarios that demand practical application, aligning seamlessly with the principles of the Competence Approach. Through this integrated approach, we seek to transform coding education into a dynamic, interactive, and intellectually stimulating experience that resonates with the diverse learning preferences of today's students.

Throughout this paper, we delve into the theoretical underpinnings of Bloom's Taxonomy and the Competence Approach, illustrating how their synergy can be harnessed to enhance coding education. Case studies of educational games developed under this framework will be presented, offering tangible insights into the practical implementation of this innovative approach.

II. LITERATURE REVIEW

The area of computer science education has witnessed significant evolution in recent years, driven by the escalating demand for proficient coders in the workforce [7, 8]. However, the traditional approaches to teaching

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8066>

© 2024 Valentina Voinohovska, Julia Doncheva. Published by Rezekne Academy of Technologies.
This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

coding often struggle to keep pace with the dynamic requirements of the field. In the literature review we examine key themes surrounding coding education, with a specific focus on integrating Bloom's Taxonomy, the Competence Approach, and educational game design to enhance students' coding skills.

A. Coding Education Challenges

Numerous studies highlight the challenges associated with conventional coding education methods. These challenges include a lack of engagement, limited opportunities for practical application, and a narrow focus on memorization rather than holistic skill development [1], [5].

B. Bloom's Taxonomy in Education

Bloom's Taxonomy has long been recognized as a foundational framework for structuring educational objectives. Its hierarchical structure, ranging from lower-order cognitive skills (remembering and understanding) to higher-order skills (applying, analysing, evaluating, and creating), provides a roadmap for curriculum development [3].

C. Competence Approach in Education

The Competence Approach emphasizes the practical application of knowledge in real-world contexts. By focusing on the development of skills relevant to professional practice, this approach aligns with the demands of the workforce and enhances students' ability to tackle complex challenges [2].

D. Integration of Bloom's Taxonomy and the Competence Approach

A synthesis of Bloom's Taxonomy and the Competence Approach offers a comprehensive framework for curriculum development. By aligning specific coding tasks with Bloom's Taxonomy levels and embedding them in real-world scenarios, educators can bridge the gap between theoretical knowledge and practical application [9].

E. Educational Game Design in Coding Education

Educational games have gained traction as effective tools for engaging students in the learning process. By combining coding challenges with game scenarios, educators create environments that motivate students intrinsically, fostering active learning and problem-solving skills [10], [6].

Successful implementation of an integrated approach requires adequately trained educators. Studies emphasize the importance of teacher training programs to equip instructors with the skills necessary for effective integration and utilization of these pedagogical approaches.

III. METHODOLOGY GUIDELINES

The proposed methodology for combining Bloom's Digital Taxonomy with a Competence Approach in the context of coding education through educational game design is designed to create a comprehensive and effective framework. This approach seeks to integrate theoretical knowledge acquisition, cognitive skill development, and practical application within the engaging context of educational games.

A. Aligning coding tasks and learning objectives with Bloom's Digital Taxonomy

Identifying specific coding concepts and skills associated with each level of the taxonomy, ensuring a structured progression from basic understanding to advanced application and creation.

Integrating real-world problem-solving scenarios into the curriculum to align with the Competence Approach. These scenarios should mirror challenges students are likely to encounter in professional settings.

B. Educational Game Design Tasks

Developing game design tasks that incorporate coding challenges aligned with Bloom's Taxonomy. Each level of the taxonomy is represented within the game's progression, providing a scaffolded learning experience.

Embedding real-world scenarios within the game design to reinforce the Competence Approach. These scenarios should require students to apply coding skills to solve practical problems, promoting a deeper understanding of how coding concepts translate to real-world applications.

C. Cognitive Skill Integration

Incorporating cognitive skills from Bloom's Taxonomy into the game design. For example, creating game levels that require students to analyse, evaluate, and create solutions using coding concepts.

Integrating reflective elements within the game to encourage metacognition, allowing students to assess their own learning and problem-solving strategies.

D. Spiral approach

A spiral approach in education involves revisiting and building upon previously learned concepts in a cyclical manner, allowing students to deepen their understanding over time.

Designing a progressive learning path within the educational games, guiding students through increasingly complex coding challenges aligned with Bloom's Taxonomy.

Ensuring that each level builds upon the skills acquired in the previous stages.

Introducing new Competence Approach elements as students advance through the game, requiring them to apply coding skills in varied and realistic contexts.

E. Assessment Strategies

Developing assessment strategies that align with both Bloom's Taxonomy and the Competence Approach.

Using a combination of formative and summative assessments to evaluate students' understanding, application, and proficiency in coding.

Implementing assessments within the game environment to provide immediate feedback and facilitate continuous learning.

IV. COMBINING BLOOM'S DIGITAL TAXONOMY WITH A COMPETENCE APPROACH FOR LEARNING CODING THROUGH EDUCATIONAL GAME DESIGN

Combining Bloom's Digital Taxonomy with a Competence Approach provides a comprehensive framework for students learning coding through educational game design. This approach focuses on developing not only knowledge and skills but also the ability to apply them in authentic contexts.

Here's how the methodology can align with both frameworks:

A. Remembering

Objective: Recall fundamental coding concepts.

Competence Approach: Memorize coding syntax and basic algorithms.

Bloom's Digital Taxonomy:

- Use online quizzes or interactive digital assessments to recall coding syntax.
- Create digital flashcards or mind maps for quick recall.

B. Understanding

Objective: Comprehend the relationship between coding concepts and game design.

Competence Approach: Understand the principles of coding in the context of game design.

Bloom's Digital Taxonomy:

- Engage in collaborative online discussions to deepen understanding.
- Watch instructional videos or online tutorials on coding and game design.

C. Applying

Objective: Apply coding concepts to design simple game elements.

Competence Approach: Implement coding knowledge to create basic game elements.

Bloom's Digital Taxonomy:

- Collaboratively code using online platforms or Integrated Development Environments (IDEs).
- Participate in coding challenges on digital platforms.

D. Analyzing

Objective: Evaluate the effectiveness of coding in game design.

Competence Approach: Analyze and critique the coding structure of existing games.

Bloom's Digital Taxonomy:

- Use digital tools to compare and contrast different coding approaches.
- Participate in virtual coding peer reviews, providing constructive feedback.

E. Evaluating

Objective: Assess the suitability of educational games for specific learning objectives.

Competence Approach: Evaluate the effectiveness of game-based learning in achieving educational goals.

Bloom's Digital Taxonomy:

- Administer online surveys to gather feedback on educational game prototypes.
- Collaboratively assess existing educational games using digital rubrics.

F. Creating

Objective: Design and implement educational games integrating coding principles.

Competence Approach: Create complete educational game prototypes demonstrating coding proficiency.

Bloom's Digital Taxonomy:

- Develop game prototypes using digital game design tools and coding platforms.
- Collaboratively code, share projects through version control platforms, and create digital lesson plans.

G. Reflecting

Objective: Reflect on the pedagogical implications of using coding in education.

Competence Approach: Reflect on personal growth in coding and its application to teaching.

Bloom's Digital Taxonomy:

- Blog or journal reflections on digital platforms.
- Participate in asynchronous online discussions about coding challenges and successes.

H. Sharing

Objective: Share completed educational games with peers and educators.

Competence Approach: Demonstrate the ability to effectively communicate the educational value of coding-based games.

Bloom's Digital Taxonomy:

- Show games through online platforms or virtual exhibitions.
- Create digital presentations or webinars to share experiences with a wider audience.

V. CASE STUDIES

Our integrated methodology, seamlessly combining Bloom's Digital Taxonomy with a Competence Approach within the realm of coding education through educational game design, has proven to be a resounding success. In this section, we proudly present a collection of case studies meticulously curated to spotlight instances where this innovative approach has led to exceptional outcomes in coding skill development. These case studies serve as compelling narratives, offering concrete examples of how the fusion of cognitive depth, practical application, and gamified learning can foster remarkable advancements in students' coding proficiency. Each case study provides a vivid illustration of the successful implementation of our methodology, offering a closer look at the transformative impact on students' learning experiences.

Game 1. The aim of the game is to follow the instructions which will help students to solve problems and learn about healthy eating.

Sprites

Annie (main character). Annie is a little girl who appears throughout the entire game. She provides various instructions during the gameplay. Based on these instructions, the player performs tasks to master new content and reach the goal - the end of the game.

Grandma Maria (additional character). Grandma is a character who appears in the game to provide guidance. She works at the market. Annie goes to the market to buy healthy food products.

Description of the activities

The game is initiated by pressing the 'n' key. Annie urges the player to help her choose healthy foods. She goes to the store, where Grandma Maria appears, providing instructions for the first mini-game.

Mini-Game 1: The game starts with pressing the '1' key. The player must use the left and right arrow keys to move and collect 20 healthy products in their basket. The player has 30 seconds to gather the groceries. If the player doesn't collect enough healthy foods, the game restarts.



Fig. 1. Screen from Mini-Game 1 (Annie)

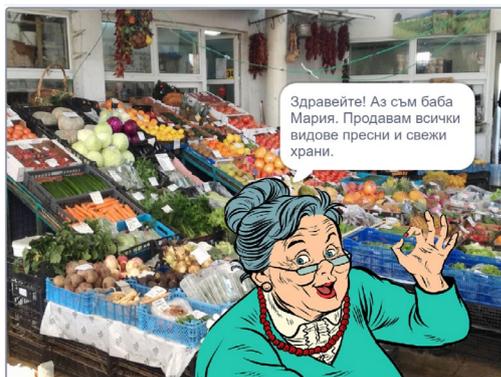


Fig. 2. Screen from Mini-Game 1 (Grandma Maria)

Mini-Game 2: The next game is activated with the '2' key. The player must guide Annie through the maze to find grain-based foods.



Fig. 3. Screen from Mini-Game 2

Mini-Game 3: After successfully navigating the maze, the girl returns home. On her way, she encounters a wall. To see the next task, the player must press the '3' key. The task is to arrange the words in a phrase related to healthy eating in the correct order.



Fig. 4. Screen from Mini-Game 3

Mini-Game 4: The player must write the name of the dish shown in the picture. If the player answers correctly, Annie is ready for lunch. Pressing the '4' key activates the final mini-game, where the player must set the table.



Fig. 5. Screen from Mini-Game 4

Game 2. The goal of the game is for the main character to dress appropriately for the season to gather fruits typical for that time of the year

Sprites

A girl (main character).

Family (mother, father, 2 sisters, 1 brother) (additional characters).

Description of the activities

The main character introduces the player to the story. The girl, Aria, comes from Australia to Bulgaria to learn more about the seasons specific to the Bulgarian climate. For each season, Aria needs to dress appropriately, which is also a condition for continuing the game. Successful dressing is followed by the second part of the game, where fruits specific to a particular season are collected. This way, the main character goes through the four seasons.

By collecting the correct fruit, the player earns 1 point, and making an incorrect choice result in losing 1 point. By gathering seasonal fruits throughout all seasons, the player can accumulate a total of 36 points, of which a minimum of 20 points is required for the successful completion of the game.



Fig. 6. Screen from Game 2 – four seasons

First Part of the Game for Each Season.

Selecting appropriate clothing for the main character according to the current season. A condition for continuing the game – collecting points."



Fig. 7. Screen from Game 2 – selecting appropriate clothing for summer

Second Part of the Game for Each Season.

Collecting fruits specific to a particular season. By gathering fruits, a maximum of 9 points can be earned in each season.



Fig. 8. Screen from Game 2 – selecting summer fruits



Fig. 9. Screen from Game 2 – selecting appropriate clothing for autumn



Fig. 10. Screen from Game 2 – selecting autumn fruits

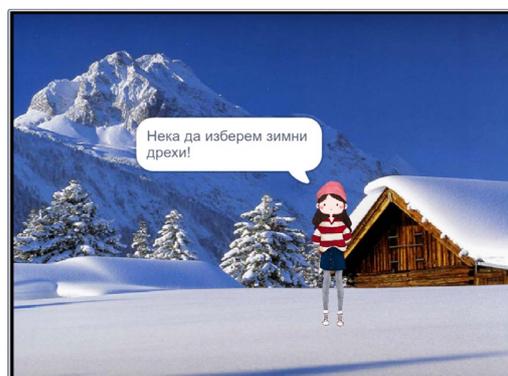


Fig. 11. Screen from Game 2 – selecting appropriate clothing for winter



Fig. 12. Screen from Game 2 – selecting appropriate clothing for spring

VI. CONCLUSION

In conclusion, the integration of Bloom's Digital Taxonomy with a Competence Approach in coding education through educational game design presents a promising and innovative way for develop holistic learning experiences. Through the exploration of this approach, we have identified its transformative potential in enhancing students' coding skills while fostering critical thinking, problem-solving, and practical application.

The presented case studies reveal the successful implementation of the integrated methodology, demonstrating its effectiveness in engaging students and promoting a deeper understanding of coding concepts. These real-world examples underscore the positive impact of aligning educational games with Bloom's Taxonomy and the Competence Approach, providing valuable insights for educators.

As the education continues to evolve, the integration of pedagogical frameworks and innovative technologies remains essential. The combined strength of Bloom' Digital Taxonomy, the Competence Approach, and educational

game design holds great promise in preparing students for the multifaceted demands of the digital age.

REFERENCES

- [1] A. Robins and J. Rountree, Learning and Teaching Programming: A Review and Discussion. *Computer Science Education*. 13(2), pp. 137-172, DOI:10.1076/csced.13.2.137.14200.
 - [2] B. M. Block, An innovative teaching approach in Engineering Education to impart reflective digitalization competences, *IEEE Frontiers in Education Conference (FIE)*, San Jose, CA, USA, 2018, pp. 1-5, doi: 10.1109/FIE.2018.8658604.
 - [3] B.S. Bloom, *Taxonomy of Educational Objectives, Handbook: The Cognitive Domain*. David McKay, New York, 1956.
 - [4] G. Fortes, H. Premsukh, and L. Nacke, A theory of gamification principles through goal-setting theory. *Hawaii International Conference on System Sciences*, 2018.
 - [5] J. E. Hannay, D. I. K. Sjoberg and T. Dyba, A Systematic Review of Theory Use in Software Engineering Experiments, *IEEE Transactions on Software Engineering*, vol. 33, no. 2, pp. 87-107, 2007, doi: 10.1109/TSE.2007.12.
 - [6] J. P. Gee, *Good Video Games and Good Learning: Collected Essays on Video Games, Learning and Literacy*. Peter Lang, New York, 2007.
 - [7] K. Dylgerova, D. Atanasova, 2020. Stem club for extracurricular work – a way to stimulate students *Proceedings of 14th International Technology, Education and Development Conference (INTED)*, pp. 6508-6517.
 - [8] K. Shoilekova, Advantages of Data Mining for Digital Transformation of the Educational System. In *Artificial Intelligence in Intelligent Systems. CSOC 2021. Lecture Notes in Networks and Systems*, vol 229. Springer, Cham, 2021, vol. 2, pp. 450-454.
 - [9] M. Sabin, H. Alrumaih and J. Impagliazzo, A competency-based approach toward curricular guidelines for information technology education, *IEEE Global Engineering Education Conference (EDUCON)*, Santa Cruz de Tenerife, Spain, 2018, pp. 1214-1221, doi: 10.1109/EDUCON.2018.8363368.
- P. Moreno-Ger, Daniel Burgos, Iván Martínez-Ortiz, José Luis Sierra and Baltasar Fernandez-Manjon. Educational game design for online education. *Comput. Hum. Behav.* 24 2008, pp. 2530-2540.

The potential of developing and creating online applications for teacher training

Oksana Voloshyna

Department of Pedagogy, Vocational
Education and Educational
Institution Management
Vinnytsia Mykhailo Kotsiubynskiy
State Pedagogical University
Vinnytsia, Ukraine
woloshina5555@gmail.com

Tetiana Melnychuk

Department of Culture, Methods of
Teaching History and Special
Historical Disciplines
Vinnytsia Mykhailo Kotsiubynskiy
State Pedagogical University
Vinnytsia, Ukraine
tmelnichuk@gmail.com

Mykyta Volodymyrovych Sapohov

Department of Innovative and
Information Technologies in
Education
Vinnytsia Mykhailo Kotsiubynskiy
State Pedagogical University
Vinnytsia, Ukraine
sopogov@ukr.net

Nelia Burlaka

Department of Pedagogy, Vocational
Education and Educational
Institution Management
Vinnytsia Mykhailo Kotsiubynskiy
State Pedagogical University
Vinnytsia, Ukraine
burlaka10@i.ua

Anna Khilya

Department of Primary Education
Vinnytsia Mykhailo Kotsiubynskiy
State Pedagogical University
Vinnytsia, Ukraine
anika.line@gmail.com

Abstract. In the modern society, technology is everywhere. From birth, children learn about technology and develop computer competence. Whether a baby, preschooler, or adult – it doesn't matter, everyone has basic skills in manipulating devices and interacting with the Internet (according to age, body functionality, etc.). However, this is not what can satisfy the growing need to change approaches to professional activities in various fields of science and life. In particular, to education at all levels, which should ensure qualitative and quantitative changes for further professional activity.

For example, we conducted a review of the latest theoretical and practical publications on the development and creation of online applications, which formed the basis for our own reflections on their implementation and use. It is not the first year that we have been addressing the issue of application development, collecting and analysing information on the involvement of future teachers in content development. After all, observing the development of technological solutions in developed countries of Europe and the USA, we analysed the development and demand for new technological solutions in education. And as a result of this introduction, based on the analysis, we were able to consider: fundamental differences in understanding and approaches to working with applications in the Ukrainian scientific community and in international practice; analyse the potential of developing and creating applications by students majoring in primary education and preschool education; to make a snapshot of

data through feedback on their e-portfolios of relevant developments of their own production and lists of applications available online.

This approach allowed us to draw conclusions about the potential risks of implementing online applications in practice. We also identified critical points in preparing teachers to use existing, create and develop their own online applications for working with children.

Keywords: app development, apps, e-portfolio, m-learning, teacher training.

I. INTRODUCTION

Technological solutions that will reduce the time spent on self-education, mastering basic knowledge, and acquiring the necessary digital competence and computer literacy. These issues require intervention not only in the process of training specialists, but most importantly in the work of teachers of the first two levels of education. After all, according to the 2015 reports of the American education system, "7,000 students drop out of school every day. That is one student every 26 seconds. 1.2 million a year, and most of them say that the key reason for this decision is that they are bored" [1]. In Ukrainian society, for example, there is no such statistical information [2], although such cases are recorded by the Ministry of Social Policy. However, it is the thesis of "boredom" that should

Print ISSN 1691-5402

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2024vol2.8086>

© 2024 Oksana Voloshyna, Tetiana Melnychuk, Mykyta Sapohov, Nelia Burlaka, Anna Khilya.

Published by Rezekne Academy of Technologies.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

be of primary concern, as most young people of primary and secondary school age not only have access to gadgets and the Internet, but also easily manipulate information, find what they are interested in, and study subjects on their own ahead of the school curriculum. This often leads to conflict situations between adults and children, but for us, the main thing is to emphasise the need to change approaches to the implementation of educational programmes through technological solutions.

Yes, of course, in countries with high economic performance, high levels of prosperity and happiness, the quality of education changes faster. This is because innovations are more quickly adapted and implemented in preschool and primary education. While countries with low development indicators do not have this opportunity. This can be traced even in the format of the entry of certain terms and technologies into the space of each country, their development through state or grant funding, and their geographical distribution. All this creates a generalised picture of possible changes in education.

While studying the implementation of technological solutions in Ukraine (which the team has done before), the review focused on the use of applications in the work of educators and teachers in preschool and primary schools. In the process of analysing the materials, it was also found out to what extent students are able to develop and store developed materials on various platforms in their electronic portfolios and to what extent they are familiar with applications that can be used when working with children on various subjects or those that can be offered to parents for home use. Of course, this research cannot describe the situation in the whole of Ukraine, but this snapshot allows us to understand the potential risks in preparing teachers to develop and create online applications.

II. MATERIALS AND METHODS

That is why the aim of this paper was to explore the potential of developing and creating online applications in teacher training as one of the steps in the digitalisation of education through affordable and widespread gadgets. Based on the defined aim, the research was launched with the hope of solving the following tasks:

- to analyse research on the development and creation of online applications and consider the fundamental differences in understanding and approaches to working with applications in the Ukrainian scientific community and in international practice;
- to explore the potential of developing and creating applications by students of primary education and preschool education, to make a snapshot of data through feedback on their e-portfolios of relevant in-house developments and lists of applications available online.

In addition to the main research method of data collection and analysis, observations and surveys were used to interact with students, which allowed us to present the results of a small sample of 46 participants.

III. RESULTS

Referring to research and scientific and practical studies on the use of various applications in the work of teachers, it was found that since 2012 [3], the international

community has begun to consider mobile devices as one of the most likely devices for organising education. After all, the modern age is characterised by personal and technical mobility, when mobile devices, including phones, MP3 players and PDAs, are carried everywhere, and the education paradigm is shifting towards distance learning [4]. This is since billions of people today use mobile devices for communication and other tasks, but only a minority of them regularly use them for learning [3], confirming that the entertainment capabilities of mobile devices distract or even conflict with learning needs beyond the educational capabilities [3].

Although, according to other studies, in our opinion, it is worth paying more attention to the trends in the use of portable and flexible learning tools such as smartphones and tablets, which are currently responsible for the m-learning phenomenon. It allows students to use mobile applications for their academic studies, to search for educational materials and exchange information, which leads them to improve their performance [5]. In addition, m-learning is considered as learning in different contexts, through social and content interaction, using personal electronic devices [5].

For example, as part of research on different approaches to e-learning, scientists have developed and analysed the results of such programmes as:

- the introduction of tablet computers in schools in Thailand and Turkey; projects on the use of mobile phones that can provide access to distance education for teachers in remote areas of Mozambique, promote literacy among girls in Pakistan, motivate young people in South Africa to read and improve their maths skills, promote literacy among adult women in Niger [3];
- AMULETS project (Advanced Mobile and Ubiquitous Learning Environments for Teachers and Students) to develop, implement and evaluate innovative educational scenarios for collaborative learning in a context supported by mobile and ubiquitous technologies in an authentic environment; Mobile Digital Narrative (mobileDN) project, which involves the creation of a collective multimedia digital narrative filmed entirely on mobile phones by a group of distributed students, from idea generation to final product [4];
- a simulation laboratory and software for students in the study of polymers and metals; a model of online computer courses on the impact of the cooperative method on group work; pilot e-learning programmes in areas such as computer mathematics education or computer programming courses; teaching methods in the structure of online learning, which investigated the limited knowledge transferred during learning in the online environment and the exhaustion of learning in a short period of time; a method of distance learning through interactive [6];
- the creation of the aprendo platform for school principals, which serves more than 12,000 teachers in primary, secondary and vocational schools, offering a wide range of learning opportunities [7], etc.

Although a number of countries use mobile learning only in specific projects and programmes, the prevalence of mobile devices is a good reason to consider smartphones

as a mainstream medium for education. That is why all countries, and their governments recognise the crucial role of technology in ensuring access to and improving the quality of education, as well as in lifelong learning [8]. But at the same time, it is noted that state education policy "focuses on technology - hardware, software, networking, content - rather than its connection to pedagogy, curriculum or assessment [3], which leads to a delay in transformations and slows down the processes of education renewal. And as a result, the loss of interest in learning, the loss of the educational system's position in front of the entertainment market. And, given the cause-and-effect relationship, the gradual loss of human capital with a high potential for innovation and productivity; demographic, social, cultural and other crisis phenomena that lead to economic downturns, among other things. In continuation of this idea, it is worth noting that before a school purchases tablets for students, it is necessary to make important organisational, ethical and usage guidelines decisions, as the introduction of 1:1 device triggers systemic changes [9]. Which means changes in the entire school system.

That is why, in the context of m-learning, special attention should be paid to the presence of a number of professionally significant functions (the ability to reflect, create, self-organise, self-develop, selectivity, manifestation of content creation, innovative solutions) in combination with professional skills that will allow teachers to act as reflective agents of industrial and socio-cultural innovations, which ensures their personal and professional success [10] in practice. And all this should take place in parallel with the development of competence and the implementation of skills within the framework of computer-oriented communication, which will allow to perform new functions to which the educational system is moving - cooperation, consulting, tutoring, monitoring, which allow to implement alternative forms of personal training, interactive classes and group teaching [10].

In addition, if necessary and possible, teachers should consider developing mobile learning activities that fulfil specific learning objectives and become rather a means of enabling activities that would otherwise be impossible or increase the benefits for learners [4]. Such a development strategy can only meet a part of the needs of teachers to implement the subject matter objectives. In addition, after the development of various elements of the game, attention should be paid to self-awareness, self-regulation and motivation [11], which will be formed by the developer's intention and as part of the processing of the proposal, team members should predict different levels of problematic issues that may arise as a result of the student's interaction with the proposed educational application.

In addition, at all stages, the team should follow a clear algorithm for testing the application, including the ethical framework or strategy for making ethical decisions in the context of which the scenario in the proposed application will be considered; the scenario itself and a set of questions to stimulate ethical discussion of the scenario [12].

Such a set should also be used when considering the use of third-party applications that are freely available either on gaming educational platforms or in the Google, Microsoft or Apple markets. After all, mobile technologies for teaching and learning in school and beyond using

multimedia content created or captured using mobile devices, teachers contribute to the possibility of students to learn for life outside of formal educational contexts, and the process of using them can expand the possibilities of

Although it is primarily a matter of developing their own software, they should understand that this creates a few problematic issues. In particular:

- the so-called "Acceptance of the Unexpected", which is related to teachers' fear that something can go wrong and can be solved by establishing "golden rules" of what is acceptable and unacceptable in a school or educational institution" [9].
- a policy of "support for open technical standards", which should be based on encouraging the use of open, standards-based platforms for mobile learning applications to increase access and simplify the development process [3]. In our opinion, we should partially agree with the approach here, since the use of data, platforms and applications on a particular device depends on the policy of the gadget manufacturer. For example, some gadgets have Android, while others have Microsoft or iPhone OS. In addition to the difference in the underlying software, there is the issue of outdated technology that cannot withstand new applications due to their requirements for screen resolution, video card, and even battery life. In addition, we no longer address the issues of programming languages, game engines, and other development nuances that directly affect the operation of applications on different devices. Even a simple website 4 years ago had to be manually adjusted for high-quality visualisation on devices with different screen sizes, resolutions, and colour spectrums. Therefore, the issue of accessibility and universality of the proposed content for education through mobile devices is quite interesting, but currently a difficult topic to implement.

In addition, continuing to address the topic of studying the development and evolution of interactive games and applications, the study will reveal a number of specific characteristics and recommendations for the evolution of these modelled microcosms based on real environments and societies, which can offer educators and educators excellent opportunities to understand how the dynamics generated on the Internet stimulate and generate the development of community learning environments [13]. This process is quite interesting, but needs further explanation for the creators of modern educational products, who present the entertainment element of educational content as a reward that can only be obtained by being willing to suffer a little from the pedagogical process itself, which from the very beginning creates an ambivalent dichotomy between entertainment and education, as if the learning process itself is an unpleasant experience that needs to be supported by a number of techniques and tools external to pedagogy [13]. This is another disadvantage that hinders the implementation of applications in practice, even if there are opportunities.

Indeed, the research outlines quite a few negative aspects of using mobile learning, including applications in the educational process, but this does not mean that it is a failed option for the traditional educational space. Developers and researchers should understand that society

and teachers of all levels of education need to be prepared to use not only ICT, distance learning, online courses, but also to shift the emphasis in the role of the teacher, in the presentation of course materials, which should primarily motivate the search for information and the formation of appropriate competencies for the professional development of the individual.

That is why, in order to address the main objectives of this paper, questions related to the results of the technical awareness of 46 students who were to participate in the educational hackathon and the interview based on the survey results were considered.

Thus, it turned out that all students in the previous year had created educational game applications on various platforms, but they could not specify which topic or subject they had developed. Except for 5 people who added descriptions and links to the exercises they created. In addition, the question of creating their own e-portfolio was not raised at all, because as students noted in the interviews: "If I need to, I will create it again", "I'd rather use ready-made exercises by teachers that I found on the Internet", "At school, I probably won't have time and need to play with children", "I will work with the Intellect programme, so I don't need to develop anything. The whole course is ready", etc. Of course, this short description does not reflect the experience and general picture among students preparing to become teachers, but it gives us an opportunity to think about why the education system is so slow to adopt innovations. And also to answer a dozen more questions about why, which are voiced by teachers, parents and children involved in the educational process.

In addition, a follow-up a year later with the same group of respondents showed that students did not remember the applications and exercises that were offered to them during the meetings a year ago. In particular, they found it difficult to find their own presentations created as part of the educational hackathon.

Thus, we can confirm the lack of motivation to create their own e-portfolio for further professional activities, which can save time when preparing for a lesson or class. Of course, such a description can be called subjective, but it is also indicative of the situation in the education sector and the gap between the offer of technological solutions and innovations and reality. In particular, the presence of a green board instead of an interactive one in schools and other educational institutions.

IV. DISCUSSION

In continuation of the topic of the use or lack of such practice in educational institutions, we must mention an important aspect - no matter how many adults try to create an artificial classroom filled with educational content, children, as true explorers and seekers of adventure or freedom, find dozens of holes and go beyond the proposed space. Therefore, it is virtually impossible to calculate and outline all the variants of interaction and cause-and-effect relationships of youth participation in learning through mobile applications as in a traditional classroom.

We also believe that the issue of longevity, i.e. the life cycle of the proposed application, its self-sufficiency and consumer interest, is among the issues under discussion. After all, in our practice, we often come across developments for individual subjects and game content, the

life cycle of which, for various reasons, does not go beyond 1 month or 1 year. Then, even if dozens of teachers want it, this app goes out of business and disappears. Therefore, there is no way to find quality content offered by businesses or indie developers that could be a permanent platform for a subject teacher, educator, or speech therapist. Apps, like any product, only become viable players in the market if they are developed and supported by the public sector, corporations, or donations.

The third issue is the attitude of the educators themselves towards the proposed applications. According to our observations, as long as the project proposal is in place and there is a constant need to report on the use of a particular application within the pilot schools or across the country, the process is ongoing. Since the end of the reporting period, only a few teachers who have "taken a liking" to the app have been included in the process, or the children themselves continue to use the app without appropriate adult supervision. This also has a significant impact on personal development, on children's attitudes to their own activities and to suggestions from others. Children see, children hear and, of course, imitate the behaviour of the adults they interact with during the 12 years of their school life. Therefore, innovations should not be introduced vertically or horizontally in accordance with state or school policy, but in accordance with the technical capacity of the school, students (today in Ukrainian reality, not all families can afford to buy a smartphone, let alone provide a separate gadget for a child) and the computer skills of the teacher.

Of course, these are not all the issues that can trigger a discussion on this topic, but not all of them are critical for scientific and practical searches for the introduction of mobile learning technologies into the educational process, along with the training of teachers who could independently or in a team create the necessary content – applications for the development and education of children, the formation of age-appropriate competencies.

V. CONCLUSIONS

Therefore, in this paper, we have dived into the issue of mobile learning, including the use of apps, their potential and controversial issues that require careful planning on the part of the teacher. In particular, what to use and how to use it; what purpose and task should the task performed in the application have; what to pay attention to when developing your own application or using a third-party application. Of course, this review does not cover all the issues related to the potential of developing and creating online applications in teacher education, but we have outlined the main positions that have been and are important components for our pedagogical activities.

REFERENCES

- [1] P. Diamandis, S. Koler. *Maibutnie blyzhche nizh zdaietsia. Yak tekhnolohii zmyniuiut biznes, promyslovist i nashe zhyttia / per. z anhli. D. Kozhedub. Kyiv: Laboratoriia, 2021. 320*
- [2] *Osvita. Demografichna ta sotsialna statystyka. Derzhavna sluzhba statystyky Ukrainy. <https://www.ukrstat.gov.ua/>*
- [3] S. Vosloo. 2012. *Mobile learning and policies: Key issues to consider.*
- [4] M. Sharples, I. Arnedillo-Sánchez, M. Milrad, & G. Vavoula. 2009. *Mobile learning: Small devices, big issues. Technology-enhanced learning: Principles and products, 233-249.*

- [5] A. A. Vacas, J. I. N. González, & S. Á. Sánchez. 2019. Uso de una app móvil para evaluar la calidad de la enseñanza superior. *Prisma Social: revista de investigación social*, (27), 65-85.
- [6] A. S. Yucel. 2006. E-learning approach in teacher training. *Turkish Online Journal of Distance Education*, 7(4), 123-131.
- [7] G. Winder, A. Kern, K. Zehetner, & J. Buchner. 2023. Unlocking Potential: Creating an Innovative Learning Platform to Foster Digital Skills of Educators. In S. Singh (Editor), *The 9th eLearning Excellence Awards. An Anthology of Case Histories 2023*. 155-161.
- [8] A. Schröder, & T. Baumeister. 2015. *Social Innovation in Education and Lifelong Learning: State of the Art Summary*. SI-DRIVE Deliverable, 4.
- [9] D. Bannister, & S. Wilden. 2013. *Tablets and apps in your school*. Retrieved September, 26, 2018.
- [10] I. L. Mosenkis, L. V. Lukianyk, O. M. Stokal, V. A. Ponomarova, & H. V. Mykhailiuk. 2020. Application of cloud educational technologies for teacher competence development. *International Journal of Learning, Teaching and Educational Research*, 19(5), 289-303.
- [11] P. F. Arias, E. O. Olmedo, D. V. Rodríguez, & A. I. G. Vallecillo. 2020. La gamificación como técnica de adquisición de competencias sociales. *Prisma Social: revista de investigación social*, (31), 388-409.
- [12] J. Wishart. 2017. *Mobile learning in schools: Key issues, opportunities and ideas for practice*. Routledge.
- [13] D. A. Martínez, & P. N. Ostúa. 2019. *Juegos y simulaciones en la educación actual*. *Prisma Social: revista de investigación social*, (25), 537-548..



Professor, leading researcher Dr.habil.geol. Gotfrīds Noviks
(15/09/1935 – 07/03/2024)

Professor Gotfrīds Noviks worked at Rezekne Academy of Technologies (RTA) since the establishment of the education institution. A lot of work was devoted to further development of the Academy. Professor Noviks was the scientist: habilitated doctor of geology, vice-rector of the Science and Studies Department, head of the Department of Natural and Engineering Sciences, creator of environmental engineering study programs and program director at the bachelor's, master's and doctoral levels. He prepared more than 320 scientific publications, obtained 25 authorship certificates, participated in more than 100 scientific conferences, led scientific projects and research groups. Professor was the initiator of the scientific conference "Environment. Technology. Resources" where the scientists and researchers from foreign countries and Latvia have been participating for many years. Professor's pedagogical experience lasted for almost 60 years. He was also the author of many textbooks which are still used in many countries of the world. Professor Noviks was the founder of rock physics, the author of the first textbook "Fundamentals of Rock Physics" which was the first one in this field in the former Soviet Union. He was the member of the International Water Federation (WEF) from 1995, the member of the ecological committee and ecological education committee from 1996, the member of the New York Academy of Sciences.

Gotfrīds Noviks was born in Ludza, graduated from Viļani Secondary School, later from Leningrad Institute of Mining, where he studied geology. In the scientific field, he worked at the Moscow Mining Institute in Russia, then at the Kabul Polytechnic Institute in Afghanistan for a short period. Afterwards he decided to return to Latvia, responding to an invitation to work in Rezekne. In 1994, Professor Noviks started to work at Rezekne Higher Education Institute (now Rezekne Academy of Technologies).

He worked at the Rezekne Academy of Technologies, led the scientific work, as well as enjoyed the hobbies that brought a lot of joy and inspiration for him. Gotfrīds Noviks once admitted that his hobby was kayak trips on rivers. His idea of ecological expeditions for 1st-year students of the environmental engineering still lives on. The first expedition was organized in 1997. Professor told that he liked reading books, cooking; he was interested in photography, enjoyed the nature with forests, rivers, and mountains as well.