Faster pedagogical framework for steam education based on educational robotics

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Abstract

Globalization and sustainable development requires shifting education targets from acquisition of structures knowledge to the mastery of skills. Robot-aided learning can used as a tool of creativity in AHSS (Arts, Humanities and Social Sciences) classes thus attracting the attention of learners to cross-disciplinary subjects with elements of STEM (Science, Technology, Engineering, and Mathematics), which is expanded to STEAM (STEM + All). The presented FASTER pedagogical framework is based on the combination of project-based teaching, educational robotics and team based learning for achieving educational aims and supporting creativity in class. We describe the practical use of the framework in a university course, with specific examples of student projects. Finally, we discuss the educational implications of the framework and beyond.

Keywords: Educational Robotics; Pedagogical Framework; STEAM; STEM; 21st century skills.

1. Introduction

Globalization have shifted the required skills from the acquisition of structured knowledge to the mastery of skills, which is referred to as 21st century competencies [1]. The employers need employees with critical thinking, problem solving, communication, and collaboration skills. The need for adapting to new requirements motivates the development of new pedagogical methodologies and guidelines, which will require substantial changes in teachers' education and practice. Robot-aided learning (r-Learning) [2] has enough potential to be used as a tool of creativity in AHSS (Arts, Humanities and Social Sciences) classes thus attracting the attention of learners to cross-disciplinary subjects with elements of STEM (Science, Technology, Engineering, and Mathematics), where the learners can explore the combination of computer science and robotics. The fascination of general public and, especially children, with robots has significant social, political, and emotional implications, including for education. Further on, the advantages of using robots in language instruction, known as Robot Assisted Language Learning (RALL) [3] can be transferred to teaching other AHSS subjects. Actually spending time working with real robot-based examples gives the students many opportunities to see the topic from standpoints that are difficult or impossible to convey in a classical textbook-oriented lecture. There is still unexplored opportunity of robots to be used not only for teaching school children to learn the STEM subjects, but also in social and humanistic sciences to increase school children engagement in technology and facilitate acquisition of trans-disciplinary knowledge.

Academic restructuring of traditional educational models, trans-disciplinary formal and informal educational STEM programs through robotics engages learners in the team-based multidisciplinary problem solving through mentoring, and using robotics based on sound pedagogical framework and educational robots. Educational STEM programs and methodologies, which include educational robotics, will be based on the model of teaching young boys and girls who will be able to gain new skill and competences necessary to address complex problems facing human society. The physical tangibility of robots raises the need for a shift to innovative and effective teaching methods for the engagement robots provide is considered conducive for learning. There is the need for fit-for-purpose technological and methodological pedagogical frameworks aimed to alleviate trivial limits of time and physical space in learning and teaching processes but also to quicken the application of innovative design-based approaches intended to modernize and reconsider the role of schools.

In this paper we introduce the FASTER pedagogical approach, which aims to introduce the design, artistic and creative processes to informal learning through the emphasis on engineering knowledge, improving student engagement and reducing boundaries between different disciplines, establishing a synergistic relationship. By using robots as an art form and attracting artists who include science in their artworks, FASTER will increase the interest of not only students, but educators and researchers in both science, technology, engineering and arts disciplines (STEAM). Introducing young people to hybrid works of art and technology and by offering a robot as an educational art tool we will be able to help young people to understand more about the mix of STEM subjects with artistic/creative process and design thinking. The hands-on, imaginative approaches to science education, combining simple robotics with many of the methods used in the creative arts and design are aimed to attract and retain young people in the fields of Science, Technology, Engineering and Mathematics (STEM). The FASTER pedagogical framework is intended to support project-based teaching via educational robotics while responding to the local context (i.e. underpins sustained improvements in learners' achievement). The framework also addresses the lack of interest in the STEM subjects among young people and future skills gap (by 2020 it is projected that there will be 20 mil-

lion high-skilled jobs and 30 million medium-skilled jobs using MST in Europe) [4].

The paper builds upon our previous experience and methodological work in developing educational robotics and teaching materials for project based teaching of computer science students [5-10]. The paper is structured as follows: Section 3 provides an overview of the state-of-the-art in the development of pedagogical frameworks. Section 3 explains the proposed pedagogical framework, Section 4 described the use of the framework in the robotics course, and Section 5 provides the conclusions.

2. State-of-the-art in the development of pedagogical frameworks

In recent years there was a flurry of new educational approaches and pedagogical frameworks proposed to address various problems of education. Pedagogical frameworks have been developed for anatomy education [11], teacher preparation [12], and integration of refugees [13]. For example, Barak [1] developed a pedagogical framework for promoting meaningful usage of advanced technologies specifically oriented at science teachers. The framework is based on cloud pedagogy and encouraged students 1) to actively acquire knowledge by investigating, experiencing, and discovering; 2) to interact with peers and communities from other institutions and countries; 3) to construct science-related content with peers by writing original essays, producing creative video-clips, and preparing colorful presentations; 4) to think critically and to undertake critique, as constructive feedback.
Bates et al. [13] used a game based approach to deliver vocational skills and intercultural communication using the VIPI pedagogical framework. Brouns et al. [14] described a collaborative approach and pedagogical framework of Massive Open Online Courses (MOOC) design based on the need to accommodate the specific context of open online education with its heterogeneity of learner needs, while putting the learner center-stage in a social networked learning environment. Cooke [15] described Metatuning - a game design pedagogical framework that aims to use game design to increase internal student motivation for learning thus providing meaningful contexts to learning processes and motivating the selection of profession in real-world. D'Souza and Rodrigues [16] proposed the Extreme Teaching-Learning paradigm (XTLP) (or Extreme Pedagogy) as a student-centered pedagogy, which derives its philosophy from Extreme Programming (XP), an agile software developmental methodology. The framework overcomes the traditional rigid course structure that limits teacher-student interactions with continuous enhancement of student performance. Doolan [17] introduced a pedagogical framework, the dialogic shamrock, for collaborative learning through technology, which synthesizes over other learning theories, specifically, online learning and collaborative technologies including Web 2.0. Eteokleous [18] examined how robotics and computer programming can be integrated within the elementary teaching practice to achieve learning objectives across disciplines beyond STEM education. Hunter [19] suggested High Possibility Classrooms (HPC) as a pedagogical framework focus on technology integration in Australian school classrooms. The framework supports and encourages teachers to take 'pedagogical steps' in their practice with technology. Koh et al. [20] presented the Team and Self Diagnostic Learning (TSDL) framework, in the context of collaborative inquiry tasks. The framework is based on experiential learning, collaborative learning, and the learning analytics process model. Mulder [21] introduced Applab as a pedagogical framework aimed to innovate HCI education. Students collaborate with urban stakeholders to better frame the design problem and deal with societal challenges, thus providing dissemination of knowledge between research, government, industry, and HCI and design education. Pierce et al. [22] described the Environments for Fostering Effective Critical Thinking (EFFECTs) pedagogical framework that has been developed for civil and environmental engineering curriculum. EFFECTs

facilitates integration of technical and professional skills to meet learning outcomes, and to enhance student communication skills, teamwork, and knowledge of contemporary issues. Pifarré et al. [23] conceptualized creativity as a social activity based on dialogue to promote collaborative creativity processes while using distributed leadership, mutual engagement, peer assessment or group reflection as tools of a technology-enhanced pedagogical framework. Townsend and Urbanic [24] proposed a learning-centered, scholarly, and pragmatic pedagogical framework for implementing industry-oriented field trips for engineering students aiming for affective learning, long-term memory, and learning anchors. The reported benefits included student engagement, deep learning, joy-in-learning, and community synergy. van Uum et al. [25] promoted Inquiry-based science education (IBSE) as an inspiring way of learning science by engaging children in performing their own scientific investigations. Colpani and Homem [26] proposed an educational framework that connects Augmented Reality (AR) with gamification to assist the learning process of children with mental disabilities.

3. Faster pedagogical framework

3.1. Concept

Innovative science education such as implemented using educational robotics will enable the students to have a different opportunity for developing their logical ability and creativity, features at the base of reasoning and critical thought. Pedagogical framework and learning scenarios with specific aims and skills developed in activities, will increase and pursue children's competences. Robotic experiences in educational contexts are particularly important and new, not only as mediators for activities in inter-disciplinary fields, but also as tools for activating abilities through a didactic approach based on action. Robotics enables recognizing the world by living, not by observing or listening to stories. Other pedagogical frameworks have already have focused on the children that were interested in technological topics, but still they did not contribute towards increasing the number of technological students in the end. The main appeal arises from the potential of educational robotics to enhance student's intellectual, social, emotional, physical, and artistic development and to foster creativity and a lifelong love of learning. The way robotics is currently introduced in educational settings usually focuses just on a narrow subset of topics mainly in the field of mathematics and physics. These developments may also be useful in changing the outlook of those who view science and technology as separate from the general culture (see, e.g., the writings of Snow [27] about "two cultures"). Further on, the interrelation between science and art is also reflected and here the term "robotic art" emerges. "Robotic art" [28] is a type of art that makes use of robotics and automated technology, coupled with computer technology and sensors. Robotic art attracted attention with the rise electronic media and technology in art. Robot music [29] also can be employed to help students enhance their educational motivation and effects as well as to promote STEM disciplines and computer science [30].
Despite these nascent efforts there is lack of pedagogical scenarios and methodological background in order to use educational robotics in non-STEM classes to attract students to STEM more systematically. There has been some effort in the context of SMART (Science, Mathematics, Art, Robot and Technology) with little emphasis on the Art part of SMART [31]. Exploring a wider range of possible applications for robotics in the context of STEAM such as poetry, history, and human anatomy [32] has the potential to engage young people with a wider range of interests and bringing both girls and boys into the scientific world via formal and informal teaching and learning and to orient them towards undertaking scientific careers. The schoolchildren interested in arts, humanities and social sciences (AHSS) still could be attracted to interdisciplinary studies (e.g. design engineering) involving a significant part of technological subjects, if properly addressed

and motivated. Instead of focusing on a single technological challenge such as design of an autonomous robotic carriage for line following or obstacle avoidance, robots could be deployed in a more creative environment such as development of robotic musical instruments for music-oriented students, development of wearable art with computing capabilities for art and design oriented students, and creation of robotic characters for humanities oriented students. Robots are to become teaching assistants in non-technical classes rather than mere tools in science and technology demonstrations. This is why the goal for students is no longer to only construct and manipulate robotic systems but rather to embrace the significant potential of educational robotics for boosting creativity, curiosity, problem-solving, team-work skills and the 21st century learning skills [33]. By using the adaptive technologies, this framework will feature socio-humanistic and collaborative capabilities and be environmentally aware and reactive, being thus able to recognize and provide the most fitting activity for needs of young boys and girls to pursue careers in STEM, while at the same time adhering to the values embedded in Responsible Research and Innovation.

3.2. Stages of the framework

The FASTER framework has the following stages (see Fig. 1).
Analysis of state of the art: to analyze the current status of research and teaching with regard to methodologies of engagement of socio-humanistic profile school-children to pursue careers in STEM and to specify a user requirement list for the development of educational robots set, pedagogical and learning scenarios.
Implementation: implementation of educational robot sets, joining it together with the educational approach currently practiced by FabLabs [34-36] in the schools.
Pedagogical design: includes specific learning methods for robotics and other subjects education that provide for scalable learning outcomes suitable for the ranges in ability across the student cohort based on different areas and to enable people to implement the learning approaches whilst modifying them appropriately
Learning scenarios: Robot-based learning scenarios and the resources that will allow successful application of the FASTER robots framework in schools.
Pilot use: the use of FASTER educational robots framework and learning scenarios in selected schools as case studies.
Validation and social evaluation: includes validation and execution of surveys required to validate the methodology.

4. Practical use in education

As a case test, this pedagogical framework was implemented in in Kaunas University of Technology, Faculty of Informatics. The students in the Robotics Programming Technologies Course, during 2012-2016, in total 293 students (2012 – 34, 2013 - 33, 2014 - 51, 2015 - 86, 2016 - 89). The course aims to teach students of the basic principles of robot programming and control using the collaborative teamwork approach [10]. During 5 years, the students have implemented 89 team projects. The robot hardware used during lab works included two LEGO NXT robots with NXT Intelligent Brick, Arduino 4WD Mobile Platform with ATmega328 microcontroller board and 4 DC Motors, Lynxmotion 5LA Robotic Arm robotic arm.
The course implements a hand-on project-based approach to teaching basic control and programming skills using robots as target devices while supporting creativity, design thinking, immersive learning and learning-by-doing [37]. The approach involves giving students a robot to assemble, and providing increasingly complex challenges to solve, starting from simple line following to roaming in a crowded, dynamical changing environment.
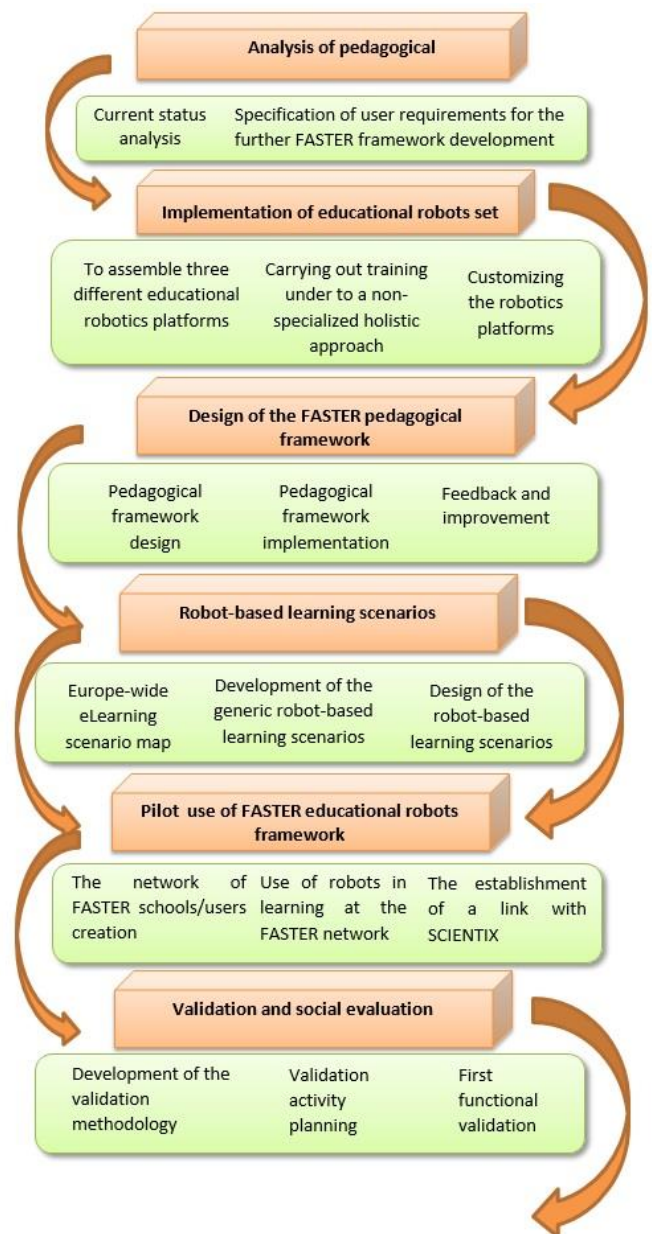

Fig. 1: FASTER pedagogical framework.

The use of entertaining ideas for project is encourage as gamification plays an important role in student engagement and interest sustainment [38], which involves organizing in-class competitions and supporting posting project results in social media.
Students work on their assignments in teams. The learning scenario is as follows: 1) A team of students are presented with a problem and materials for solving it. 2) The select/adopt appropriate solutions under the guidance of the teacher. The design and modeling of a robotic system involves the use of visual programming environment [9] such as Microsoft Robotics Developer Studio or NXT-G. 3) The students construct, model and deploy a robot. 4) The students empirically validate the solution. 5) The students present their solution to other students and the teacher at workshop. Presentation framed as a Learning Object (LO) [39] is encouraged, i.e., the students formulate their educational aims, describe the implementation of the projects using multimedia materials (videos, photos, diagrams) and present conclusions what they have learned. The Moodle learning platform is used as a common media to discuss projects, and share learning experience. Examples of some of the implemented robotics projects are given in Fig. 2.
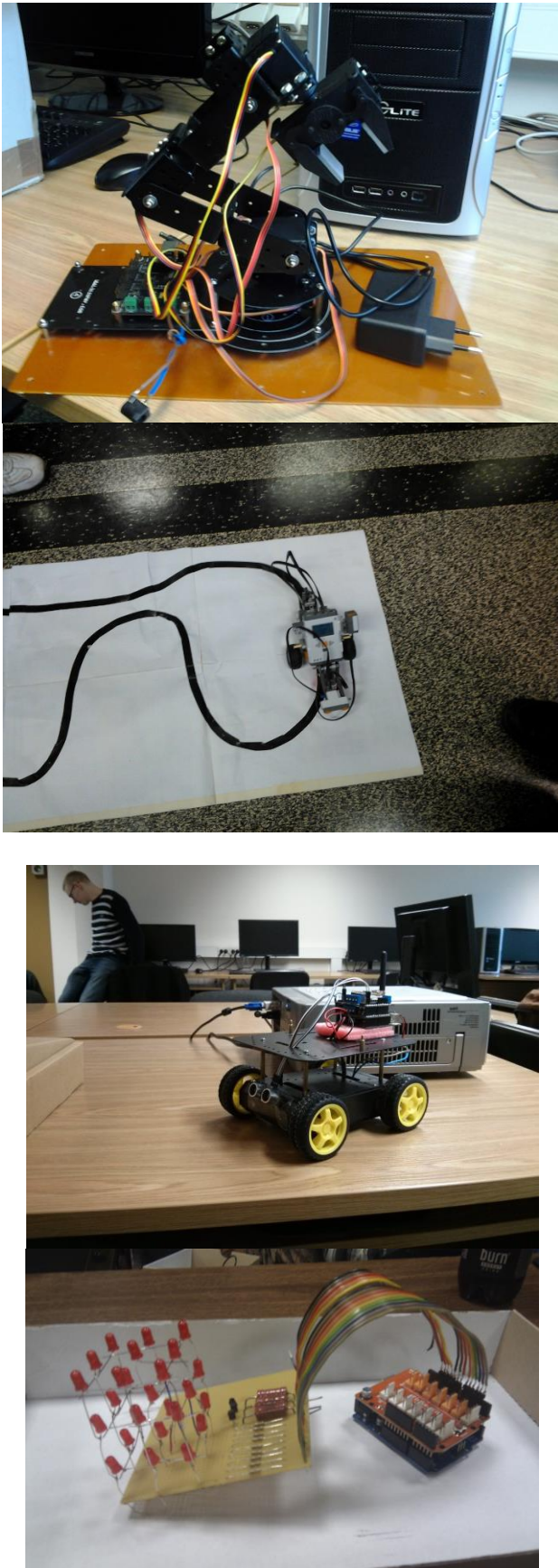
Fig. 2: Examples of implemented student robotics projects: robotic hand, Lego car, Arduino 4WD car, and LED cube.

5. Discussion and conclusions

Educational robotics focuses on the link between physical materials of the educational actions and the virtual ones like project website, student and teacher online support tools, etc. and to cultivate creativity and problem solving skills via easy accessible robotic DIY (do-it-yourself) experiences, looking at it not as a robot hard-ware, but as a virtual paintbrush, story teller, singer, etc. in the integrated learning environment. The use of Moodle as the robotic learning (r-Learning) environment assures the interactivity of the educational content and the effective knowledge assimilation.

The presented FASTER pedagogical framework based on the project-based teaching and educational robotics provides opportunities for the following achievements:

Impact on innovation stimulation and development: The FASTER framework is foreseen to contribute greatly to provide the educators with an easy access to highly usable methodological and technological knowledge. It will help to apply the framework in a variety of content-related settings enabling the participation in science education, in formal, non-formal and informal settings to reach EU targets for smart and sustainable growth responding to the need to design science-based decisions to the global challenges.

Impact on a new STEM-based educational platform: The FASTER will increase awareness of educational robotics in science teaching and learning and the new platform is anticipated to establish long-term value through enhanced cooperation between science educators. Knowledge gained from on-hands experimental robotic activities will lead to a deeper and continuous connectivity between schools and non-formal and informal learning and teaching environments. A broader knowledge base, advanced analytical capacities will directly correlate to the joint European high-level and long-term objectives as anticipated in the Framework for Science Education for Responsible Citizenship.

Impact on economics: It is a known fact that investment in pure STEM fields - science, technology, engineering, and math increases innovation and supplements to the economy development. The decrease in unemployment through a positive notion of social impact of robots is expected. FASTER will indirectly reduce the fear of robots as an alternative workforce and increase the familiarity of technical objects. A more direct economic impact will results from school children as future workforce which generates country GDP and makes it competitive in the world's economics. Consequently the development invites growth in new jobs in a community. A notion of an economical impact is also expected by introducing arts into STEM.

21st century skills. The issues of Intercultural education (IcE) and Computer Science (CSE) education are of paramount importance in the 21st century. In the FASTER framework, the learning environment will be developed that will be able to equally promote both IcE and CSE promoting the cause of universal science. Robotics can facilitate multidisciplinary and multicultural projects using a low cost, easily exported robot platform that allows students to expand their academic and personal experiences. The immediate feedback offered by robot behavior and the confidence offered by the project also can help students overcome linguistic and cultural obstacles in communication and collaboration.

Acknowledgement

References

[1] Barak M (2017), "Science teacher education in the twenty-first century: A pedagogical framework for technology-integrated social constructivism", *Research in Science Education*, Vol. 47, No. 2, pp. 283–303, 10.1007/s11165-015-9501-y

[2] Han J (2010) "Robot-aided learning and r-learning services", D. Chugo Ed., *Human-Robot Interaction*, pp. 288, INTECH, Croatia

[3] Aidinlou NA, Alemi M, Farjami F & Makhdoumi M (2014) "Applications of Robot Assisted Language Learning (RALL) in Language Learning and Teaching", *International Journal of Language and Linguistics*. Special Issue: Foreign Language Teaching and Learning (Models and Beliefs), Vol. 2, No. 3-1, pp. 12–20.

[4] ERT Societal Changes Working Group (2009), "ERT Mathematics, Science and Technology Report", European Roundtable of Industrialists.

[5] Burbaite R, Stuikys V & Damasevicius R (2013), "Educational robots as collaborative learning objects for teaching computer science", *ICSSE 2013 - IEEE International Conference on System Science and Engineering*, *Proceedings*, pp. 211–216.

[6] Štuikys V, Burbaite R, & Damaševičius R (2013), "Teaching of computer science topics using meta-programming-based glos and lego robots", *Informatics in Education*, Vol. 12, No. 1, pp. 125–142.

[7] Burbaite R, Bespalova K, Damaševičius R & Štuikys V (2014), "Context-aware generative learning objects for teaching computer science", *International Journal of Engineering Education*, Vol. 30, No. 4, pp. 929–936.

[8] Plauska I & Damaševičius R (2014), "Educational robots for internet-of-things supported collaborative learning", *International Conference on Information and Software Technologies, ICIST 2014*, Springer, Communications in Computer and Information Science, Vol. 465, pp. 346–358.

[9] Plauska I, Lukas R & Damasevicius R (2014), "Reflections on using robots and visual programming environments for project-based teaching", *Elektronika Ir Elektrotechnika*, Vol. 20, No. 1, pp. 71–74, 10.5755/j01.eee.20.1.6169

[10] Damaševičius R, Narbutaite L, Plauska I & Blažauskas T (2017), "Advances in the use of educational robots in project-based teaching", *TEM Journal*, Vol. 6, No. 2, pp. 342–348.

[11] Barry DS, Tierney P & O'Keeffe GW (2016), "The need for ethical and pedagogical frameworks for developing online media in anatomy education", *Anatomical Sciences Education*, Vol. 9, No. 5, pp. 498–499, 10.1002/ase.1628

[12] Bell RL, Maeng JL & Binns IC (2013), "Learning in context: technology integration in a teacher preparation program informed by situated learning theory", *Journal of Research in Science Teaching*, Vol. 50, No. 3, pp. 348–379.

[13] Bates M, Breheny A, Brown D, Burton A & Standen P (2014), "Using a blended pedagogical framework to guide the applications of games in non-formal contexts', *2014 International Conference on Interactive Technologies and Games*, iTAG 2014, pp. 79–83, 10.1109/iTAG.2014.14

[14] Brouns F, Teixeira A, Morgado L, Fano S, Fueyo A & Jansen D (2016), "Designing massive open online learning processes: The sMOOC pedagogical framework", *Jemni M., Kinshuk, Khribi M. (eds) Open Education: from OERs to MOOCs*. Lecture Notes in Educational Technology. Springer, Berlin, Heidelberg, pp. 315–336, 10.1007/978-3-662-52925-6_16

[15] Cooke L (2016), "Metatuning: A pedagogical framework for a generative STEM education in game design-based learning", *ISEC 2016 - 6th IEEE Integrated STEM Education Conference*, pp. 207–214, 10.1109/ISECon.2016.7457534

[16] D'Souza MJ & Rodrigues P (2015), "eXtreme teaching-learning paradigm: A pedagogical framework for higher education", *International Journal of Applied Engineering Research*, Vol. 10, No. 9, pp. 153–156.

[17] Doolan MA (2013), "A pedagogical framework for collaborative learning in a social blended e-learning context", 10.1108/S2044-9968(2013)000006G012

[18] Eteokleous N (2017), "Integrating Robotics and Programming as Cognitive-Learning Tools: Meeting Disciplinary Learning Objectives", *Proceedings of Society for Information Technology & Teacher Education International Conference*, pp. 1545–1551.

[19] Hunter J (2017), "High possibility classrooms as a pedagogical framework for technology integration in classrooms: An inquiry in two Australian secondary schools*", *Technology, Pedagogy and Education*, Vol. 26, No. 5, pp. 559–571, 10.1080/1475939X.2017.1359663

[20] Koh E, Shibani A, Tan JP & Hong H (2016), "A pedagogical framework for learning analytics in collaborative inquiry tasks: An example from a teamwork competency awareness program", *ACM International Conference Proceeding Series*, 25-29-April-2016, pp. 74–83, 10.1145/2883851.2883914

[21] Mulder I (2015), "A pedagogical framework and a transdisciplinary design approach to innovate HCI education", *Interaction Design and Architecture(s)*, Vol. 27, No. 1, pp. 115–128.

[22] Pierce CE, Caicedo JM., Flora JRV, Berge ND, Madarshahian R & Timmerman B (2014), "Integrating professional and technical engineering skills with the EFFECTs pedagogical framework", *International Journal of Engineering Education*, Vol. 30, No. 6, pp. 1579–1589.

[23] Pifarré M, Martí & Cujba A (2015), "Technology-enhanced pedagogical framework for collaborative creativity: Analyses of students' perception", *12th International Conference on Cognition and Exploratory Learning in the Digital Age*, CELDA 2015, pp. 225–232.

[24] Townsend V & Urbanic J (2013), "Industrial field trips: An integrated pedagogical framework of theory and practice", *International Journal of Engineering Education*, Vol. 29, No. 5, pp. 1155–1165.

[25] van Uum MSJ, Verhoeff RP & Peeters M (2016), :Inquiry-based science education: Towards a pedagogical framework for primary school teachers", *International Journal of Science Education*, Vol. 38, No. 3, pp. 450–469, 10.1080/09500693.2016.1147660

[26] Colpani R, Homem MRP (2016), "An innovative augmented reality educational framework with gamification to assist the learning process of children with intellectual disabilities", *IISA 2015 - 6th International Conference on Information, Intelligence, Systems and Applications*, 10.1109/IISA.2015.7387964

[27] Snow CP (2001) [1959], "The Two Cultures", London: Cambridge University Press., pp. 3.

[28] Kac E (1997), "Foundation and Development of Robotic Art", *Art Journal*, Vol. 56, No. 3, Digital Reflections: The Dialogue of Art and Technology, pp. 60–67.

[29] Sobh TM, Wang B, Coble, KW (2003), "Experimental Robot Musicians", *Journal of Intelligent and Robotic Systems*, Vol. 38, No. 2, pp. 197–212.

[30] Chung CJ, Cartwright C & Chung C (2014), "Robot music camp 2013: An experiment to promote STEM and computer science", *Integrated STEM Education Conference (ISEC)*, 2014 IEEE, pp.1–7, 10.1109/ISECon.2014.6891012

[31] Hong SY & Hwang YH (2012), "A Study on Smart Curriculum Utilizing Intelligent Robot Simulation", *Issues in Information Systems, IACIS 2012*, Vol. 13, No. 2, pp. 131–137.

[32] Hamner E & Cross J (2013), "Arts & Bots: Techniques for Distributing a STEAM Robotics Program through K-12 Classrooms", *Proceedings of the Third IEEE Integrated STEM Education Conference*, Princeton, NJ, USA.

[33] Zawieska K & Duffy BR (2015), "The Social Construction of Creativity in Educational Robotics". *Progress in Automation, Robotics and Measuring Techniques, Advances in Intelligent Systems and Computing*, Vol. 351, pp. 329–338.

[34] Angrisani L, Arpaia P, Bonavolonta F & Lo Moriello RS (2018), "Academic FabLabs for industry 4.0: Experience at university of naples federico II", *IEEE Instrumentation and Measurement Magazine*, Vol. 21, No. 1, pp. 6–13, 10.1109/MIM.2018.8278802

[35] Gaeiras B (2017), "Fablab lisboa: When a municipality fosters grassroots, technological and collaborative innovation", *Field Actions Science Report*, Vol. 16, pp. 30–35.

[36] Vasilescu MD & Ionel I (2017), "3D printer FABLAB for students at POLITEHNICA university Timisoara", *Paper presented at the Proceedings - IEEE 17th International Conference on Advanced Learning Technologies, ICALT 2017*, pp. 512–513, 10.1109/ICALT.2017.106

[37] Blumenfeld PC, Soloway E, Marx RW, Krajcik JS, Guzdial M & Palincsar A (1991), "Motivating project-based learning: Sustaining the doing, supporting the learning", *Educational Psychologist*, Vol. 26, No. 3-4, pp. 369–398, 10.1080/00461520.1991.9653139

[38] Aseriskis D & Damasevicius R (2014), "Gamification Patterns for Gamification Applications", *6th International Conference on Intelligent Human Computer Interaction, IHCI 2014*, Évry, France, Procedia Computer Science 39, pp. 83–90.

[39] Stuikys V, Burbaite R, Drasute V, Bespalova K (2016), "Robot-Oriented Generative Learning Objects: An Agent-Based Vision", *10th KES International Conference on Agent and Multi-Agent Systems: Technology and Applications, KES-AMSTA 2016*, Springer, Smart Innovation, Systems and Technologies 58, pp. 247–257.