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THE COLLABORATIVE DESIGNING OF A PERSONALIZED HYBRID LMS USING A VIRTUAL MACHINE IN A CLOUD ENVIRONMENT

Abstract. A teacher currently needs to acquire a huge amount of educational information and knowledge as part of his/her practice for the purposes of teaching, self-study, publishing, research, language support and related activities. In the academic environment, so-called learning management systems (LMSs), especially Moodle in the European Union, have proven suitable for the processing of educational content under e-Learning. LMSs usually function as online platform, at the same time as a supplement to academic information systems (AIS) on the local servers of universities. These are used by a larger number of participants, so these do not always meet the pedagogical needs of the teacher in all the activities he/she does. For example, these do not allow multilingual support, multiple searches and mass processing of e-Learning content. There are a large number of articles in the scientific literature describing the design of add-on modules for LMS. The authors offer their own approach to solving the problem of processing educational information to support a virtual team's work. As part of collaborative research in the field of technology-enhanced education and e-Learning design, the international team in the V4 EDUPORT project is implementing a personalized hybrid system on the IT infrastructure consisting of a specially designed desktop application WPad or web application (PIKS) and a common shared remote computer (virtual computer on a cloud server with Windows 2022). In this paper, the researchers share their experiences gained with their universities' academic LMSs (Moodle and AIS) and compare their personalization capabilities level to the teacher level and their use in the cloud. Part of current and future research is the development of the PIKS internet application, which operates as a multi-functional communication channel for e-Learning purposes (including use for the visually impaired).

Keywords: learning management systems; technology-enhanced learning; e-Learning design; educational software; cloud collaboration in virtual teams; Moodle.

1. INTRODUCTION

The problem statement. Today, knowledge workers, including teachers, must process vast amounts of information and knowledge for the purposes of teaching, self-study, research, publishing, and various related activities related to their profession. However, the current state of technology is characterized by the fact that an individual is overloaded with information (e.g., email overload), up to his burnout [1], also because he has to manage multitasking as well (switch our attention between different types of information while doing different types of tasks) [2]. It is a fact that the speed at which a person can input information into a computer is the slowest stage of information processing. This is currently being dealt with by the IT field of human center computing, which according to NASA's definition, can be a combination of IT and social processes [3]. This is also related to the research results presented by the authors within the design of their own educational software.

Analysis of recent studies and publications. Technologies supporting IT integration at the teacher level are addressed within e-Learning. However, the interpretations in the scientific literature of the processes of e-Learning and their explanations are very diverse. Teachers can rely on the International Classification for Standards (ICS), where e-Learning is included in the category of ICS 35.240 Applications of Information Technology, from the global standardization point of view. Specifically, it is included in the category of ICS 35.240.90 - IT Applications in Education [4] and is covered by the Technical Committee ISO/IEC JTC 1/SC 36 - Information Technology for Learning, Education and Training.

In recent years, many literature sources have been focused on IT support for education, e.g., [5]-[9] consider the phenomenon of technology-enhanced learning from different positions and with different approaches, but the latest studies (with the exception of [1]) prefer either an educational or an informatics perspective, even though this is an interdisciplinary education-

informatics field. From the integrating IT into education point of view and implementing teachers' needs, this can be supplemented by pedagogical theories [10], [11] or software solutions [12]. There is a lack of the appropriate definition of knowledge, which should respect its interdisciplinary. An universal knowledge representation is published by authors Svetsky, Moravcik as basic element of WPad software, see e.g., in [13] (as a part of the registered utility model of 7340/2015 - the patent classification IPC G06F17/30, G06Q 10/10).

Teachers can rely, as well, on the constructivist model of e-Learning devised by Littlejohn [14], as "any technologically mediated learning using computers, whether in a face-to-face classroom setting or from distance learning".

There are different theories of e-Learning, but in principle it is a very wide range of activities that teachers perform during teaching, lecturing, conducting exercises, self-study, as part of research activities, publishing, as well as other administrative and economic activities. Part of these issues is supported by Learning Management Systems (LMSs), which function within cloud platforms (Blackboard, Canvas) or run on local servers of universities. Moodle, the most widespread LMS in the European Union, operates on them. Since education is a very complex activity, neither Moodle nor other LMS can cover all activities performed daily by teachers. On the LMS webpages of universities, it is usually stated that it is a type of e-Learning that mainly provides study courses, their creation, delivery and management. So universities design additional modules for complementing activities to LMS [15], [16]. Of course, this already requires higher IT skills, so it is not for a less experienced teacher. The effectiveness of students' use of Moodle and research methodologies are widely researched and described e.g., in [17]-[20]. It could be also mentioned, that at time of writing this paper Open Education Global week was running with around 250 webinars. In these events open LMS was also presented as a tool for open study courses. For example, main author of this paper participated on a Canadian university presenting Fanshawe's Open LMS resource (<https://fanshaweprospectcc.brightspace.com/>). Such events are activities within UNESCO OERpolicy, i.e. focused on Open Education Resources.

In this article, some aspects of designing e-Learning are discussed on the example of the infrastructure implemented within the V4 EDUPORT project. This IT infrastructure uses a specially designed software (WPad and PIKS - programmed by the main author of this article) and a cloud virtual machine, as well as Virtual learning Environment/Space (VLE). This even allows implementing a personal LMS, as shown below in examples from the practice of teaching undergraduates. At the same time, the collaborative design of additional modules to any LMS implemented within the mentioned project (researchers from five countries are working together) is also presented. In the further sections, aspects of modeling collaborative activities in the hybrid space, such as activities related to the mass creation of educational packages, publishing support and multilingual applications using Human Language Technologies (HLT) will be clarified. These also mention the partners' individual experiences with using and supplementing Moodle, or university LMS, or if these are integrated into the university's academic system (AIS). Pilot modeling and implementation of these collaborative activities in the hybrid space are also the subjects of our future research (a utility model registered at the patent office is also used).

The research goal. As part of collaborative research in the field of technology-enhanced education and e-Learning design, the international team in the V4 EDUPORT project is implementing a personalized hybrid system on the IT infrastructure consisting of a specially designed desktop application WPad or web application (PIKS) and a common shared remote computer (virtual computer on a cloud server with Windows 2022).

The research goal is to present V4 EDUPORT IT Infrastructure as the possible model of IT infrastructure for designing of a personalized hybrid LMS using a virtual machine in a cloud

environment and consider the examples of its application within the activities of the international team of researchers.

In this paper, the researchers share their experiences gained with their universities' academic LMSs (Moodle and AIS) and compare their personalization capabilities level to the teacher level and their use in the cloud. The project manager Stefan Swetsky, who is also a software designer, has developed the WPad desktop application that was installed on a remote server (Virtual Machine with Windows 2022) that acted as a shared computer. Partners from V4 countries (Poland, Slovakia, Czech Republic, Hungary) and Ukraine, who also have the WPad program installed offline, joined. The shared environment was used by the project team and this inspired the idea the usage of a personalized hybrid LMS in a cloud environment. *Stefan Swetsky* proposed the methodological approach for the investigation, he wrote Introduction, Conceptual Framework, the Results - examples of use in teaching undergraduates and collaborative research within the international project V4 EDUPORT, and Conclusions parts; *Dariusz Mikulowski* described and tested the approaches to adjusting the software for people with disabilities, he wrote 4.3. LMS from a blind and visually impaired (BVI) experience point of view; *Oliver Moravcik* investigated the technology-enhanced learning and a personalized knowledge-based approach to the integration of digital technology into teaching and associated processes, he collaborated in defining the characteristics of the issue from the teacher's point of view and conceptual framework; *Branislav Mišota* gathered the experience of the teachers from the personal use of LMS, he wrote 4.5. Examples of LMS use in STUBA; *Enikő Nagy, Peter Galambos and Tamas Haidegger* elaborated 4.2. Example of the personal LMS use the a Hungarian Óbuda University; *Pavel Smolka* wrote 4.1. Example of the LMS use at a Czech university; *Lina Čeponienė* wrote 4.4. Example of the personal LMS use at Kaunas University of Technology; *Mariya Shyshkina* contributed to the analysis and evaluation of the experience of WPadV4 implementation within the cloud-based settings and wrote 4.6. Experience of using Moodle in Ukrainian universities.

2. CHARACTERISTICS OF THE ISSUE FROM THE TEACHER'S POINT OF VIEW

Regarding the use of LMS, it should be remembered that it is a software tool that allows learning content or activities to be organized and managed, but does not improve the quality of the content or its impact on the teaching. It is just a tool, similarly like a person has a musical keyboard at home, which allows him to choose an instrument, tempo, volume, drums, automatic accompaniment or write notes, choose a demo song, record tracks, and a bunch of other functions, but to play or to invent a melody, whether an entire song and the lyrics must be created by the individual himself. Analogously, LMS is a tool, but the teacher as the key player in teaching determines or designs the learning content and its level. He decides how to use it, how to deliver it, and how to evaluate the feedback, i.e. to what extent the students understood his interpretation (from cybernetic point of view, it is basically a process, where the result of the gained knowledge is feedback). The quality of the LMS is also assessed based on whether the teacher could deliver existing own or external content through the LMS, e.g., according to SCORM (<https://scorm.com/>), which is a set of technical standards for e-Learning products (meta data is based on the XML language).

Although more modern systems allow the design of e-Learning study courses, this should be considered as a function of a support tool, with the teacher himself decides the computer formats in which the content will be created. Currently, there is a great incompatibility of computer formats, software, hardware from the point of view of teaching or self-study. In principle, with the help of a computer, a teacher can use texts, images, sounds, visualization, videos, or a combination of them. Then he creates thematic blocks from these, which he either

uses as needed, in combination with face-to-face learning in the classroom or asynchronously, that is, individually within the online spaces provided by the LMS. The fact that a lesson is usually 40 to 50 minutes long is rarely mentioned in the professional literature, and the teacher needs to have concentrated content, which is suitable in time duration so useable within the lessons. In other words, the teacher may also have pedagogically high-quality videos that last up to an hour, but the duration of the lessons is shorter. In addition, it is necessary to combine several thematic areas when teaching beginner bachelors. For example, when teaching the basics of industrial environmental protection, the teacher must also use sequences of knowledge from chemistry, biochemistry, mathematics, and physics during his presentation. And all this is complicated by the fact that new students who come to the university have different apriori knowledge and therefore different understanding of the teacher's interpretation. It is known that today's undergraduates have significant deficiencies in mathematics and chemistry. Therefore, an experienced teacher needs to have suitable additional materials at his disposal, which he may use within the lessons or as study material in the virtual educational environment of the faculty as needed. Logically, LMS systems cannot solve these problems, so teachers create their own learning content. To support their activities with the content, they can also write additional software applications or have them produced by the universities' programmers' team. The basis of learning is working with content, that is, with knowledge that is transferred between teacher and student in an interactive way. In case this knowledge or content is digitized, the teacher will have text, visual, audio-visual files at his disposal, and the transfer of learning content practically means that the teacher transfers a large number of files between his personal computer and online environments, such as clouds or the educational virtual space of the faculty, or within his private web hosting (this is also important in case the teacher changes workplace and the "old" content remains on the server of the faculty or an external cloud). However, the scientific literature practically does not emphasize the fact, that the teacher has a huge number of files with educational content on his computer, which he transfers daily between the directories of his computer, and LMS systems do not deal with it. Everyone creates a certain structure of folders and files. Certainly, there might be colleagues whose entire computer screen is filled with directories or, conversely, colleagues who have created a sophisticated directory structure. Today's teacher has almost a small private Internet on his own computer. Therefore, similar to searching with browsers, he needs to search on his own computer, in the web environment or in the virtual learning space of the faculty. However, deeper computer skills are needed, which is helped by file managers, for example, the well-known Total commander. Even though management systems are specialized for teaching support, it should be clear that LMSs are not sufficient to fully satisfy the teacher's needs or might even be unusable in some cases.

Consequently, it is necessary to have specific educational software tools from which there is a lack [21]. What is more important, there are no clearly known theoretical starting points in terms of didactic algorithms for which machine codes could be written. As part of the authors' research in the field of telecommunications, the need for IT integration into teaching emerged in 3 areas: design of pedagogical algorithms, design of software algorithms, and as a separate area, the solution's adaptation and compatibility along operating systems, hardware, software and cloud infrastructure. Thus, it is a hybrid environment that teachers have to use today, LMS systems are basically online platforms, whether they work on clouds or locally on university servers.

The main author of this paper has been working as a teacher, researcher and programmer for years, designing technology according to the daily needs of teachers in teaching, research, publishing and related activities. Based on his experience, paradoxically, it is much easier to create didactic program algorithms than work with content in a hybrid environment. It is not easy to realize that it is a big problem to place the learning content on a small computer screen, in the necessary time and to be able to work with it dynamically, for example, regarding the

motion of the text, images, audio-visual inputs and outputs. Nowadays, the progress of technology is so fast and affordable, even at the level of individuals, that one can design his own LMS system, or various add-ons to it that LMS does not support. And similar to when playing on the keyboard for creation of songs, the teacher creates the content according to his requirements, tailored to the needs of the teaching. An example is the modeling of collaborative teaching. The teacher found that beginner students had deficiencies in the basics of chemistry, so they could not understand the course content on the basics of industrial environmental protection. In this case, the students had the WPad program installed on each desk in the classroom, with which they created WPad tables. So they received the task that each student pair should perform an Internet search with the OPERA browser on selected topics, for example the periodic table, chemical bonds, chemical calculations, formulas, and then copy the received outputs from the browser into the WPad tables and add a description. Since they had a virtual learning environment available on the faculty's server, they also received this task in the online space in the form of an HTML table. Since the classroom computers were not networked, the teacher downloaded the WPad tables from the students' computers to a USB stick, converted them to a pdf file and also placed it on the faculty's educational environment. This material was then used by students in the following semesters. Another area that cannot be comprehensively solved by LMS systems is language support for teaching. This is necessary for the reason that English or another foreign language is not the native language of undergraduates and teachers. For undergraduates, Wikipedia is useful from this point of view, where the basic areas are sufficiently professionally processed and are available simultaneously in several languages. This was used, for example, in teaching photosynthesis and the basics of chemistry. In this way, the teacher's teaching content was expanded by other possibilities (usually a small group of students used it for their self-study to expand their knowledge of study and language).

3. CONCEPTUAL FRAMEWORK

Since it is not possible to write source codes - information algorithms, if pedagogical/didactic algorithms are not described, it is obvious that LMS cannot contain functions for something that does not yet exist. For educational institutions, LMSs are primarily useful in enabling the automation of administrative and managerial processes (although educational content forms an important possibility to design tests, etc.). If these are integrated into the Academic Information Systems of the universities, they form a support tool for the teachers, mainly for registration processes, they, as employees need to do, e.g., to manage student registration for exams, to assess students within ongoing study programs, while the use of internal mass emails is also a useful tool. In other words, regarding IT integration LMS systems are more important for automation at university level than for automating the activities of individual teachers, since e-Learning is not the only activity performed by a teacher.

The authors' long-term research in the field of technology-enhanced learning is focused on the automation of educational processes for supporting the teachers' activities and needs. It assumes that the educational process is a knowledge-based process. Knowledge is its parameter, by which the process can be generally controlled according to feedback or by eliminating the slowest points of the process.

In the years 2007-2008, the idea was that the teacher is a knowledge worker who needs to process a huge amount of multilingual knowledge and needs to be equipped with personal sophisticated technology. At the same time, it was emphasized that the teacher should not see differences between online and offline working, and the number of interfaces, windows, and software should be minimal not to click constantly between them.

In this empirical phase, it was possible to develop a multi-purpose all-in-one software WPad (current name) for teaching the undergraduates and as part of pre-service teachers'

diploma theses, which was also used for blended learning in the classroom. When publishing the progress of research in comparison with the current state of technology, the question arose how it is possible to cover with one program activities for which the teacher needs several software modules in the field of informatics (applications were presented at thematically different conferences and in scientific journals). It might have been due to the database structure that forms the basis of the WPad software application. This structure was declared as a virtual unit of knowledge, so the WPad tables created by the program fulfill the function of virtual knowledge tables in which learning content is inserted and concentrated. Since computer software cannot be patented within the European Union, two technical solutions were registered at the patent office instead, the essence of which are that the WPad table can be used to convert unstructured and undefined data into semi-structured or structured forms.

The reader can find further details in several publications of the present article's authors [23, 24], in which the theoretical foundation based on the knowledge WPad table is described as a universal representation of knowledge, which can be understood by both the computer (processes it as an informatics structure) and the human (uses natural language). From a cybernetic point of view, it is a kind of isomorphic switch between human mental activities and physical computer processes. It is necessary to emphasize that the learning content is inserted into knowledge tables as selected, while LMSs use unselected content that is stored in computer files. For creating the content of study courses it is fundamental, that the WPad table can be converted to an HTML table with a simple click, so even a less skilled user can create his own table immediately, that will be a ready-made e-Learning material, since the HTML format is the basic language of the Internet. In this way, one can create his own educational sets and packages, i.e. personalized learning content, on the virtual educational environment of the faculty or on his web hosting. All he needs is a regular computer with installed Windows and WPad educational software.

The concept of "selected" learning content is very well understood by students who use the WPad to take notes during lectures and exercises, when the teacher tells them to write down in the table what they need from his explanation or instructions. It's a complete paradox that practically no teacher will understand it at first, even if dozens of outputs are shown to him. One of the reasons is probably that teachers do not know such a simple way of processing personal information and knowledge, and partly also that they have lower skills to install the program themselves and familiarize themselves with it.

The term "selected" can be explained by creating a presentation in PowerPoint, which teachers know intimately and thus everyone will immediately understand that the presentation was created from several sources. So, from some bulk content, they create one computer file that contains only selected useful content. Similarly, in the case of the WPad table, not the entire content is inserted into it, but only a part, e.g., annotation or abstract. In addition, WPad educational software also provides sophisticated activities, the description of which goes beyond the scope of this article. In case a teacher wants to analyze the proceedings of a conference, he can drag it all into a table, select the part he needs and delete or filter out the rest.

For working with educational content, the desktop application WPad, extended by the Internet application PIKS for the purposes of interactive communication, works with defined knowledge. Thus, it can be used to automate learning processes, in which knowledge fulfills the function of a controlled parameter of the process and works as a useful selected content. In contrast, LMSs work with vague, general and unstructured content. Using the WPad application on a cloud virtual machine with a Windows 2022 server (it connects to the same WPad application and tables that the teacher has on his laptop) or the faculty VLE, a more experienced teacher or in cooperation with the relevant IT workplace can also create his personal LMS system. However, it is more appropriate to use the presented IT infrastructure for more

sophisticated activities that are not provided by LMS. The laptops work faster in an offline environment than online.

4. EXPERIENCE OF THE TEACHERS ON THE PERSONAL USE OF LMS

4.1. Example of the LMS use from a Czech university

From the point of view of using MOODLE, a co-author from a Czech university highlights the potential of LMS Moodle in teaching students, declaring that LMS Moodle offers a comprehensive system for managing learning activities. In this system, the area of identity management and connection with external services and the area of teaching implementation can be identified. The identity management area is connectable to other meta-directories or enables separate identity management. Examples of linkable services can be Active Directory or OpenLDAP, which provide users with a comfortable situation of one access to multiple systems. Identities in the LMS Moodle environment are assigned to individual roles within individual courses. Thus, one identity can hold both the roles of student and possibly teacher, or the role of higher management of the system. Connection to communication modules supporting both off-line and on-line communications is also a matter of course.

The key component of the LMS Moodle is the part that implements the learning activity. The key unit of this part is the course, which can be a representation of the whole subject, part of the subject or a one-time educational activity. As already mentioned above, in this part the assignment of roles to individual identities is implemented. In the course, one can also work with the group apparatus, which allows individual identities to be grouped based on different criteria.

The course configuration allows to set the basic characteristics of the learning environment, which is then composed of individual modules. These modules can be divided into two basic groups according to their nature. The first group consists of publication modules, the aim of which is to publish study information towards the student. Here, LMS Moodle uses both internal repositories and connections to online resources via the http or https protocol. When activating the extension modules, one can integrate platforms such as Dropbox, YouTube, GoogleDrive, OneDrive and others.

The second group of modules in LMS Moodle are activity modules, which assume active involvement by students, both in the form of synchronous or asynchronous approaches. In this category one can find modules such as tasks, polls, questionnaires, communication modules, tests and others. A key element of these modules is the ability to evaluate the student in a variety of ways that respects the type of school. Individual assessments can then fulfill defined competencies. These partial assessments create a profile of the student in terms of meeting study standards.

Filling out the student profile and using its structure are key tools for managing the student's progress through the course based on the gradual opening of study units and adaptation of the study content with the aim of adapting the structure and form of the study environment to the individual needs as much as possible. The modular system enables this adaptation not only on the basis of performance parameters, but also on the basis of diagnosis of study prerequisites and preference of study forms of individual materials.

The configuration of the appearance of this environment is based on the same logic of adaptation, when based on preferences, age and results, it can be automatically adapted to the student's individuality.

4.2. Example of the personal LMS use from a Hungarian university

At Óbuda University in Budapest, Moodle is used extensively at all levels and types of education (see <https://elearning.uni-obuda.hu/?lang=en>). In recent years, the extensive use of Moodle is also due to the fact that during the COVID pandemic, almost forced development and rapid solutions were needed to ensure the high quality of the education [33]. Moodle is also regularly forms the basis of excellent research projects and support the staff at Óbuda [34-36]. The specific Moodle element allows to work with the database and to train the SQL language on practical examples proved to be particularly useful in the training sessions provided by the Antal Bejczy Center for Intelligent Robotics. The project models the creation of educational packages and communication channels (PIKS), which are PHP/MySQL web applications where SQL is also used, so that integration with the Moodle database elements can be tested. For example, html scripts for PIKS and educational packages are also modeled and tested in the form of multilingual audio-outputs in the languages of the V4 countries and Ukraine, which can also be added to the Moodle system in its final version.

Nevertheless, the core of Óbuda University's MOOC and e-learning platform, there Carpathian Basin Online Education Centre (K-MOOC), was established at the Óbuda University much earlier, almost 10 years ago, on September 1, 2014. It aims to provide the available knowledge for higher education based on Moodle for lifelong K-MOOC learning courses, to make available the knowledge that can be obtained in higher education through the development and distribution of online courses in Hungarian. It focuses primarily on Hungarian subjects in the Carpathian Basin, and secondly to all native Hungarian speakers around the world. The Centrum operates as a network, the participants of which are Hungarian-language universities/colleges in Hungary and across the border. Since its establishment, 22 institutions in Hungary and 14 institutions across the border have joined the network, and more than 30,000 students have participated in its courses so far. In terms of its form of education, it is an online course recognized with a credit or certificate, which is open to everyone, the courses are not fixed to a place, and the pace of learning the course material is regulated by the student. The equal institutions joining the Network prepare and announce credit courses in Hungarian in all fields of science, and their students can take courses from any institution of the Network, thus increasing the range of their freely chosen subjects. In the spirit of lifelong learning, the K-MOOC courses are also available free of charge to those who have already left higher education institutions, but wish to return, want to learn more, acquire new information, and also to those who have never been a student, but still get a glimpse they get into higher education, they can test and train themselves. Within the framework of this project, the basic goal is to increase the course offering by developing 45 new study materials, and the secondary goal is to strengthen the infrastructural background that ensures the functioning of the system.

4.3. LMS from a blind and visually impaired (BVI) experience point of view

According to the experience of a BVI teacher, probably the best-known solution today is a suite of applications from Google. It is not only a universal solution but also available to various groups of users with special needs, such as the blind and visually impaired (BVI) persons. When one consider a scenario where a BVI teacher needs to conduct online lessons for sighted but also visually impaired students, he can use, for example, a Google document as a whiteboard that he shares among all students. To share a Google document or spreadsheet for his requirements, all he need to do is go to the menu after opening it and turn on the accessibility options for the screen reader and Braille display. Once this is done, a change to the content of the document or worksheet made by any participant is read by a screen reader for the BVI teacher. It is a very useful function, but it causes problems when several people are working on a document at the same time, e.g., a class of several students. Because each content change is

read on an ongoing basis, the number of these messages interferes with the work on the document itself, although this option can be turned off.

Google meet application can also be a good solution to support providing online lessons. A blind teacher can share the entire screen of his computer or a single window and thus present the discussed issues to the students. In addition, a special feature built in the visual settings of the NVDA screen reader (<https://www.nvaccess.org>) helps in this, where the place where the teacher places the cursor is surrounded by a frame that students can see. Due to this, they know what the teacher wants to point out. The only completely unavailable app in the Google suite is the whiteboard built into the Meet app. Its content is not readable by a screen reader, so it cannot be used by a blind person.

Other solutions such as Jamboard (<https://jamboard.google.com>), Zoho Writer (<https://writer.zoho.eu>), WPS Docs (<https://eu.docs.wps.com>) or Slite (<https://slite.com>) are much less available for BVI because they do not support full keyboard navigation, font enlargement, contrast changes and do not work well with screen readers. However, in all these systems, the problem is the presentation of mathematical content that should be read in text form for a blind person. Although there is a special screen reader plugin called access8math (<https://github.com/tsengwoody/Access8Math>). It allows to read and edit mathematical expressions in LaTeX AsciiMath and MATHML notations. However, this is currently a partial solution because it does not take into account languages other than English and braille mathematical notations that are different for different countries. In addition, there are such solutions supporting teaching mathematics as Euromath [25] or Lambda [26].

A BVI teacher can also use the PIKS channel to communicate with students between two lessons when they do their homework. In this case, all entered data can be added as records in the PIKS channel table dedicated for teacher and students. How does it work? When one add a record, the name of the entry in the first column has an asterisk in front of it. After confirming the form with incorrect data, one can use the undo function from the browser to return to the record adding form with previously entered data. One can correct them there and confirm the addition of the record. Note, that after performing this operation, one already has two records with asterisks. One can repeat the operations of correcting previously entered records until one decides that the content of the entry is correct. Then one can delete the asterisk in front of the name from the first column and in this way one saves the record permanently in the database. Then one can remove all intermediate records that had asterisks using the appropriate PIKS channel function. It would be good mainly if students could enter temporary records and the teacher would have the right to validate them permanently. A good solution within the PIKS testing would be the ability to highlight any record in an existing table and then load it into the add form and make corrections. Though having all entries in one table is a good solution this seems to be not very convenient for a BVI teacher if he needs to work quickly with students to communicate. Instead, he can simply use a collection of folders on a cloud drive to check student assignments. It works in the way that each student has a separate folder shared by the teacher. In this context, PIKS is a starting beta version, so, in principle each students can have his own PIKS channel.

As one can see, different IT tools are used depending on the specific activities and what teaching technology the teacher chooses, e.g., for lectures, exercises, tests, examinations, assessment, including self-study.

4.4. Example of the personal LMS use at Kaunas University of Technology

In the course for teaching Unified Modeling Language (UML) for undergraduate students at Kaunas University of Technology, Moodle is used as a learning management system, which is also enriched with the elements of gamification, for increasing student engagement and

motivation. The analysis of students' grades confirmed the hypothesis which states that students' grades can increase as a result of applying gamification to their learning process [15]. In this context, the results of students' questionnaire (based on the Intrinsic Motivation Inventory scale) also confirmed the hypothesis which states that gamification can improve students' motivation.

This is an example of design of additional modules for accompanying activities as above-mentioned. For these activities also file system repositories, portfolios, media (video), SCORM package, e.t.c., can be used. This however requires higher IT skills level (see https://docs.moodle.org/39/en/Table_of_Contents).

The co-author of Kaunas University of technology uses Moodle for several courses for both graduate and undergraduate students, e.g., UML teaching course, Information Systems Project Management Technologies, Teamwork in Information Systems Projects, and Software Systems Analysis and Design Tools. Moodle environments of the courses cover the whole study process, i.e. lecture material, video recordings of the lectures, material for laboratory works, assignments for students, tests, and any required additional resources for independent learning. It is mandatory for the students to submit their assignments to Moodle in their courses. These courses usually have several Moodle tasks of the assignment type which are used to present the task for the students and to collect their works in a form of files of required type. The grades for these assignments can also be provided in Moodle environment, although in the university the internal Academic Information System is used for student grades management. The tests are used for students final exams of mid-semester exams. Moodle enables drag and drop onto image type of question, select missing words type of question. It can be added that My SQL database is used as a part of any Moodle installation.

4.5. Examples of LMS use in STUBA

As part of the V4+ACARDC consortium, some of the authors conducted an online survey at the parent technological university and at other Slovakian universities. As a result, it was found that technological universities have mostly LMS integrated into Academic Information Systems and Moodle is much less used than at other non-technological universities. At these universities Moodle is presented under the heading of e-Learning, as an example the Comenius University https://moodle.uniba.sk/?lang=en_us which has the following on its website:

"Comenius University uses the e-Learning management system (Learning Management System) Moodle. Every teacher and employee of the University can use Moodle to support teaching and communication with students".

The main author of this article simultaneously as a teacher, researcher and designer has solved e-Learning with his own program (predecessor of WPad and PIKS) back in 2007-2008 within the framework of teaching undergraduates for several courses. At that time he also experimentally tested Moodle on a home computer, but the remote faculty site where he taught did not yet have sufficient internet connection for about 15 computers. So he implemented his personal LMS and submitted his e-Learning system in the ICETA 2007/8 conference competition for the best e-Learning solution [27].

He further developed this system as part of his research on Technology-enhanced learning and this also formed the core of his habilitation thesis on mass production of educational content and e-learning [28]. In it, he presented the idea that the automation of IT support for teachers and thus e-Learning design must be based on pedagogical principles, i.e. primarily based on the processing of the content to be taught and not solving as a test of a technology to see whether it can be used in teaching or not. The details have been given in the previous section Conceptual framework.

Thus, in the context of this paper, the main author uses a personal LMS, which he supplements with applications from teaching, self-study, research, and also combines with the University's Academic Information System (AIS) into which e-Learning is integrated as needed. Figure 1 illustrates a snippet from the university's AIS portal. Thus, most of the activities under the categories My teaching, eLearning, Personal management and eAgenda are handled by the user menu items of his personal software. Section 5 provides a number of examples of implemented applications and add-on modules used in teaching undergraduates, dissertations or research.



Figure 1. Example of integrating LMS into Academic Information System (STUBA)

To complement this, an example of the use of e-Learning integrated into a university AIS in a Basics of Management and Enterprise course can also be given, where the teacher assigns tasks to students via the AIS application and sees their chronological progressions. At the same time, the teacher monitors the submission of the assignments by the set deadlines, so that the students are also better informed through graphical interpretation whether they are completing their assignments in time. To complete the administration of handed-in work, feedback on the quality of students' work is also provided in an effective way. This also allows them to improve their skills and knowledge. For students it is easy to understand and use this functionality of AIS. For teachers, in turn, its use leads to an increase in the quality of evaluating assignments and working with online resources.

4.6. Experience of using Moodle at Ukrainian universities

Forming a high-tech educational environment in educational institutions is an essential prerequisite for the training of specialists capable of active, expedient, scientifically based use of information and communication technologies in their professional activities.

In Ukraine, significant results have been achieved in the study of the theoretical and methodological foundations of modeling and designing the information and educational environment of open education (Yu. Bogachkov, V. Bykov, G. Kravtsov, V. Kukharenko, A. Manako, L. Panchenko, S. Semerikov, O. Spivakovsky, and others). In particular, in the works of V. Bykov, models of organizational systems of open education, models of a single informational educational space; methodological systems of electronic distance learning; models of the education management system at its various organizational levels; modern training of informatics teachers in higher pedagogical educational institutions and others were considered [29]. These works serve as methodological bases for further research in this direction, given the cloud-oriented environment as a new stage in the development of open education systems.

On November 4, 2022, the Tenth international scientific and practical conference "MoodleMoot Ukraine 2022. Theory and practice of using the Moodle learning management system" was held in Ukraine. The event was organized by the International Scientific and Educational Center of Information Technologies and Systems of NAS of Ukraine, the Institute for Digitalization of Education of NAES of Ukraine, the Kyiv National University of Construction and Architecture. During the work of the conference considerable experience of using the Moodle system in Ukraine was collected and processed.

The conference scope covered organizational, technical, technological, didactic, methodical issues of using LMS Moodle in institutions of higher education, in the system of training and professional development, in the process of continuous education, and included the following areas of content:

1. Experience in implementing and using the Moodle system in distance learning and network support of the educational process.

2. Development of the Moodle system. Creation and use of new Moodle modules, integration of Moodle with other software tools.

3. Organizational, pedagogical and methodical problems of using the Moodle platform.

Access to reports and video recordings of speeches is free on the conference website and does not require registration: <https://2022.moodlemoot.in.ua/>

The participants of the conference developed a number of recommendations that contribute to the solution of those problems that prevent the successful development of education in this direction. Among the scientific problems, the role and place of Moodle in the system of tools and technologies used by the teacher is considered. The system of planning the teacher's work in distance or mixed learning is fundamentally changing, it should be built precisely on the planning of the teacher's individual work with a student, and work with a group can be considered as an additional form. In this regard, the issue of maintaining a personalized learning environment came to the fore.

Considerable attention is paid to the integration of Moodle with other learning tools, which should be useful in studying various disciplines, in particular, programming and physics [30]. Research was conducted at the Institute for Digitalisation of Education using a cloud-oriented component based on the Moodle system installed on a virtual server with the Ubuntu 10.04 (Lucid Lynx) operating system [31]. It is a cloud-oriented solution that allows to achieve more flexibility, openness and adaptability of the learning environment, therefore considerable attention is devoted to this modern approach.

The problem of integrating Moodle with other tools is quite acute and is therefore the subject of numerous studies and discussions. The plug-in technology is generally used, but it is not always convenient, when, for example, the programming tools required for the teacher's work are not available in the repository. A separate group of studies deals with assessment issues, which are quite controversial, because they concern to the design of a personalized learning environment [32]. The researchers also note that the teacher-student communication system is not flexible enough, which is also related to the problem of integrating various messengers into the Moodle environment.

The cloud computing approach to the service-based educational environment design is considered in [37]. The adaptiveness of the environment is stressed. LMS Moodle is also a service-based system still the cloud-based approach may give a more flexible, mobile and easy for renovation environment. It may be an especially sensitive factor in the case of IT learning as it requires the combination of many kinds of services deployed on different platforms. The whole system of services may be maintained and retrieved within the cloud-based settings ready to be flexibly updated in case of new educational tasks.

Given the significant pedagogical potential and novelty of existing approaches to design a personalized cloud-based learning environment, its formation and use in educational

institutions still require theoretical and experimental research, clarification of approaches, models, methods and techniques, possible ways of implementation. In particular, the theoretical and methodological aspects of determining the structure, functions, means and technologies of the organization of personalized learning and designing an adaptive cloud-oriented educational and research environment, forms and methods of using cloud services for supporting various types of educational and cognitive activities require more attention.

5. THE RESULTS - EXAMPLES OF USE IN TEACHING UNDERGRADUATES AND COLLABORATIVE RESEARCH WITHIN THE INTERNATIONAL PROJECT V4 EDUPOINT

5.1. Examples of use in teaching undergraduates

5.1.1. STEM teaching - Chemistry (2011)

Applying the WPad, it was sufficient to use more or less texts in the classroom with computers when teaching management courses, but for subjects such as chemistry or the basics of environmental protection, it was necessary to visualize formulas and diagrams or video tutorials. Although only plain text can be written into the WPad tables, by working as a HTML editor, the visualization and tests and the electronic scripts for each study course could be implemented. In practice, this was managed by taking pictures of the diagrams from the tables, scanning them from paper, and calling up links to offline or online images from the tables. Figure 2 shows such a scheme (left). A few simple tests like the one on the right were also performed with the program. The advantage of WPad is that when the teacher makes a basic test in one row of the table, then by copying it to the next row and editing it, the production of the test set will be automated. Surprisingly, the students in the class liked these tests, probably because they performed self-assessment and they could go back and correct them.

The image shows a screenshot of a digital learning tool interface. On the left, there is a scanned handwritten document with various chemical formulas and diagrams. The formulas include the ideal gas law $pV = nRT$, molar mass calculations $M = \frac{m}{n}$, and a diagram of a gas cylinder with labels for 'gas', 'liquid', and 'solid' phases. On the right, there is a digital test interface with two questions in Slovak. The first question asks which elements are not inert gases, and the second asks which elements are not in the periodic table.

ZÁKLADY => Ktoré z týchto prvkov nepatria medzi inertné plyny

- :: kyslík - fluór
- :: hélium, neón
- :: radón, kryptón

ZÁKLADY => Ktoré z týchto prvkov nepatria do periodickej tabuľky

- :: Americium
- :: Kurčatovium
- :: Luténium

Figure 2. Screenshot of scanned hand made schemas and teaching test

5.1.2. STEM teaching - Communication channels

As part of the integration of IT into the teaching of bachelors, there was a need to connect undergraduates from the classroom to the faculty's web. For this, an online version of PHP/MySQL was programmed, which served as communication channel for individual

courses, so that students could communicate from the classroom or from home. It was also used during research for cooperation with foreign researchers. Such communication channels are universal, so the teacher could use them for testing students and also for distance learning. Figure 3 illustrates such a case. Students sat in the classroom and viewed the assignment from the communication channel. From a methodological point of view, the teacher used diagrams from books or hand-drawn. The picture shows five "schemes" and the students were specifically assigned to explain spectra, hybridization or how Daniel's cell works in the oral exam. They wrote the answers into the communication channel, and when they used formulas or equations, they wrote them on clean paper. It may seem old-fashioned to orthodox technological adherents, but it should be remembered that manually drawing a diagram requires max. a few minutes, but using existing computer programs it would take tens of minutes (however, the teaching hour is shorter). Computer program, video, etc. can be ingenious, but unless these can be used operatively during the lesson, these will be useless in practice.

Note, that in case the teacher knows the PHP language, he can also design interactively solved examples in this way and place them in the faculty's virtual learning space (for example, this was used to design calculations from chemical thermodynamics). It can be seen from the previous parts that the educational software WPad and communication channels (predecessor of today's PIKS version) were used for activities provided by LMS and VLE systems, i.e. these also performed the function of the teacher's personal LMS and VLE systems.

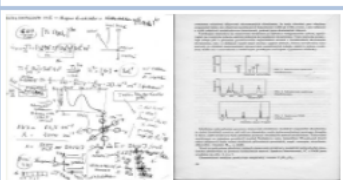
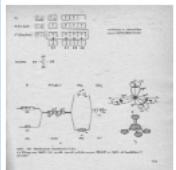
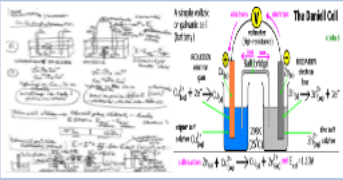
Skúste vysvetliť spektrá (kliknite aj na číslo záznamu)	CUPA	SKUSKA	2011-06-10 DPMTF	
Popíšte hybridizáciu metánu (kliknite aj na číslo záznamu)	ANDRISIK	SKUSKA	2011-06-10 DPMTF	
Popíšte Danielov článok (kliknite aj na číslo záznamu)	REPKOVA	SKUSKA	2011-06-10 DPMTF	

Figure 3. Screenshot of using communication channel for final exam in Chemistry course of study in which the hand made schemas were applied

5.2. V4 EDUPORT examples

The given examples from the teaching of undergraduates illustrate the initial stage of development of the educational software WPad, which user menu was gradually expanded according to the situations implemented in the classroom and in research in the field of Technology-enhanced learning. e-Learning design. Currently, both WPad and PIKS (Personal Information and Knowledge System), a new version of communication channels, are being tested within the V4 EDUPORT project for teachers' collaborative activities, and a hybrid IT infrastructure is being used, the model of which can be seen on the Figure 4.

As can be seen from the diagram, the project manager, who is also a software designer, has the WPad desktop application on his computer working as the control software. The same

WPad was installed on a remote server (Virtual Machine with Windows 2022) that acts as a shared computer. The partners from V4 countries (Poland, Slovakia, Czech Republic, Hungary) and Ukraine, who also have the WPad program installed offline, join to it. The collaborative pilot creation of educational packages and educational content is managed on a virtual computer that directly connects the WPad tables with the teachers' tables having on their laptops. e-Learning outputs are transferred to the university server, where PIKS channels are installed on the university's database server. It is a PHP/MySQL internet application, so the data in the WPad table is written in the standard way, just as when using an internet chat (PIKS can provide more functions than a simple chat, e.g., like Wordpress). Partners use a common remote computer (Virtual Machine) to work with documents, while they can also use external cloud services, such as BOX, Google Drive.

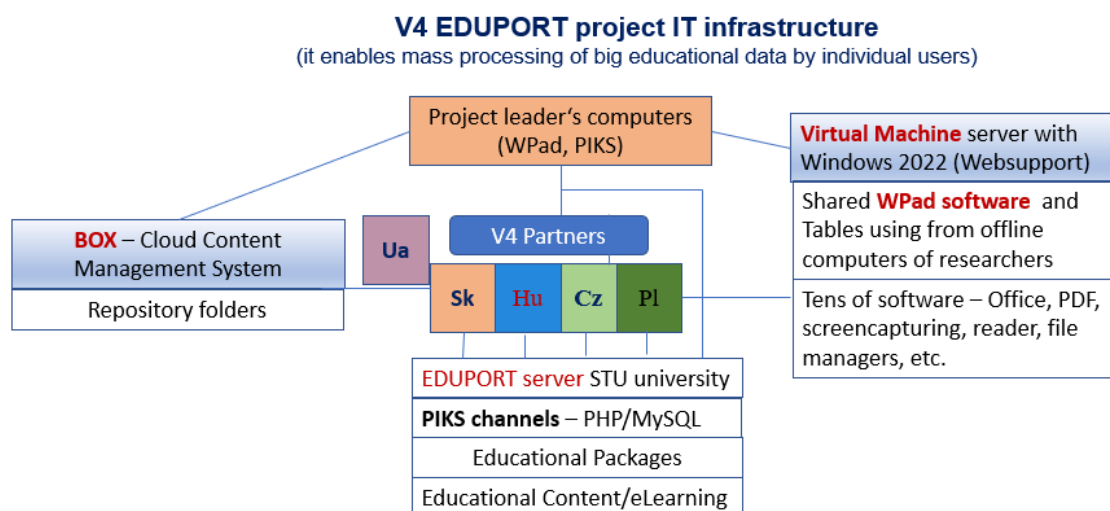


Figure 4. The model of V4 EDUPORT IT Infrastructure

5.2.1. Multilingual audio outputs (V4 languages and Ukrainian)

Because the implemented CSA project (Coordination and Support Action) is solved at regional level, the researchers' effort is to design multilingual outputs in the languages of the V4 countries and Ukraine. WPad tables are used for these purposes, taking advantage of the fact that WPad is also a HTML editor and outputs on a laptop or remote computer are therefore opened by the default browser. The Figure 5 shows a sample of such an audiovisual output.

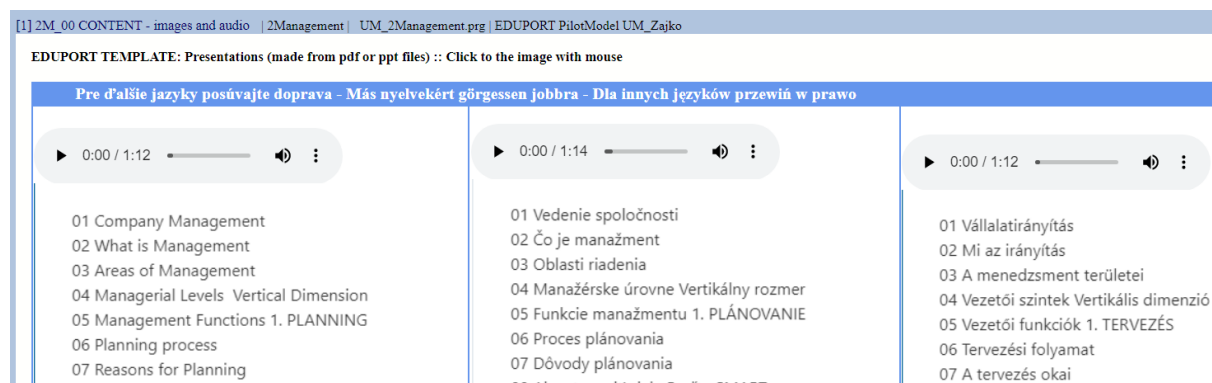


Figure 5. Modeling multilingual teaching outputs using the knowledge tables

5.2.2. Educational packages design

Users selectively enter educational content into the WPad table, but they also have educational content stored on their computers in thousands of computer files in various formats. In this case, the content concentration and navigation are implemented in such a way that WPad has the option in the user menu to create a WPad table automatically, which links the selected files for the given topic. This creates a raw educational package. This table can be modified, edited and always converted into an output HTML table by the teacher. The following Figure 6 illustrates such an educational package. In the first phase, a raw WPad table was created, which is functional, but in case of pedagogical purpose usage, it is advisable to edit the texts, add HTML tags to it (the text on the right is inserted as an image taken from the beginning of the pdf-file), or write notes or instructions for students.

Figure 6. Modeling educational packages design

5.2.3 PIKS testing when using a Smartphone

<ul style="list-style-type: none"> • Mobile phone testing <p>Testing from smartphone</p>	Now I am testing PIKS from smartfone whithout electriscity
<p>[178] MSHY :: 2023-01-30 EDUPORT</p> <ul style="list-style-type: none"> • Mobile phone testing: it works <p>Testing</p>	The testing successful! I have uploaded form without electricity. This means that I can use PIKS in autonomus mode. This is very convinient because the periods of unlocking are still rather large. For examle now from 12.00 to 16.00.
<p>[175] MSHY :: 2023-01-27 EDUPORT</p> <ul style="list-style-type: none"> • Speech recognition: Dictating to Google translator <p>Speech recognition</p>	Марія, продовжуй тестувати все, що тобі спадає на думку. Я додав в меню гугл-перекладач. На семінарі я презентую нашу співпрацю як тестування диктанту зі смартфона. Тоді ви виставляєте нам рахунок. Ви можете видалити цей запис.
<p>[173] MSHY :: 2023-01-27 EDUPORT</p> <ul style="list-style-type: none"> • Supper that dictation works <p>Testing smartphone dictation in native language</p>	<p>The chat works well with the voice Well done Everything well recognized the citation with the smartphone everything was successful sorted everything out with the voice</p> <ul style="list-style-type: none"> • You can test whatever use only Ukrainian language only I will use Slovak! • I have Windows 11 and when clicking right mouse in MS EDGE computer speeks it in English but not in Ukrainian

Figure 7. Example from modeling Speech Recognition using mobile phone

At the time of the V4 EDUPORT project, there was a war going on in Ukraine, therefore the Ukrainian partner could not sufficiently use the IT infrastructure due to power outages and limited supply during the days. Since mobile phones can work without electric network supply, the possibility of using PIKS channels (using them for chat or Speech Recognition - dictation) was tested, as illustrated in Figure 7. As you can see, communication worked both in Ukrainian and in English.

The Ukrainian researcher has written a brief manual for the partners as follows: PIKS is a Personal Information and Knowledge System. Using PIKS you may share information, messages and files with your colleagues and also retrieve them in the table for your own needs. You may submit rows in the table, share it, delete the unnecessary rows and collect the valuable ones. You may also use it with a Smartphone, and use many functions of information processing available in databases. Speech Recognition: For example, you may use the function dictate on a smartphone, the function of translation to different languages and others. So PIKS may be used as a communication channel and also as a personal database.

6. CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

The proposed IT infrastructure solution contributes to designing a personalized hybrid LMS using a virtual machine in a cloud environment. This is a promising trend in the digitalization of education development that concerns the collaborative design and sharing of educational resources in the processes of learning and research. So the approach for designing the special software tools and their implementation within the proposed IT infrastructure model developed and tested by the research team is a promising solution that needs further implementation in IT education.

For working with educational content, the desktop application WPad, extended by the Internet application PIKS for the purposes of interactive communication, works with universal “interdisciplinary” knowledge representation. Thus, it can be used to automate learning processes, in which knowledge fulfills the function of a controlled parameter of the process and is worked with as a useful selected content. In contrast, LMSs work with vague, general and unstructured content, moreover Moodle does not enable batch files processing, to work as a HTML-editor or internet browser tool and cannot supply such level of personalization without specific IT skills as when using WPad. So, from the teachers point of view, WPad can be also considered as add-on software or add-on plug-in to Moodle or any LMS.

As it was presented, in the case of using the WPad application on a cloud virtual machine with a Windows 2022 server (it connects to the same WPad application and tables that the teacher has on his laptop) or the faculty VLE, a more experienced teacher or in cooperation with the relevant IT workplace can also create a personal LMS system. However, it is more appropriate to use the presented IT infrastructure for more sophisticated activities that are not provided by LMS. Currently, this IT infrastructure, paradigm and software are being tested within the collaborative research of an international team within the frame of the V4 EDUPORT project. As part of the joint research with the Ukrainian partner, an unexpected benefit was also achieved when testing PIKS and WPad software in conditions where electricity supplies were limited to only a few hours a day. PIKS can be used from a mobile phone and WPad works on a laptop as a desktop (much faster than working on the Internet), so both software can work even without a direct connection to the electrical network, since they also work on backup sources. Furthermore, in the case of PIKS, it was found that the Speech recognition technology already works on mobile phones even in the native languages of the researchers (Slovakian, Ukrainian), so it is possible to design educational activities where the content is dictated into a knowledge table, or for simple interactive communication between teachers and students. This fact is also significant since the project partners are members of the V4+ACRDC consortium,

which is also focused on the IT field of Human Languages Technologies (Speech recognition, Text-To-Speech). In this context, it is very important to note that the Windows 11 version already enables Speech recognition in the Slovakian language, i.e. dictating text to the WPad table (Windows 10 did not support this in this language). As an illustration, it can be mentioned that half of this article was dictated as a manuscript.

Part of further future research is the development of the PIKS internet application, which operates as a multi-functional communication channel for e-Learning purposes (including use for the visually impaired). This can also be used from a mobile phone, and most recently, together with an Ukrainian partner, the possibility of using HLT technology (Human and Language Technologies) is being tested, also because Speech to recognition in the native languages of teachers and students is starting to work there.

It is possible to focus further research on the application of these technologies to activities where IT integration into teaching has not yet been possible, e.g., to multilingual audio-visual outputs, and on controlling the WPad program by voice. For the sake of completeness, it should be added that MOODLE or other LMSs are very useful especially in terms of institutional teaching management. However, nowadays, technology has advanced so much that teachers can also design personal LMSs or information systems and integrate them into their university LMSs, as presented in this article introducing examples from the authors' real teaching practice. In this respect, collaborative activities in international teams are challenges for further research.

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КОЛАБОРАТИВНЕ ПРОЄКТУВАННЯ ПЕРСОНАЛІЗОВАНОЇ ГІБРИДНОЇ LMS З ВИКОРИСТАННЯМ ВІРТУАЛЬНОЇ МАШИНИ В ХМАРНОМУ СЕРЕДОВИЩІ

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Анотація. Педагогу нині необхідно підтримувати і опрацьовувати величезну кількість освітньої інформації та знань під час його/її професійної діяльності для досягнення цілей викладання, самонавчання, публікації, проведення дослідження, мовної підтримки та пов'язаних з цим процесів. В академічному освітньому середовищі так звані системи управління навчанням (LMS), особливо Moodle в Європейському Союзі, знайшли широке застосування для опрацювання освітнього контенту електронного навчання. LMS зазвичай функціонують як онлайн-платформи і водночас як доповнення до академічних інформаційних систем (AIS) на локальних серверах університетів. Вони використовуються великою кількістю учасників, але не завжди відповідають потребам педагога в усіх видах діяльності, які він/вона виконує. Наприклад, вони не підтримують багатомовне опрацювання даних, багаторівневий пошук і спільне опрацювання контенту електронного навчання. У науковій літературі є велика кількість статей, що описують дизайн додаткових модулів для LMS. У межах спільних досліджень у сфері підтримки та проєктування ІКТ-навчання міжнародна команда проєкту V4 EDUPORT впроваджує персоналізовану гібридну систему в ІТ-інфраструктурі, що складається з прикладного додатка WPad, вебдодатка (PIKS) і віддаленого робочого столу (віртуальний комп'ютер на хмарному сервері з Windows 2022). У цій роботі дослідники діляться своїм досвідом, отриманим в освітньому середовищі з використанням LMS своїх університетів (Moodle та AIS), і порівнюють їхні можливості персоналізації з рівнем їх використання в хмарі. У цій статті пояснюється, як викладачі використовували цю систему для навчання студентів STEM (у той час, коли Moodle ще не використовувався в Словацьких університетах), і як питання проєктування аудіовізуальної багатомовної підтримки ІКТ-навчання, дослідження та автоматизації створення освітніх пакетів вирішуються спільно в межах проєкту (в середовищі Windows паралельно з розробкою універсального освітнього програмного забезпечення WPad). Перспективою поточних і майбутніх досліджень є розвиток Інтернет-додатка PIKS, який працює як багатофункціональний канал зв'язку для цілей електронного навчання (зокрема використання людьми з вадами зору).

Ключові слова: системи управління навчанням; ІКТ-навчання; освітнє проєктування; освітнє програмне забезпечення; співпраця у хмарі у віртуальних командах; Moodle.

