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Implementation of Robotics as a Modern Trend in STEM Education

Abstract

The paper is devoted to the issues of implementation of STEM education in the learning process of educational institutions. The authors analyse the development of STEM education in Ukraine, determine the level of readiness of educators for understanding the principles of STEM education, and substantiate the need for the introduction of robotics into the educational process as a modern and important trend in STEM education. The concept of educational robotics is analysed. This makes it possible to identify the technical inclinations of students (at an early stage) and development of these inclinations, as well as formation of STEM competency in general. The study focuses on the interdisciplinary aspect of STEM education, in particular on the implementation of interdisciplinary links between STEM subjects and robotics in the conduction process of research and training projects. The authors provide examples of the implementation of robotics in the educational process based on the use of a project method. The article also includes a description of the project for the creation of the Juno Rover robot based on the Arduino robotic platform in university education and two examples of the robotics projects in school education (one of them is implemented on an open platform with freely distributed materials for creating and using 3D printed robots).

K e y w o r d s: robot, robotics, educational robotics, STEM, STEM education

Introduction

The world is abundant in innovations. There are new ideas, new products, and new solutions to existing problems. Science, technology, engineering, and mathematics are the foundation for innovation. The development of STEM directions in education is crucial for the development of the modern society.

The word "STEM" means the following: **S** – Science (natural science), **T** – Technology (technologies in common understanding, not only computer technologies), **E** – Engineering (engineering and designing), and **M** – Mathematics (pure science).

The world economy and the development of Ukraine are moving towards innovations. The key educational requirement to this transition is preparation of young people for creation of such innovations. Only the economy based on high-performance science and effective innovation systems can be successful in our country in the next decades. The world where our children live and learn is rapidly changing. The future is here, and it requires us and our children to be well-versed in science, technology, engineering, and mathematics.

Unfortunately, the Ukrainian innovation indicator as well as the level of technological availability of the labour force are one of the lowest compared to the remaining indicators of the country's competitiveness. These indicators are typical of the post-Soviet countries. The Global Competitiveness Index Framework is shown in Figure 1.

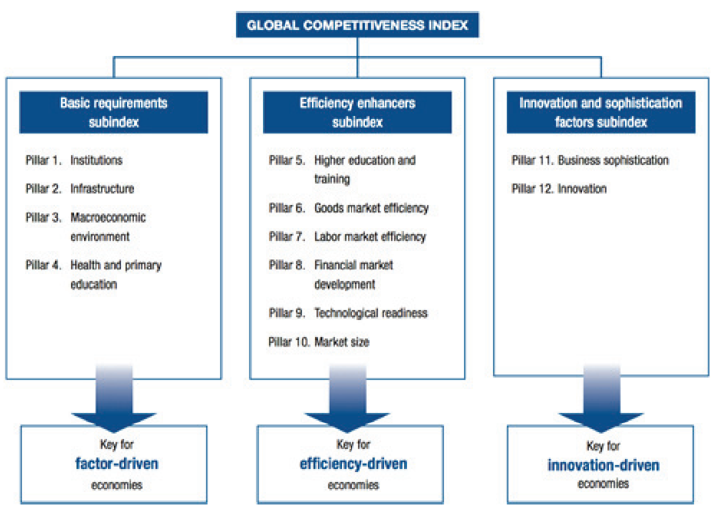

Figure 1. The Global Competitiveness Index Framework.

Source: Global Competitiveness Report 2015–2016 (Reports: World Economic Forum). Retrieved from http://reports.weforum.org/global-competitiveness-report-2015-2016/methodology, accessed 31 December 2018.

In accordance with the Global Competitiveness Report (2018), Ukraine was ranked 83rd out of 140 countries (see Figure 2). According to the indicator of innovation availability of this index, it was ranked 58th.

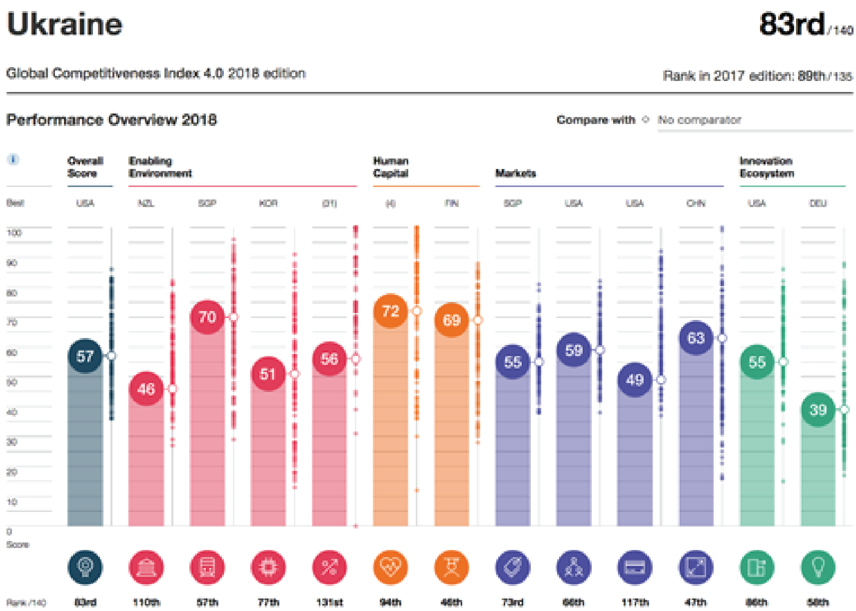

Figure 2. The Global Competitiveness Index of Ukraine.

Source: Global Competitiveness Report 2018 (Reports: World Economic Forum). Retrieved from http://reports.weforum.org/global-competitiveness-report-2018/country-economy-profiles/#economy=UKR, accessed 31 December 2018.

According to the Global Innovation Index – WIPO – Ukraine was ranked 43rd in the world and 30th in Europe (Dutta, Lanvin, & Wunsch-Vincent, 2018). In accordance with the World Digital Competitiveness Index (2018), Ukraine was ranked 58th out of 63 countries. According to the Bloomberg Innovation Index, the annual ranking of innovation in the economies of the world countries (2018), Ukraine was ranked only 46th out of 50 countries, having dropped by four positions in a year. Our country has fallen in the ranking for the third year in a row; contrastingly, in 2015, it took the 33rd place.

It was recently stated at the World Economic Forum in Davos that the fourth industrial revolution was accompanied by radical changes in the labour market. The report "The Future of Employment" by the president of the forum Klaus Schwab ("The Fourth Industrial Revolution…") focuses on the fundamental transformation of the quality of life in the near future, communication, activities, and interaction of society members. In the beginning of the 2020s, a radical change of more than 35% of the modern-day skills will lead to the disappearance of some professions, and the ones that do not yet exist will become commonplace. It was determined that talent (intellect) would be a more critical factor for innovation production, which would lead to a sharp increase in demand for highly skilled specialists.

In 2018, the McKinsey Global Institute's US-based prognosis revealed a potential global deficit of 140–180,000 specialists with deeper analytical skills, as well as 1.5 million managers and technology analysts in high-tech professions. Such a gap in the modern sector jobs could be measured by dozens of years.

The information society requires globally competent citizens. The global community relies on a new generation of children who will be able to:

- make a considered decision about their health and safety;
- participate in public policy and debate;
- manage their everyday life, which is increasingly associated with technologies; and
- find solutions to challenges facing the global population.

"1.2 million" vacancies in STEM were projected in 2013, which seemed to be very high. Then this figure turned into a forecast of "2.4 million."

In order to meet the needs of the technological society and to develop the desire and ability of the population to study science and technology, the STEM direction in education should be developed at school. This is particularly important with regard to the countries with a goal of overcoming the "STEM gap" problem. This problem lies in a large number of vacancies due to the lack of skilled specialists. For example, it is believed in Finland that if young people are at the end of the school process, they will have actual practical knowledge, taking into account all the modern computer technologies and information search skills. So, even benefits for the state can be estimated and expected. Thus, there is an urgent need for the training of future teachers and for the improvement of the skills of working teachers who could implement the principles of STEM education.

A theoretical analysis of scientific papers by leading scientists and in-service teachers in the field of STEM education shows the lack of a scientifically substantiated system of teacher training for the systematic introduction of STEM education into the learning process.

The Ukrainian education is currently at the stage of developing new standards and introducing the new school concept. However, despite the fact that STEM approaches are being implemented in many Ukrainian educational institutions, now this is mainly the out-of-school STEM education, e.g., various natural, mathematical, and scientific competitions, the activities of Junior Academy of Sciences, events for students (Intel Techno Ukraine, Intel Eco Ukraine, Sikorsky Challenge Science Festival), scientific meetings, hackathons, etc. (Morze, Strutynska, & Umryk, 2018). Therefore, it is urgent to introduce the reform of natural-mathematical and engineering education on the basis of the adaptation of foreign experience and proven foreign and domestic practices in the implementation of STEM education.

The main components of STEM education (teaching of natural sciences, mathematics, and technologies) are also important to attract current and rapidly developing industries. Finally, this also involves robotics.

Research focus. The focus of the research is on the interdisciplinary aspects of STEM education, in particular on the implementation of interdisciplinary links between STEM subjects and robotics in the research training projects in Ukraine.

Methodology of Research

Research goals. Our goals are: analysis of the development of STEM education in Ukraine, determination of the readiness level of educators to implement the principles of STEM education, and substantiation of the need in introducing robotics into the educational process as an important component of STEM education.

This article aims at addressing the following questions:

- analysis of the theoretical research background,
- analysis of the STEM education as the most important educational trend among educators,
- analysis of the readiness level of the Ukrainian educators to implement the principles of STEM education,
- analysis of the global trend in the development of robotics as one of the current trends in the development of STEM education, and
- implementation of crossdisciplinary links between STEM subjects and robotics.

The research also considers examples of the implementation of robotics in university and school education as an important component of STEM education with the use of the project method.

Instrument and Procedures, Data Analysis

Research methods. The authors have used the following research methods and tools for the investigation (2018):

- questionnaire;
- survey and interview of the Ukrainian educators;
- observation;
- documents and content analysis;
- meeting, conference, seminar, workshop, etc.; and
- analysis of the research papers.

2,403 Ukrainian educators took part in this research. The Ukrainian educators from the target group (562 members of academic staff, 239 teachers and 1,602 students from different Ukrainian regions) were involved in this process.

The questionnaire aiming to determine the readiness level of the Ukrainian educators to implement the principles of STEM education was created during the project.

Instrument and Procedures, Data Analysis

STEM Education as One of the Most Important Educational Trends among Educators

STEM is a concept of an educational system used by developed countries in different education sectors to develop the skills necessary for children and young people to succeed in the 21st century and to promote the innovation development of the country in general. This concept has arisen in response to the demand of business (first of all, large corporations), which requires professionals of the next level. It involves a combination of different sciences, technologies, engineering creativity and mathematical thinking.

A successful economy is based on a way of thinking that relies on innovation and creativity, research and new technological developments. Many successful entrepreneurs around the world have STEM experience, which helps them create innovative companies or develop existing ones.

In 2020 there will be a growing demand for 80% of rapidly developing professions with the need for STEM knowledge (see Figure 3). The survey of leading employers from around the world contributed to the ranking of 10 high-demand competencies up to 2020 with a prominent role in the ability and willingness to complex problem solving, critical thinking, creativity, governance, coordination, cooperation, reflection, decision-making, service orientation, negotiation, and cognitive flexibility (Hassan, 2001). The Department of Education of the United States forecasts an increase in demand for the following professions related to STEM jobs:

- biomedical engineers – 62%,
- medical scientists – 36%,
- systems software developers – 32%,
- computer systems analysts – 22%,
- mathematics – 16%,
- all occupations – 14%.

Forecast estimates show that in the 2017–2027 period the total number of STEM jobs will increase by 13%, compared with 9% of non-STEM professions, especially in the sector of computing, engineering, and high-tech production.

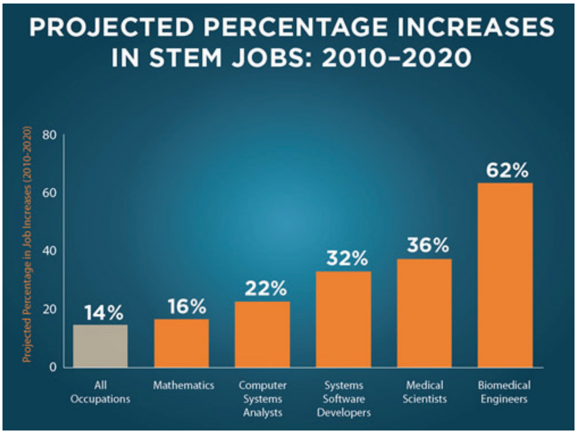

Figure 3. U.S. Department of Education.

S o u r c e : Global Competitiveness Report 2018 (Reports: World Economic Forum). Retrieved from http://reports.weforum.org/global-competitiveness-report-2018/country-economy-profiles/#economy=UKR, accessed 31 December 2018.

STEM education is becoming one of the most important educational trends among educators. This conclusion has been reached by a number of scientists, especially involved in the research in Ukraine, which has been carried out among academic staff, teachers, and students in September 2018 (Morze, Smyrnova-Trybulska, & Gladun, 2018). 562 members of academic staff, 239 teachers, and 1602 students took part in the survey (see Figures 4 and 5).

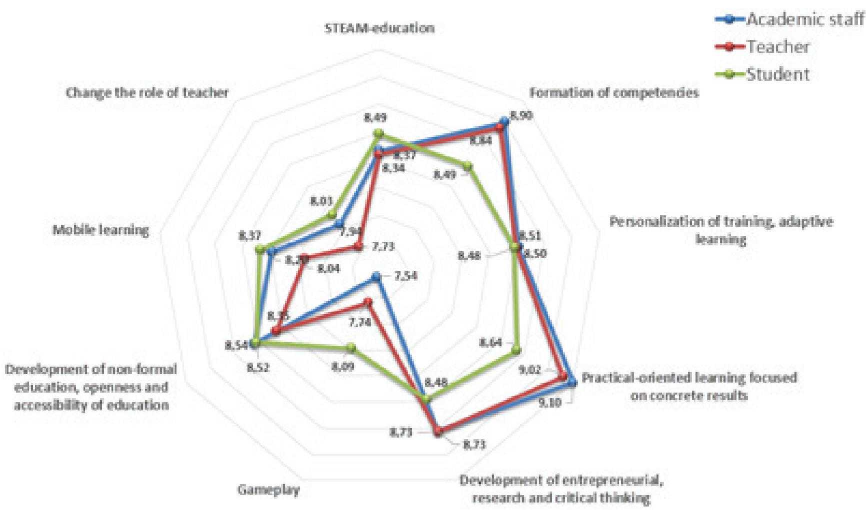

Figure 4. Results of the survey of the Ukrainian students, teachers, and professors regarding current educational trends.

S o u r c e : Own work.

Figure 4 shows that STEM education is one of the most popular trends among the Ukrainian students, teachers, and professors. In 2017 and 2018 the authors analysed the world trends of using of ICTs in education and scientific research (Strutynska & Umryk, 2017, 2018).

It is necessary to note that according to a 10-point scale, STEM education has obtained most points from students (8.49 points) out of 1,602 respondents. Professors and teachers give STEM education an almost equal number of points – 8.37 and 8.34 out of 562 and 239 respondents respectively. The results of the survey show a high demand for STEM education and a high interest of all participants in the implementation of this kind of training. On the other hand, as already indicated, there is a low level of implementation of STEM education in the Ukrainian educational space.

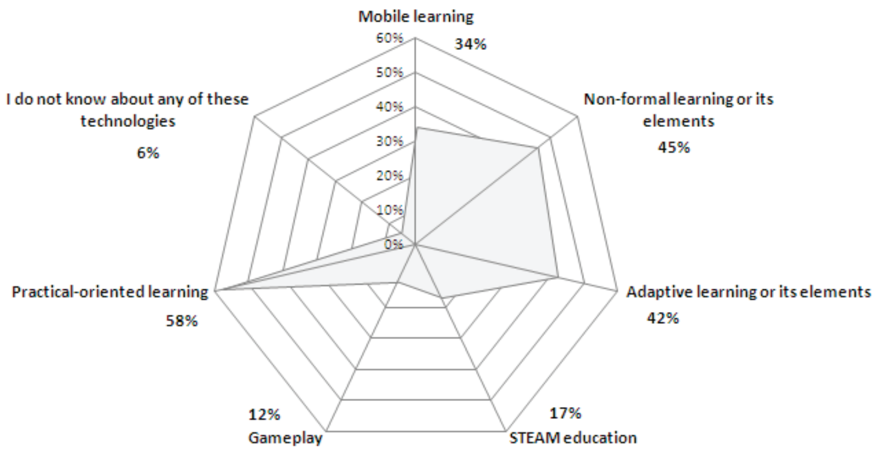

Figure 5. Results of the survey responses on innovative approaches usage in own professional activity.

Source: Own work.

As we can see in Figure 5, STEAM education turned out to be less important than mobile learning or adaptive learning among Ukrainian students, teachers, and professors (multiple answers are possible, which is why the total responses can be more than 100%). It means that they are less familiar with STEAM if compared with other approaches.

In order to effectively overcome this STEM gap problem, we will focus in detail on some aspects of STEM education, especially on the concept of interdisciplinarity, which is one of the key STEM points.

Interdisciplinarity in education is considered to be a pedagogical innovation (Volodchenko, Stryzhak, & Chrapach, 2016). The key pedagogical problem in the development of STEM-oriented curriculum is the technology of integration of components. This is a combination of close disciplines as well as independent ontologies: *science* as a cognitive way to understand the world; *technology* as a way to improve the world sensitive to social changes; *engineering* as a way to design and improve devices to solve real problems; *mathematics* as a way of describing the world, or "the analysis of the world and real problems by the means of numbers" (Meeth, 1978).

It is necessary to note that scientists distinguish (Meeth, 1978) between several types of an interdisciplinary approach depending on the nature of the relationship between disciplines, namely:

- *a crossdisciplinary approach* provides consideration of one discipline through the prism of another (for example, the history of mathematics);
- *a multidisciplinary approach* compares several disciplines that focus on one problem, but does not combine them;
- *a pluridisciplinary approach* combines related disciplines (for example, physics and mathematics, or physics and engineering);
- *a transdisciplinary approach* goes beyond the scope of some disciplines, and focuses on a certain problem and obtaining relevant knowledge.

Therefore, the combination of the scientific method, technology, design, and mathematics is based on the educational STEM programme. It is important that the integration may result in the introduction of a separate STEM / science discipline or in some changes in the curriculum of each of the STEM disciplines based on the introduction of innovations and the enhancement of the practical component for solving real problems.

The authors take into consideration one of the sectors of STEM education development, namely robotics. The article introduces the potential foundations of robotics as a modern trend in STEM education development.

Global Trends in the Development of Robotics

Robotics is one of the world industries that is currently developing in the most intensive manner. This is evidenced by the World Robotics Report of the International Federation of Robotics (IFR) for 2018 (October 2018, Tokyo, Japan), as seen in Figure 6.

According to the results of the World Robotics Report for 2017, the new record figure for production of industrial robots has been achieved, i.e. the volume of their production has increased by 30% in comparison with the previous year. Besides that, during the last five years (2013–2017), the total sales of industrial robots doubled (see https://ifr.org/ifr-press-releases/news/global-industrial-robot-sales-doubled-over-the-past-five-years, accessed 8 December 2018).

Figure 6. Estimated growth in output of industrial robot production until 2021.

Source: International Federation of Robotics. Retrieved from https://ifr.org/downloads/press2018/Executive_Summary_WR_2018_Industrial_Robots.pdf, accessed 22 December 2018.

As of today, industrial robots and integrated automation of production are in demand in many areas of social activity:

- *industry* (robots for painting, welding robots, robots for cutting metal, etc.),
- *military industry* (military robots, intelligence robots),
- *medicine* (microscopic robots for use in microsurgery, robots-couriers in hospitals),
- *aircraft* (unpiloted robots-airplanes),
- *space industry* (self-propelled vehicles based on robotic systems),
- *service sector* (robots to help people with special needs), and
- *domestic life* (robotic vacuum cleaners).

Robots change the way we live and work. This also means that there is already an urgent need for specialists to design, construct, and programme robots.

Educational Robotics

The rapid development of the IT industry, robotics, and nanotechnology results in the necessity in the training of professionals. To implement this, a high-quality STEM-subject training is needed (mathematics, physics, technology, engineering, programming, etc.).

Robotics is also one of the areas for the development of the modern STEM education (Morze, Strutynska, & Umryk, 2018). Educational process with robotics provides students with the opportunity to solve real life problems that require knowledge of STEM disciplines, in particular:

- *mathematics* (spatial concepts, geometry for understanding the methods of robot movement),
- *physics* (electronics, principles of sensors operation that constitutes the basis of robots),
- *technology and design* (design of devices, parts of robots, their design), and
- *ICT* (programming of robotics systems).

Robotics is an applied science about the design, development, operation, and use of robots. Nowadays, increased attention is paid to robotics as to applied science, including its educational and developmental potential. This has created a new trend in education: educational robotics. Educational robotics is a crossdisciplinary area of students' learning. Its process integrates the knowledge of STEM subjects (physics, technology, mathematics), cybernetics, mechatronics, and informatics. Teaching educational robotics corresponds to the ideas of advanced training (learning the technologies that will be needed in the future) and allows students of all ages to be involved in the process of innovation, or scientific and technical creativity (Morze, Strutynska, & Umryk, 2018).

Robotics is a popular and effective method for studying important fields of science and for designing. This is based on the active use of modern technology in production, ICT, and high intellectual level professionals who will work under the conditions of innovation economy.

Incorporation of basic knowledge on the fundamentals of robotics into school education will enable the training of specialists for future professions related to the industries that do not exist today. It is important to remember that the use of educational robotics makes it possible to identify the technical inclinations of students at an early stage and develop them in regard to the STEM competencies formation in general.

Thus, now the issue of robotics implementation in the educational process of educational institutions is of importance. The training of future specialists with regard to robotics requires updating school and university education in accordance with the present requirements.

Examples of Implementation of the Robotics Fundamentals in the Educational Process

Training in robotics fully corresponds to the principles of STEM education and is best realised by means of the project technology learning. Application of this improves formation of students' skills of team work, development of independent search and creative activities, and formation of interpersonal competencies.

There are examples of STEM-research projects, related to robotics in university and school education.

An example of a research training project in university education

For the implementation of research projects on robotics in university education, it is proposed to use freely distributed materials from open robotics platforms. For example, the project described in this article uses the materials of the open platform thingiverse.com for 3D printing of robots (ExploreMaking, 2016). As part of the open platform support, all projects have Creative Commons licence, which means that anyone can use or modify any product design that has already been developed.

The research project includes design, 3D part printer work, Juno Rover assembly, and programming based on the Arduino platform (Figure 7).

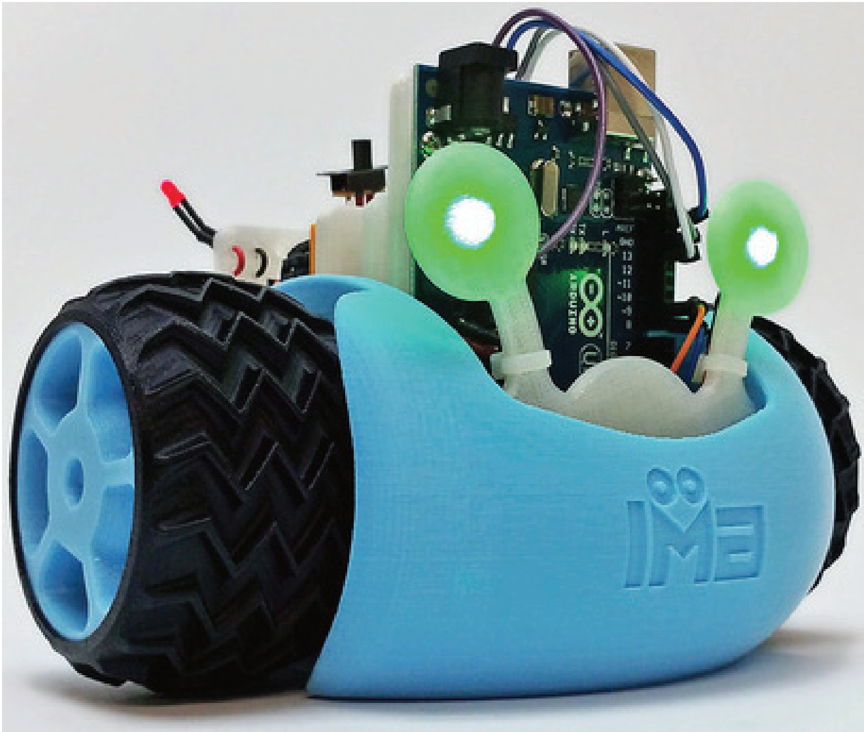

Figure 7. The exterior of Juno Rover robot on the basis of the robotic platform Arduino by ExploreMaking.

S o u r c e : Thingiverse (Juno Rover). Retrieved from https://www.thingiverse.com/thing:1720394, accessed 22 December 2018.

The robot design is made with the use of SolidWorks software package. The peculiarity of the robot is its 3D parts. They are optimised and designed for printing on any desktop 3D printer.

Work within the research project begins with printing the details of the robot on a 3D printer. The estimated total print time for the Juno Rover is set to 15 hours. Project participants print housing, panels, wheel disks, and tires. Tire covers are made of special *Elastan* flexible plastic.

In the lower part of the case, the robot provides a battery compartment, and in its upper part it has slots for panels. By using the free online version of the SolidWorks product, project participants can also design additional robot modules, expanding their functions. These modules will be installed in the slots on the panel and connected to the Arduino Uno platform.

For the robot assembly, it is necessary to use electronic cards: Arduino Uno, Bluetooth module, switch, LEDs, holder for 4xAA batteries, spin connectors, shrink tubing, plastic clamp, etc.

After a successful collection, the programming stage begins (coding). The Juno Rover can be programmed with the use of a smartphone via the Bluetooth module connected to the Arduino Uno platform. Programming “behaviour” of the robot can be done using the online Arduino web editor (www.arduino.cc), as seen in Figure 8. It is also convenient to keep all developments in the cloud with all Arduino built-in libraries.

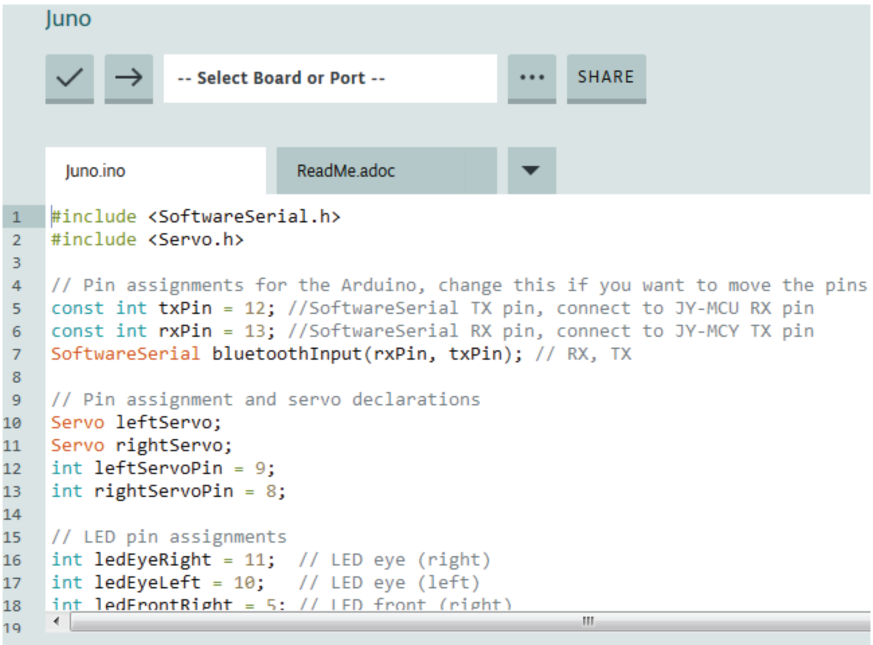

Figure 8. An example of code for the programming of Juno Rover robot based on the Arduino Uno platform.

S o u r c e : Own work.

Successful completion of the project consists in:

- implementing the robot assembly;
- working out the code for the robots to make their movements forward, backwards, and turns;
- developing full project documentation; and
- designing additional robot modules.

An example of a research training project in secondary school education

One of the examples of research projects on robotics is Poppy Project (https://www.poppy-project.org/en, accessed 17 December 2018). This project is also implemented as an open source platform with freeloading materials for the creation and use of 3D printed robots. The resources of the platform are proposed for educators, artists, scientists, and hackers.

One of the interesting projects of the platform is Poppy Ergo Jr (https://www.poppy-project.org/en/robots/poppy-ergo-jr, accessed 17 December 2018), which can be used effectively in school education, since it is possible to programme a created robot in a visual programming system Scratch. This is envisaged in the Ukrainian school computer science course starting from 2013.

The open-source Poppy Ergo Jr robot has been developed by the Flowers lab at Inria (France). The use of educational platforms like Poppy Ergo Jr was added to the French lower secondary curriculum for autumn 2016 for teaching computer science and robotics.

The Poppy Ergo Jr robot is a small 6-degrees-of-freedom robot arm. It is made of 6 cheap motors (XL-320 Dynamixel servos) with simple 3D-printed parts (Figure 9).

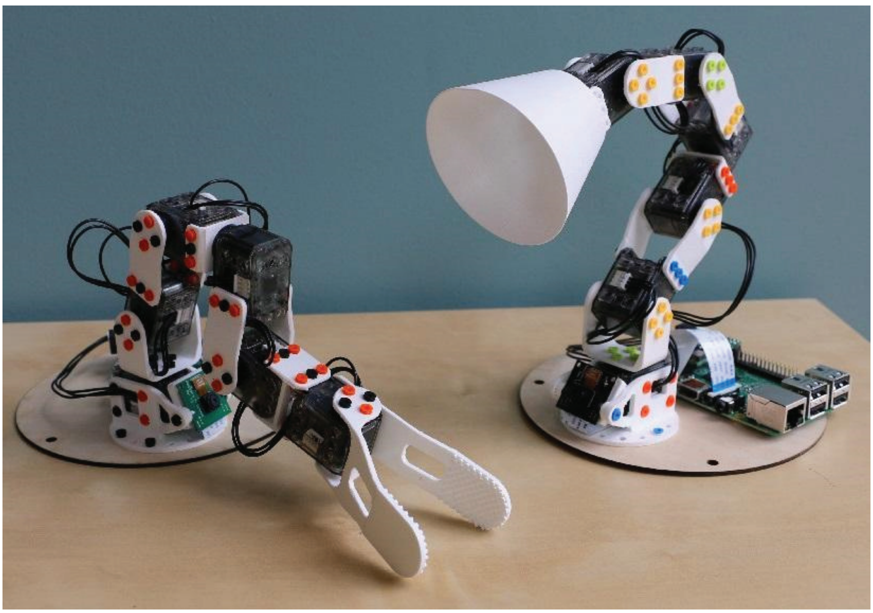

Figure 9. The exterior of Ergo Jr robot based on Raspberry Pi robotic platform.

Source: Poppy Project (Ergo Jr). Retrieved from https://www.poppy-project.org, accessed 22 December 2018.

The project consists of the following stages:

1) printing parts of the robot on 3D printer;
2) designing a robot arm with the use of 3D printed parts, robotic platform, and other details; and
3) coding a robot arm.

The peculiarity of such projects lies in the students' need to work with the following technologies:

- use of 3D technology (basic knowledge and skills in using 3D slicer software for printing 3D models, and work with 3D printers);
- work on robotic platforms such as Arduino, Raspberry Pi; and
- robotic platforms programming, for instance Poppy Ergo Jr robot programing needs the use of the visual programming system Snap! (a variant of Scratch) or Scratch (see Figure 10).

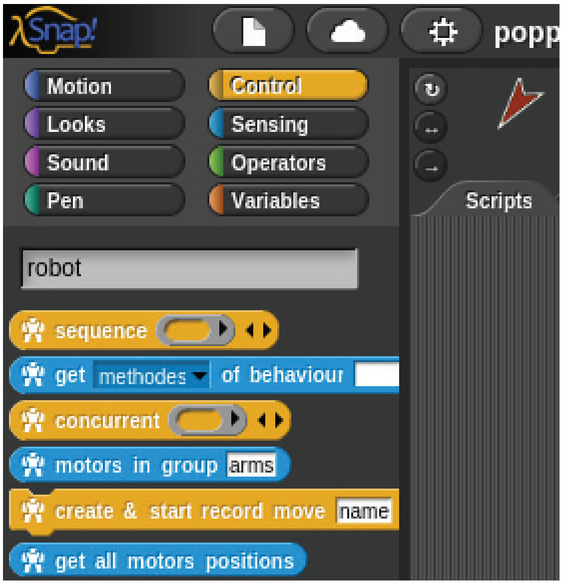

Figure 10. An example of code for the programming of Ergo Jr robot using a visual programming system Snap!

Source: Own work.

It is obvious that students need the knowledge and skills of STEM subjects. For example, in the process of Poppy Ergo Jr project, students use pre-acquired knowledge from:

- mathematics (spatial awareness and movement);
- computer science (networks, 3D technology, understanding computer network functions and how 3D printing works);
- modelling, engineering, physics, robotics (creation of a technological object, and analysis of its structure and how it functions);
- coding (knowledge of programming, how to create, write, and execute a computer programme); and
- design (using or creating illustrations, robot parts design).

Besides that, there is formation of pupils' skills in collaborative creation of a communicating object prototype. Thus, the crossdisciplinary connections of STEM are realised (robotics and 3D technologies).

An example of a research training project in primary school education

Another example of a research training project on robotics in primary school is a scientific all-terrain vehicle. This project can be realised using different robotics platforms. In our own professional activity, we used a robotics platform Makeblock (see Figure 11).

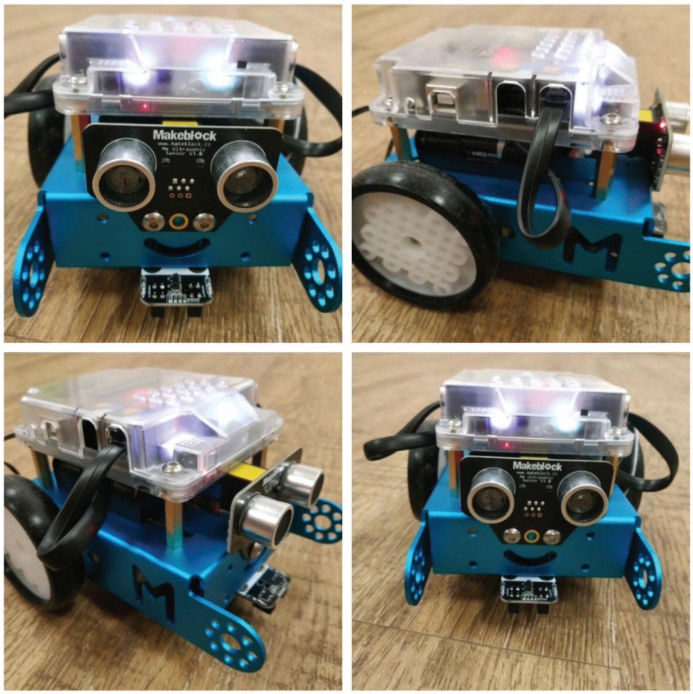

Figure 11. An example of a scientific all-terrain vehicle constructed by primary school pupils.

Source: Own work.

This project can teach students the various ways in which scientists and engineers can explore hard-to-reach places, including distant planets. The training project includes constructing, programming Makeblock, and checking code to make robot' movements forward, backwards, and turns. An example of code is seen in Figure 12.

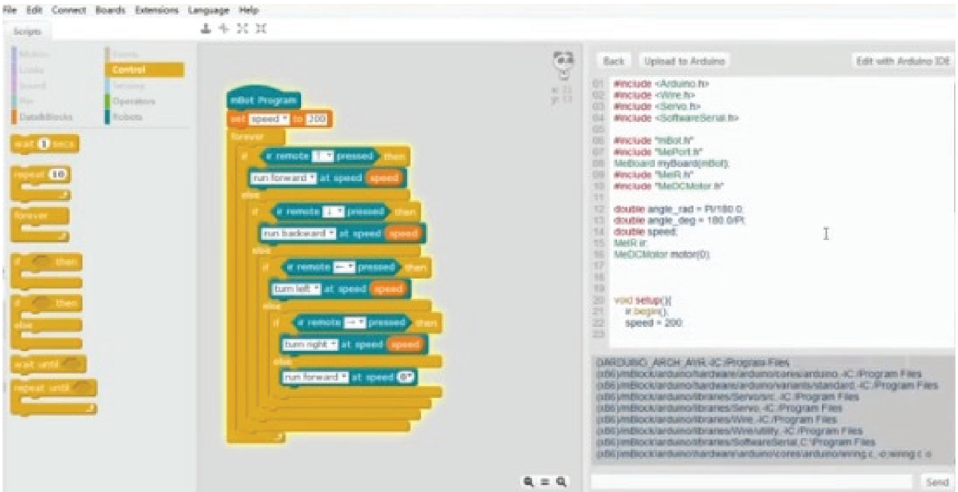

Figure 12. An example of code for the programming of a scientific all-terrain vehicle using a visual programming system mBlock.

Source: Own work.

As a result of the training project, primary school pupils obtain the knowledge and skills in such STEM subjects as technology, programming, physics, and robotics.

As was discussed above, we can make tentative conclusions about research training projects in university and school education. Therefore, the project activity embodies the priority trends of the modern education to the integration of the subject disciplines.

Implementation of these projects contributes to the formation and development of the following (Morze, Strutynska, & Umryk, 2018):

- cooperation skills;
- complex problem solving skills;
- research skills;
- critical and creative thinking;
- ability to analyse, synthesise, critically estimate, and present information; and
- ability to obtain and practically use knowledge and skills in the design process.

In addition, there is an obvious crossdisciplinary aspect of the implementation of such projects as integration of several subjects in the implementation of projects using 3D technology and robotic platforms.

Discussion

Thus, the paper addresses the following issues:

- analysing the STEM education development in Ukraine;
- determining the readiness level of educators for understanding the STEM education principles;
- implementing the crossdisciplinary aspect of STEM education and, as a result, increasing the technological availability of the future specialists; and
- introducing robotics into the educational process based on the use of the project methodology.

According to the research conducted, the authors propose several ways to improve the development level of the STEM education implementation for different target groups of Ukrainian educators (academic staff, teachers, and students):

a) increase of the awareness of some educators' groups regarding different aspects of the STEM education (for all targets groups);
b) implementation of crossdisciplinary links between STEM disciplines and robotics through implementation of the research projects (for all target groups);
c) update of curricula for future teachers through the inclusion of the STEM approach and robotics (for students);
d) trainings for educators regarding implementation of the STEM approach in the academic process (academic staff and teachers); and
e) development of the methodology for teaching STEM, based on the use of innovation technologies, in particular IBL and 5E models, and purposeful skills development.

In order to increase the level of technological availability in the society, it is necessary to develop STEM in education starting from school time, not as a separate discipline, but through well-founded integration and crossdisciplinarity based on the use of pedagogical innovation technologies such as PBL and IBL. It is proposed to teach STEM and robotics through training research projects, by means of integrated faculty courses or by including such projects in a school-based course in informatics and technology. To eliminate the STEM gap in university education, we suggest incorporating STEM education elements into separate disciplines and then engaging students in research projects. Moreover, what is suggested is the elaboration of an appropriate training method based on the use of 5E model and purposeful skills development of all participants of the educational process. This is the target of further development of the described research.

Conclusions and Perspectives for Further Research

The results of the survey show the willingness and motivation of the Ukrainian educators to use STEM approaches in the educational process. However, a theoretical analysis of scientific papers by leading experts in the field of STEM education, studying the experience of teachers, shows that there is no scientifically substantiated system for training teachers to prepare them for the systematic introduction of STEM education into the educational process on the basis of the appropriate methodology.

Overcoming the STEM gap needs correct identification of areas for further research which include:

- awareness improvement and development of techniques for using the STEM approach in the educational process,
- understanding of the conditions for the introduction of educational robotics into the process of training for future teachers of natural sciences (informatics, mathematics, physics) as a promising direction of STEM,
- development of an appropriate training method based on the use of 5E model, and
- purposeful skills development of all participants of the educational process.

The quality upgrading of STEM education could be reached through the improvement of curricula for future teachers of informatics, mathematics, or physics and the implementation of crossdisciplinary links between STEM disciplines, robotics, and related industries.

One of the points of our future work is to elaborate a new survey for the Ukrainian educators to define their needs in STEM education and robotics.

References

Dutta, S., Lanvin, B., & Wunsch-Vincent, S. (2018). Global Innovation Index 2018. Energizing the world with innovation. Accessed 18 December 2018. Retrieved from https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2018.pdf.

Executive summary World Robotics 2018 Industrial Robots. Accessed 8 December 2018. Retrieved from https://ifr.org/downloads/press2018/Executive_Summary_WR_2018_Industrial_Robots.pdf.

ExploreMaking. (2016). Juno Rover: Intro to electronics and coding. *Thingiverse*. 15 August 2016. Accessed 17 December 2018. Retrieved from https://www.thingiverse.com/thing:1720394.

Hassan, I. H. (2001). From postmodernism to postmodernity: The local/global context. *Philosophy and Literature, 25*(1), 1–13. DOI: 10.1353/phl.2001.0011.

International Federation of Robotics. Global industrial robot sales doubled over the past five years. Accessed 8 December 2018. Retrieved from https://ifr.org/ifr-press-releases/news/global-industrial-robot-sales-doubled-over-the-past-five-years.

Meeth, L. R. (1978). Interdisciplinary studies: Integration of knowledge and experience. *Change*, *10*, 6–9.

Morze, N., Smyrnova-Trybulska, E., & Gladun, M. (2018). Selected aspects of IBL in STEM-education. In: E. Smyrnova-Trybulska (Ed.), *E-learning and smart learning environment for the preparation of new generation specialists*. E-learning series, volume 10 (pp. 361–379). Katowice–Cieszyn: University of Silesia, Studio Noa.

Morze, N., Strutynska, O., & Umryk, M. (2018). Osvìtnâ Robototehnìka Âk Perspektivnij Naprâm Rozvitku Stem-Osvìti /Educational robotics as a prospective trend in STEM-education development/ (in Ukrainian). In *Open Educational E-environment of Modern University*, *5*. Accessed 22 December 2018. Retrieved from http://openedu.kubg.edu.ua/journal/index.php/openedu/article/view/175/233#.XCVa1fmLTcs.

Poppy Project – Ergo Jr. Accessed 17 December 2018. Retrieved from https://www.poppy-project.org/en/robots/poppy-ergo-jr.

Strutynska, O. V. & Umryk, M. A. (2017). ICT tools and trends in research, education and science: Local survey. *Open educational e-environment of modern University*, *3*, 150–160. Accessed 17 December 2018. Retrieved from http://openedu.kubg.edu.ua/journal/index.php/openedu/article/view/79/112#.Wdys_4-0Pcs.

Strutynska, O. & Umryk, M. (2018). Analysis of development level of the certain digital competences of the Ukrainian educators. In E. Smyrnova-Trybulska (Ed.), *E-learning and smart learning environment for the preparation of new generation specialists* (pp. 293–315). Katowice–Cieszyn: University of Silesia, Studio Noa. Retrieved from http://ig.studio-noa.pl/pub/us/E-l-10/10-615.pdf.

The Fourth Industrial Revolution, by Klaus Schwab. Accessed 18 December 2018. Retrieved from https://www.weforum.org/about/the-fourth-industrial-revolution-by-klaus-schwab.

Volodchenko, A. Y., Stryzhak, O. Y., & Chrapach, H. S. (2016). Transdisciplìnarnij harakter operacìonal′nostì rozvitku obdarovanostì učnìvs′koï molodì /Transdisciplinary nature of the development of giftedness of school youth/ (in Ukrainian). *Navčannâ ta vihovannâ obdarovanoï ditini: teorìâ ta praktika /Teaching and Upbringing of a Gifted Child: Theory and Practice/*, *16*, 100–110. Retrieved from: http://irbis-nbuv.gov.ua/cgi-bin/irbis_nbuv/cgiirbis_64.exe?C21COM=2&I21DBN=UJRN&P21DBN=UJRN&IMAGE_FILE_DOWNLOAD=1&Image_file_name=PDF/Nivoo_2016_1_13.pdf.

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Wprowadzanie robotyki jako współczesnego trendu w edukacji STEM

S t r e s z c z e n i e

Artykuł poświęcono kwestii wprowadzania edukacji STEM (edukacji w zakresie nauki, technologii, inżynierii i matematyki) w procesie uczenia się w instytucjach edukacyjnych. Autorzy analizują rozwój edukacji STEM na Ukrainie, określają poziom gotowości edukatorów do zrozumienia głównych zasad edukacji STEM, konkretyzują potrzebę wprowadzenia robotyki do procesu edukacyjnego jako współczesnego i ważnego trendu w edukacji STEM. Zanalizowano pojęcie robotyki edukacyjnej.

To umożliwia zidentyfikowanie (na bardzo wczesnym etapie) oraz rozwijanie zdolności technicznych, jak również formowanie ogólnych kompetencji STEM. Przedstawione badanie koncentruje się na interdyscyplinarnym aspekcie edukacji STEM, a szczególnie na wprowadzeniu interdyscyplinarnych powiązań między przedmiotami, które obejmuje edukacja STEM a robotyką w prowadzeniu badań i projektów szkoleniowych. Autorzy przedstawiają przykłady wprowadzenia robotyki do procesu edukacyjnego opierając się na metodzie projektów. Podano opis projektu tworzenia robota Juno Rover w oparciu o platformę Arduino oraz Projekt Poppy realizowany w edukacji szkolnej, który wprowadza otwartą platformę zawierającą rozprowadzane za darmo materiały edukacyjne poświęcone tworzeniu oraz wykorzystaniu robotów tworzonych z wykorzystaniem drukarki 3D.

S ł o w a k l u c z o w e: robot, robotyka, robotyka edukacyjna, STEM, edukacja STEM

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Внедрение робототехники как современного направления в STEM-образовании

А н н о т а ц и я

Статья посвящена вопросам внедрения STEM-образования в учебный процесс образовательных учреждений. Авторы анализируют развитие STEM-образования в Украине, определяют уровень готовности педагогов к пониманию принципов STEM-образования, обосновывают необходимость внедрения робототехники в образовательный процесс как современного и важного направления в обучении STEM. Анализируется концепция образовательной робототехники. Это делает возможным выявление технических способностей студентов (в раннем возрасте) и развитие этих способностей, а также формирование STEM-компетентностей в целом. Исследование фокусируется на междисциплинарном аспекте обучению STEM, в частности на реализации междисциплинарных связей между предметами STEM и робототехникой в процессе проведения исследовательских учебных проектов. Авторы приводят примеры внедрения робототехники в учебный процесс на основе использования метода проектов. Представлено описание проекта создания робота Juno Rover на основе роботизированной платформы Arduino в университетском образовании. Также приведены примеры робототехнических проектов в школьном образовании, один из которых реализуется на открытой платформе со свободно распространяемыми материалами для создания и использования роботов с использованием 3D-технологий.

К л ю ч е в ы е с л о в а: бихевиоризм, конструктивизм, электронное обучение, смешанное обучение, цифровая среда, IRNet

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Implementación de la robótica como una tendencia moderna en Educación CTIM

Resumen

El trabajo versa sobre la implementación de la Educación CTIM en el proceso de aprendizaje de las instituciones educativas. Las autoras analizan el desarrollo de la Educación CTIM en Ucrania, determinan también el nivel de preparación de los docentes para comprender los principios de la Educación CTIM, y justifican la necesidad de introducir la robótica en el proceso educativo como una tendencia moderna e importante de la Educación CTIM. Se analiza el concepto de robótica educativa para identificar los intereses técnicos del alumnado (en las primeras etapas) en estos temas, así como la formación de la competencia en Educación CTIM. El estudio se centra en los aspectos interdisciplinares de la Educación CTIM, en particular en la implementación de los vínculos interdisciplinares entre los temas CTIM y la robótica en el proceso de desarrollo de proyectos de formación e investigación. Las autoras proporcionan ejemplos de implementación de la robótica en el proceso educativo basado en métodos basados en proyectos. Se describe el proyecto basado en el desarrollo del robot Juno Rover, robot desarrollado en la plataforma Artuino. También se describen dos ejemplos de aplicación de la robótica en los centros educativos. Uno de ellos es la implementación en una plataforma abierta, con materiales de distribución gratuita, para crear y utilizar robot impresos en 3D.

Palabras clave: robot, robótica, robótica educativa, CTIM, educación CTIM