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N V Valko[1] and V V Osadchyi[2]

[1] Kherson State University, 27 Universytetska Str., Kherson, 73000, Ukraine
[2] Bogdan Khmelnitsky Melitopol State Pedagogical University, 20 Hetmanska Str., Melitopol, 72300, Ukraine

E-mail: valko@ksu.ks.ua, osadchyi@mdpu.org.ua

Abstract. One of the most effective ways to implement STEM education in full secondary education is through research activities. It is implemented by performing certain projects. Professional activity of teachers of natural and mathematical disciplines in STEM education is aimed at the students' mental, cognitive, and personal qualities formation and development. Their level determines the possibility of further mastering by students of a promising specialty STEM industry. It also involves the formation of the ability and willingness to solve complex problems, which is possible with the appropriate level of critical thinking, creativity, cognitive flexibility, teamwork, as well as the ability to implement research activities. In article determines the nature of the relationship between disciplines and the degree of integration. The place of project activity on robotics in school training is considered, describes the competencies that are formed as a result of such project activities. the possibility of teaching robotics to future teachers within the framework of existing curricula is also considered. The concept of STEM education has a broad interpretation: from a simple list of "exact" or "engineering" disciplines to inventive activity. In Ukraine, this area has become synonymous with scientific and research work: research and experiments. From this point of view, robotics is an effective means of developing STEM education. But this is a new tool and schools have a low level of interest in its study. Therefore, our article focuses on finding opportunities to implement the basics of robotics in education. The article formulated course requirements in accordance with the educational needs of the future teachers of science, mathematics and the level of technology development. The paper presents an example of project implementation in robotics, describes the stages of its implementation and achieved educational results.

1. Introduction

In the course of research activities, students have the opportunity to independently search for information on the project's topic, to analyze and systematize it, using a variety of information technologies. This allows them to see and solve a specific problem situation, which is essentially a research activity. Such activities also make it possible to fully work out a certain technological algorithm, which begins with the emergence of an innovative idea and ends with the commercial product creation – a startup, which must learn to present to potential investors.

Educational robotics is an innovative tool that ensures the effective implementation of STEM education [1–7]. The combination of basics of robotics, the natural sciences and mathematics study, design and research activities significantly expands the scope of educational projects that can be performed by students at school. For example, the issues of environmental projects

may include environmental protection, disaster relief, conservation of flora and fauna, creating favorable conditions for humanity in extraterrestrial conditions, eco-energy, and etc. Also quite interesting are projects related to technologies for development of artificial intelligence, big data processing, nanotechnology and bioengineering, the Internet of Things, etc. Soon, it is projected to move from "desktop" robotics to the cloud, on the principle of IoT (Internet of Things) [8].

All this should contribute to the formation of students' holistic picture of the world, awareness of the practical value of knowledge in mathematics, physics, engineering, and other STEM education subjects, as well as the formation of soft skills necessary for the information society [9, 10]. But the activity of a teacher in STEM education is not limited to school activities, but also includes extracurricular activities in the form of excursions, quests, competitions, festivals, hackathons, workshops, etc. In distance learning, it is not always possible to fully implement such projects [11–13]. Therefore, the question of future teachers training in research work in distance learning is important.

2. Related works

Research works of recent years [14–25] are particularly informative, they determine the essence of the project activity process, the corresponding technology, and the conditions for its use in the educational process.

The scientific works analysis convincingly testifies that project activity is an effective form of the pedagogical activity, one of the most productive technologies of the person's formation. It is based on an interdisciplinary approach to the learning process and the direct application of students' acquired knowledge during practical activities.

The curriculum determine the nature of the relationship between the disciplines and the degree of integration. There are the following types of inclusive courses [26]:

1. *Discipline-based integration* – focusing on each discipline provides students with specialized skills and concepts in the field. The specialized training provides teachers and students with an in-depth knowledge of the sector. However, this study may lead to fragmentation of information that does not reflect the comprehensiveness of scientific research. There is no knowledge of the connection between the different subjects. This type is possible for theoretical courses, as a basis for further study of scientific concepts and formation of ideas on the orientations of scientific research in certain areas.
2. *Study of parallel courses/modules* – in this case, the content of each discipline does not change. Only the study order changes. In this way, an effect is obtained when students can establish the connections between individual phenomena by themselves or with the help of a teacher. The only disadvantage is that students do not see cooperation among teachers. Moreover, this work requires sufficient time for planning.
3. *Additional courses or disciplines* – comparison of different disciplines focused on a problem, without a direct attempt of integration.
4. *Integrated courses/modules* – are short-term project activities. Some activities are based on an interaction between different subjects. Efforts are being made to address issues of social importance.
5. *Integrated days* – long-term projects, mainly on topics and issues arising from personal experience.
6. *Full-time program* – fully integrated programs in which the daily learning of students is linked to their lives. An example is a summer scientific camp.

Project activity contributes to the formation of the modern student personality; it can be considered an educational process independent structural unit.

Project technology is a special type of cognitive activity, which consists in contrasting the known and the unknown, and aims to activate the process of learning and understanding new things. It stimulates cognitive activity, promotes creativity and the formation of certain personality traits.

In [27] the authors classify educational robotic resources. They distinguish between the terms "educational robotics (ER)" and "robotics in education (RiE)". Using the results of the study [28], they define robotics in education as a category that includes "the learning environment, the impact on students' school curriculum, the integration of the robotic tool in the activity and the way evaluation is carried out".

The importance of the educational environment is also emphasized [29]. In the concept of Smart Pedagogy, they distinguish between three conditions that must be taken into account for successful training: human developmental regularities, the taxonomy of the educational process, technological progress, a shift from an activity-based approach to a results-based approach.

Thus, the characteristic features of natural sciences and mathematics teacher's professional activity in terms of STEM education are:

- the usage of active and widespread use of students' research activities through the implementation of various projects, the most important of which are projects related to educational robotics;
- the professional activity of natural and mathematical disciplines teacher in STEM education is not limited to teaching natural and mathematical disciplines at school, but also covers significant extracurricular work (excursions, quests, competitions, festivals, hackathons, workshops, etc.);
- in extracurricular work, an important role is played by the Minor Academy of Sciences, which provides regular research training in many areas, including STEM disciplines;
- the role of information and STEM technologies, which are ubiquitous in teaching natural and mathematical disciplines, performing projects, as well as in extracurricular activities, is extremely important.

The training of future teachers in the context of STEM education has its characteristics. One of the problems is the inability to fully exploit interdisciplinary research until the teacher acquires an in-depth knowledge of the different disciplines in which integration takes place [30, 31]. Adequate attention should therefore be paid to basic subjects in future teachers' programs. In 2010, an attempt was made to compare teacher-training programs in the European project SITEP [32]. The purpose of this study was to obtain information on the content of curricula for future teachers, as well as to establish skills and competencies that are important for the training of professionals. Following this study, many proposals were put forward to improve the practice of teacher training in different stages of learning according to different parameters:

- Knowledge of the subject is the main criterion for evaluating the educational activities of future teachers and future teachers with experience in teaching.
- Self-evaluation and independent professional development are sufficient for an experienced teacher, but it will be more appropriate to manage self-evaluation for future teachers.
- Self-learning experience often turns into a transfer to professional activities. Thus, the use of different practices and approaches during education will have a positive effect on both teachers' teaching and professional activities.
- Cooperation with colleagues (future colleagues) will be an incentive for professional growth.
- The involvement of teachers with experience in teaching in the development and implementation of the evaluation system will enable the development of professional standards that will influence the quality of the training for future teachers.

Based on the value attitude of future teachers of natural sciences and mathematics to technology, we will follow such guidelines: awareness of the place and role of technology in human life; efficient use of equipment (literate, rational, timely, effective; safe use (both for themselves and others); environmental consequences of use.

3. Results and discussion

Project-based learning reinforces students' desire to learn because it is:

- person-oriented;
- uses a whole arsenal of didactic approaches: business training, independent classes, collaborative learning, interactive learning exercises;
- implies a high motivational level, which means an increase in interest and inclusion in joint activity in the course of its implementation;
- supports pedagogical tasks at all levels – knowledge, understanding, application, analysis, synthesis;
- promotes the formation of your own experience when performing specific tasks.

Project activity is one of the most active methods, its main advantage is that children's activities take place in a micro-social environment, where they acquire practical skills and can test their theoretical achievements in practice.

At the same time, the project activity of schoolchildren differs significantly from educational and research activities. If the educational and research activity is individual and is aimed at obtaining new knowledge, then the goal of design is to go beyond a separate study, implement the acquired knowledge and skills in practice and form certain competencies.

The project method involves a detailed and comprehensive study of the topic and the development of a specific final practical result, and not just certain information analysis.

Robotics is also a unique technology that involves exploring interdisciplinary connections in various subjects based on active learning, integration with science, technology, engineering, mathematics, and other subjects. It is this direction that opens up huge opportunities for students to study technologies of the 21st century, forms communication skills, spatial imagination, teaches interaction, the ability to make decisions independently, reveals the creative intellectual potential of students, and develops design thinking and creative imagination.

Teachers who use robotics in their practice can achieve a number of goals:

- joint work on ideas;
- analyze results and search for new paths;
- systematic observation;
- development of logical thinking;
- formation of the ability to establish cause-and-effect relationships.

Nowadays, robotics constructors for children are becoming increasingly popular. Most designers assume that several models can be assembled from one set at once. Kids also have the opportunity for creativity and can create their own original models.

The fundamental novelty of using robotics in the educational process lies in the change of fundamental approaches: the introduction of new information technologies into the learning process that encourages students to solve various logical and design problems. The study of each topic involves the implementation of projects implemented with the help of innovative technologies.

However, it should be noted that today teachers have very little material to prepare for robotics classes. Therefore, the development of materials for practical use by teachers in the preparation and implementation of STEM projects is very important.

- The elementary school – materials should focus on primary STEM courses, as well as STEM fields and professions. This first step offers training based on standards, structured queries, and actual tasks that integrate the four STEM topics. The aim is to involve students in the desire to continue their studies, not because they have to. The focus is also on the combination of STEM learning opportunities within and outside the school.
- Junior high school – at this stage the courses must be more complex. The awareness of students in STEM areas and professions, as well as the academic needs in these areas. At this level, students are beginning to study careers related to STEM.
- Senior school – a curriculum focused on the use of materials in a complex and rigorous manner. Courses and areas are now available in STEM areas and professions, as well as in preparation for employment. Greater attention is paid to the combination of STEM opportunities within and outside the school.

The main regulatory document in the activity of a computer science teacher is the curriculum of the course "Informatics", which regulates the specifics of using project activities in the classroom: individual and group educational projects are focused on independent activities of students – individual, pair or group. In the process of implementing educational projects, both the educational goal (expansion and deepening of the theoretical knowledge base of students, giving the results practical significance, their suitability for solving everyday life problems, differentiation of learning according to requests, inclinations and abilities of students) and research are achieved.

According to this document, the solution of competence tasks, the implementation of individual and group educational projects is allocated in 7th grade – 8 hours, in 8th grade – 9 hours, in 9th grade – 15 hours. In addition, the teacher can use spare time, from 3 to 4 hours in grades 5-9.

The curriculum of the course "Informatics" for 8th and 9th grades of secondary schools with in-depth study of informatics determines that for individual and group educational projects in 8th grade provides 8 hours, in 9th grade – 12 hours with the possibility of using spare time in the amount of 4 and 5 hours in accordance.

The curriculum of elective-compulsory subject "Informatics" for students of 10-11 grades of secondary schools (standard level and profile level) provides even greater opportunities for the use of project activities, because to implement the activity component of the curriculum provides for various tasks, including individual and collective projects. The teacher can plan the time for their implementation independently within the hours provided for the development of the basic module or elective modules.

In order to realize curricula, we have formulated course requirements in accordance with the educational needs of the future teachers of science and mathematics:

- the content of the course should be appropriate to the level of technological development and should encourage students to adopt new approaches in practice,
- the content of the course reflects and builds understanding of current developments and trends in science and technology,
- the objectives should be of practical significance and the result should be the completed product,
- the task should be creative and address the problem in an integrated manner,
- each task is performed in the following stages:
  - formulation of the research task,
  - research planning,
  - hypothesis formation,

  - role allocation,
  - implementation of the action plan,
  - study of theoretical material,
  - performing works,
  - testing and analyzing results,
  - testing hypothesis,
- course elements (problems, surveys, etc.) should help students see the availability of innovations and feel successful in STEM disciplines,
- the clarity of the criteria and requirements for the preparation of the project, its evaluation and the availability of all teaching materials designed to increase the motivation for training,
- every project completed must pass a public demonstration (protection, competition); the demonstration should be based on evaluation criteria,
- students should have the opportunity to influence course development, to express their wishes for further design work, the level of difficulty in learning about projects to organize teamwork; active use of formative assessment techniques.

The level of interaction and contribution of each discipline in different projects will vary. There will also be different types of activities at each stage of the stem robotics project implementation.

Cross-cutting lines include environmental security and sustainable development, civic responsibility, health and security, entrepreneurship, and financial literacy. They show the main social and personally meaningful ideas, which are constantly revealed in the process of teaching and educating students. They are common to all subjects, they are a means of integrating the educational content, correlated with the key competencies, whose mastery provides the formation of values and visions of the student's world, which determine their behavior in life situations.

In the course of design and research, a holistic vision of the problem forms as a complex scientific task that requires the integration of knowledge from various fields (e.g. physics, mathematics, geography, algorithmization, programming) and has a socially significant component. For design and research activities to succeed, coordinated work is required for the entire team.

The future teacher training program consists of:

- general disciplines of social and humanitarian orientation, which contribute to the development of the general culture and the socialization of the personality of the future teacher;
- the main disciplines providing disciplinary training (theoretical, practical);
- the disciplines of the psychological and pedagogical cycle which prepare future teachers for educational work.

Besides, practical training in the form of training and production practices (pedagogical) and research work in the form of written and final qualified research courses are mandatory.

Some of these disciplines can be classified as those that contribute to the development of skills in one of the fields: science, technology, engineering, mathematics. A quantitative evaluation was carried out of the number of profile discipline credits in the list of curricula programs was carried out taking into account their membership in one of the areas.

In the disciplines of the scientific direction, they have been considered as: bases of scientific research, methods of optimization and research of operations, the theory of information and coding, etc. The cycle of these disciplines allows future teachers to carry out research and evaluate the importance of using mathematical methods and basic science knowledge. Mathematical disciplines of specialty "014. Secondary Education (Mathematics)", such as

calculus, algebra and geometry, discrete mathematics and others, are designed to provide an understanding of the fundamentals of building algorithms and mathematical methods of information processing to solve applied and scientific problems. For the specialty "014. Secondary Education (Mathematics)" these disciplines are specialized and, as a result, most of the credits. In curricula, in which mathematics is not specialized, the disciplines of this block have small differences and almost the same number of credits allocated to the study.

Relationships between areas are almost indistinguishable, except for engineering and technology components. They differ according to the scientific traditions of educational institutions and scientific schools. Technological and engineering disciplines are profile disciplines for the specialty "014. Secondary Education (Informatics)". They include disciplines such as algorithm theory and data architecture, programming and databases, and so on [33]. The disciplines of technology management are also included in those that allow you to navigate in the modern world of technology and learn future teaching techniques to work with digital tools. For example, information technology, operating systems, web programming, mobile device programming, databases, etc. It should be noted that in all curricula there were working disciplines on information technologies, distance learning technologies, algorithmization, and programming. Engineering disciplines include computer architecture, the basics of the physical organization of computer systems, and computer networks. The curricula under consideration outline the modernization of curricula from the point of view of the development of technologies. For example, teachers of mathematics and physics introduce modeling and 3D printing, robotics, and the Internet of Things in the list of disciplines. Computer education programs introduce disciplines such as data analysis and machine learning, modeling and programming robots, cloud computing, and digital marketing. As a result, each of curricula contains between 12 and 15 percent of the discipline credits in which an integrated STEM course can be taught. The presence of disciplines corresponding to modern trends in the digital development of society suggests that the list and content of disciplines are being modernized in higher education institutions. Such a renewal is possible only if there is a professional community that supports innovation and meets the requirements of modern society for educational activities. This community projects STEM culture through its activities, forming through the education and education STEM culture of future teachers.

Here is an example of a long-term project for the construction of a self-driving vehicle, which was implemented by the students to participate in robot-refuge competitions. The model creation process has gone through the following steps.

1. Study of the rules of competence and determination of the technical characteristics of the vehicle. This phase of project activity is organizational. To implement it, it is necessary to:
   - Define the theme and objective of the project: in this case, the theme is the creation of autonomous transport, and the aim is to participate in the competitions and to achieve maximum results. Technical task formulated briefly: to create an autonomous robotic vehicle (TC), capable of moving autonomously along the line (without leaving its path) and to be part of the urban traffic model, following the rules of the road (traffic).
   - Problem formulation – you must carefully study the rules of the competition and pay attention to the particularities of their conduct that should be taken into account. The creation of such a project consists of two interdependent processes: the construction of a physical model – the vehicle is subject to technical requirements and the programming of the model – describes the rules of conduct in certain situations. It is also necessary to take account of the needs of the environment. For example, traffic lights, road signs, and a pedestrian model must be used to construct an urban traffic model.
2. Review of modern autonomous vehicle control systems and study of control autonomy levels. This is the planning phase of the activities and the determination of the means for

the implementation of the projects. At this stage, existing automotive systems are taken into account and a decision is made on the technology that will be used to implement the autonomous control, review, and analysis of existing semi-autonomous automotive systems and their functions of the main manufacturers (Audi Traffic Jam Pilot, BMW Traffic Jam Assistant, Cadillac Super). Cruise and others), technologies for detecting objects and interferences (surveillance chambers, radars, handles, etc.), different levels of automation are also considered. The Society of Automotive Engineers (SAE) has defined the term "driving mode", meaning "a type of scenario with characteristic requirements for dynamic driving". The familiarity with this material makes it possible to form the concept of standard for the development of hardware and software products. The familiarity with standards and their comparison offers an opportunity to professionally evaluate their results and form a technological literacy and gives the concept of society's technology and the degree of change that occurs with the development of technology.

3. Development and creation of a model. Vehicle design and model testing. This step in the implementation of the project is the main one in the development of an autonomous model. As part of the model of autonomous, unmanned vehicles for on-line traffic, it is necessary, first of all, to become familiar with the processes of development, creation, configuration, and operation of robotic systems, which are prototypes of systems that will be implemented under real conditions to reduce car accidents. At this stage, the development of the technical base for the creation of the model, the selection of components, the definition of patterns will help to achieve the maximum of results. The material architecture of the model is developed, the basic concepts of the circuits are studied, the principles of micro-controller programming are studied and projects are created with its application. The main problem in the implementation of such a project is the problem of speed regulation: on the one hand, speed must be maximum for the rapid passage of the route; on the other hand, the excessive speed does not allow the vehicle to follow traffic rules or to follow the line. This part of the project has become experimental and has required proof of different hypotheses. When creating the model there was a problem with the regulation of the vehicle and determining the current speed. Based on the studied material, it was decided to record the fact of rotation by the sensor. Several hypotheses have been taken into account to solve this problem and experiments have been carried out with which this operation can be performed. Each hypothesis has been tested and analysis of these results has been carried out. The calculation of velocity in each hypothesis is based on the data obtained by the sensor. When testing the model for each of these options, its disadvantages and advantages have been identified.
4. Programming of car's autonomous movement following traffic regulations. At this stage, autonomous vehicle movement algorithms are considered as discrete control systems and proportional control. It investigates the apparatus of automation theory for the realization of the logic of vehicle management that should respect traffic rules are studied.

The development and running of this project require substantial training from students and teachers. The content of the educational material involved in the project's implementation corresponds to the fundamental concepts of such disciplines/scientific sections such as classical and electronic mechanics, automatic theory, programming, mathematical modeling in the curriculum of future teachers of natural sciences and mathematics. The process of preparing and implementing a STEM project contributes to the formation of a scientific approach to problem-solving, technological literacy, the skills in the use of modern digital technologies, the integration of scientific concepts, and the understanding of interdisciplinary connections in future teachers.

4. Conclusions

Research analysis showed that STEM education forms certain competencies that determine the ability to innovate, as well as contributing to the participation of future teachers in research and understanding/motivation to follow/study new technologies.

The future teacher of natural sciences and mathematics must be able to train key competencies among students, according to the current level of technological achievements, and to involve them in innovative activities. For robotics to become an integral part of the educational process, it is necessary to train future teachers in a sustainable interest in its application in the future and to show its benefits as a tool for universal learning. The development and running of this project require substantial training from students and teachers. The content of teaching material involved in the implementation of the project corresponds to the fundamental concepts of such disciplines/scientific sections as classical mechanics and electronics, automatic theory, programming, mathematical modeling in the curriculum of future teachers of natural sciences and mathematics. The process of preparing and implementing a STEM project contributes to the formation of a scientific approach to problem-solving, technological literacy, the skills in the use of modern digital technologies, the integration of scientific concepts, and the understanding of interdisciplinary links.

Analysis of the curricula for future teachers in natural and mathematical disciplines has shown. They are focused on the training of thematic skills in knowledge and application levels. Valuable components are present but to a lesser extent. They are more often concerned with the integration of information technologies into the education process and, in a smaller number of cases. They are concerned with STEM education technologies.

The results of the study have led us to conclude that there are disciplines in curricula contribute to the development of competencies in each of the fields: scientific, technical, technological, or mathematical. There are sufficient disciplines in the curricula. So, it is desirable to carry out integrated classes that contribute to the construction of a holistic vision of fundamental laws in the study of science and the formation of the image of the world's natural sciences. The presence of disciplines such as 3D moderation, robotics, the Internet of Things provides construction of the educational process according to integration and innovation criteria. They offer a mastery of technological and innovative skills.

References

[1] Khine M S (ed) 2017 *Robotics in STEM Education* (Cham, Switzerland: Springer International Publishing AG)
[2] Benitti F B V and Spolaôr N 2017 How have robots supported STEM teaching? *Robotics in STEM education* (Cham, Switzerland: Springer International Publishing AG) pp 103–129
[3] Kushnir N, Valko N, Osipova N and Bazanova T 2018 *CEUR Workshop Proceedings* **2104** 431–446
[4] Merzlykin P, Kharadzjan N, Medvedev D, Zakarljuka I and Fadeeva L 2018 *CEUR Workshop Proceedings* **2104** 359–365
[5] Hrybiuk O, Vedyshcheva O, Lukavyi P, Ivaniuk A and Kulish N 2020 *CEUR Workshop Proceedings* **2732** 770–785
[6] Valko N, Kushnir N and Osadchyi V 2020 *CEUR Workshop Proceedings* **2643** 435–447
[7] Osadchyi V V, Valko N V and Kuzmich L V 2021 *Journal of Physics: Conference Series* **1840** 012027
[8] Semerikov S O, Striuk A M, Vakaliuk T A and Morozov A V 2021 *CEUR Workshop Proceedings* **2850** 1–15
[9] Varava I P, Bohinska A P, Vakaliuk T A and Mintii I S 2021 *Journal of Physics: Conference Series*
[10] Sultanova L, Hordiienko V, Romanova G and Tsytsiura K 2021 *Journal of Physics: Conference Series* **1840** 012038
[11] Shokaliuk S, Bohunenko Y, Lovianova I and Shyshkina M 2020 *CEUR Workshop Proceedings* **2643** 548–562
[12] Syvyi M, Mazbayev O, Varakuta O, Panteleeva N and Bondarenko O 2020 *CEUR Workshop Proceedings* **2731** 369–382
[13] Bobyliev D Y and Vihrova E V 2021 *Journal of Physics: Conference Series* **1840** 012002
[14] Semerikov S, Teplytskyi I, Yechkalo Y, Markova O, Soloviev V and Kiv A 2020 *SHS Web Conf.* **75** 04018

[15] Han S, Capraro R and Capraro M M 2015 *International Journal of Science and Mathematics Education* **13** 1089–1113
[16] Goncharenko T, Kushnir N, Valko N and Osipova N 2019 *CEUR Workshop Proceedings* **2393** 132–143
[17] Iatsyshyn A, Kovach V, Lyubchak V, Zuban Y, Piven A, Sokolyuk O, Iatsyshyn A, Popov O, Artemchuk V and Shyshkina M 2020 *CEUR Workshop Proceedings* **2643** 134–160
[18] Vlasenko K, Kondratyeva O, Khyzhniak I, Chumak O and Volkov S 2020 *CEUR Workshop Proceedings* **2732** 756–769
[19] Horbatiuk R, Voitovych O and Voitovych I 2020 *E3S Web of Conferences* **166** 10026
[20] Horbatiuk R M, Bilan N M, Sitkar O A and Tymoshchuk O S 2021 *Journal of Physics: Conference Series* **1840** 012047
[21] Balyk N, Grod I, Vasylenko Y, Oleksiuk V and Rogovchenko Y 2021 *Journal of Physics: Conference Series* **1840** 012032
[22] Glazunova O G, Parhomenko O V, Korolchuk V I and Voloshyna T V 2021 *Journal of Physics: Conference Series* **1840** 012030
[23] Pavlenko M and Pavlenko L 2021 *Journal of Physics: Conference Series* **1840** 012031
[24] Shuhailo Y V and Derkach T M 2021 *Journal of Physics: Conference Series* **1840** 012042
[25] Gryshchenko I M, Jin L, Derkach T M and Tang S 2021 *Journal of Physics: Conference Series*
[26] Meeth L R 1978 *Change: the magazine of higher learning* **10** 1–10
[27] Scaradozzi D, Screpanti L and Cesaretti L 2019 *Towards a Definition of Educational Robotics: A Classification of Tools, Experiences and Assessments* (Cham: Springer International Publishing) pp 63–92
[28] Eguchi A 2014 Robotics as a learning tool for educational transformation *Proceeding of 4th International workshop Teaching robotics, teaching with robotics and 5th International conference Robotics in education* (Padova, Italy) pp 27–34 ISBN 978-88-95872-06-3
[29] Daniela L 2019 *Smart Pedagogy for Technology-Enhanced Learning* (Cham: Springer International Publishing) pp 3–21
[30] Meyer J H F and Land R 2003 *Threshold concepts and troublesome knowledge: linkages to ways of thinking and practicing* (Oxford: OCSLD) pp 1–16
[31] Griffiths R 2004 Knowledge production and the research–teaching nexus: The case of the built environment disciplines vol 29 (Taylor and Francis Ltd) pp 709–726
[32] Menter I, Hulme M, Elliot D, Lewin J, Baumfield V, Britton A, Carroll M, Livingston K, McCulloch M, McQueen I, Patrick F and Townsend T 2010 *Literature review on teacher education in the 21st century* (Scottish Government Social Research)
[33] Ponomareva N S 2021 *Journal of Physics: Conference Series* **1840** 012035