Training of practicing teachers for the application of STEM education

Training of practicing teachers for the application of STEM education

V E Velychko[1], N V Kaydan[1], O G Fedorenko[1] and V P Kaydan[2]

[1] Donbas State Pedagogical University, 19 Batyuk Str., Sloviansk, 84112, Ukraine
[2] Separate structural subdivision Kramatorsk Vocational College of Industry, Information Technologies and Business, 99 Velyka Sadova Str., Kramatorsk, 84303, Ukraine

E-mail: velichko@ddpu.edu.ua, kaydannv@gmail.com, fedorenko.elena1209@gmail.com, kajtan.kt@gmail.com

Abstract. The modern informational society poses new challenges to the education system, and one of the ways to solve them is STEM education, which has become one of the popular learning trends. The solution of the set tasks encourages not only the growth of the economic indicators, but also the general stable development of society with a careful attitude to resources, both material and immaterial. The practitioners are the leaders in high-tech changes of the education system, that is why they are the ones who can implement the STEM approach in the most effective way. This is important because the scientific component of technology is evolving over time and, accordingly, the skills of employees that are needed are changing, too. And the STEM approach in education, in turn, is the best to meet this requirement. The professional development of practicing teachers means to update knowledge in the field and acquire new teaching methods and technologies. Thus, in addition to professional necessity, professional development of practicing teachers is of innovative importance. The proposed certificate program of advanced training aims to develop students' skills to implement STEM education in a scientifically sound and critical way; widely use interdisciplinary interaction; to introduce methods and means of STEM education in professional activity. The target audience of the program is future and practicing teachers of general and professional higher education.

1. Introduction

The development of STEM education is recognized as a priority both in the world and at the state level. The Government of Ukraine has adopted the Concept for the Development of Natural and Mathematical Education (STEM education) and developed an Action Plan for the implementation of the Concept for the Development of Natural and Mathematical Education (STEM education) until 2027 [1]. The document defines a set of measures related to the formation and development of skills in research and engineering, invention, entrepreneurship, early professional self-determination and readiness for informed choice of future profession, promotion of scientific, technical and engineering professions, dissemination of innovations in education. The provisions of the Concept for the Development of Natural and Mathematical Education (STEM education) are implemented through all types of education: formal, non-formal, informal - on the basis of online platforms, media products, STEM centers / laboratories, including virtual ones. The use of the leading principle of STEM education – integration – allows to modernize the methodological principles, content, volume of educational material of natural sciences and mathematics, technologicalization of the learning process and the formation of

educational competencies of a qualitatively new level. The implementation of measures is directly related to teacher training. It is the competence of teachers in the field of STEM education that is the necessary condition for the large-scale implementation of STEM education. Researchers from a number of European research centers hold a similar view. Adina Nistor and her colleagues consider teacher training to be a major factor in promoting STEM education [2]. The TEMI project is given as an example [3]. The TEMI approach is built around contextual learning, encouraging teachers to use "riddles" in teaching scientific concepts. The project complements classroom training seminars, theater events and other online skills development exercises in the form of smartphone applications, videos, publications and online seminars. In addition, the European Commission has adopted a Digital Education Plan for 2021-2027 [4]. Among the planned actions is the involvement of women in STEM. According to the European Commission, such activities should increase the involvement of more participants in STEM education. Given that the majority of teachers are women, this activity is aimed at expanding the number of professionals involved in STEM education.

2. Literature review

Science, technology, engineering and mathematics have already improved many aspects of life, such as health and well-being, infrastructure, sustainable energy production, agriculture and more. In synergy with the social sciences and humanities, STEM has the potential to transform and improve people's lives, while ensuring environmental sustainability and providing a basis for new approaches and solutions to current and future global problems. The question is to realize this potential through the training of specialists in this field. Training should begin in secondary school, and therefore an important step in this direction is the training of teachers who are able to convey the concept of STEM to students. University curricula for future teachers are adapted to the introduction of STEM education. The issue of retraining of practicing teachers, formation of their competencies in the implementation of STEM education, expansion of interdisciplinary learning skills, sustainable use of educational material based on a scientific approach and combining theoretical material with its practical content remains unresolved.

In the course of this study, open sources on the process of future teacher training and professional development of practicing teachers in the field of STEM education were analyzed. General analysis of educational trends and their impact on STEM technologies were used to identify the role and place of STEM education in the modern educational environment. An analysis of existing best practices in the training of future teachers in the field of STEM education and in-service teacher training courses was used to build a model of retraining of practicing teachers. In addition, the available data were analyzed to find relevant information to determine the conditions for the implementation of STEM education in the educational process of educational institutions. The results of the development and implementation of certified refresher courses for practicing teachers provided an opportunity to start collecting statistics for their further analysis.

STEM is a science-based concept, a learning system used by developed countries in various fields of education to develop in children and young people the skills needed for sustainable development in the 21st century. This concept arose at the request of economic stability, which is impossible without innovative growth, which requires professionals of new content. It involves a combination of different sciences, technologies, engineering and mathematical thinking. An important concept related to STEM education is interdisciplinarity. The key pedagogical problem in the development of STEM oriented curricula is the technology of integration of components, which, on the one hand, are close disciplines, and on the other – independent established ontologies: Science as a method of cognition that helps to understand the world; Technology as a way to improve a world that is sensitive to social change; Engineering as a way to create and improve devices to solve real problems; Mathematics as a way of describing the

world, presenting its abstract model capable of research.

Yeping Li and Judy Anderson have presented an expanded overview of the content of research and trends in teacher training for STEM education [5]. The authors summarized and analyzed the research data, as well as discussed the need for further research and their development.

Mi Song Kim and Najmeh Keyhani explored STEM technology teacher training in non-formal education. The study analyzes the available sources on the development and progress of the informal personality of STEM teachers, recognizing its compatibility with the self-authorship framework. The results of the study emphasize the importance of teacher support initiatives that involve collaboration, mentoring and curriculum development that can help STEM teachers on their path through non-formal education [6].

The research and project activities are important means of conducting STEM education. School teachers have to implement and control these activities in the classroom. However, little is known about teachers' attitudes towards the use of research or even design projects. The study by T.E. Vossen, I. Henze, R.C.A. Rippe, J.H. Van Driel and M.J. De Vries [7] present the results of work with Dutch teachers who taught STEM, O&O (research and design) and NLT (nature, life and technology). Researchers have concluded that STEM teachers need to be further trained, especially for teachers who are starting to teach STEM subjects. As STEM teachers have different backgrounds, it is important that they are provided with sufficient time, support and professional development courses. Teacher professional development is often focused on the content of STEM projects, but in order to teach support for research and project processes, it is necessary to pay attention to the methodological support of project and research activities. In addition, teachers may need first-hand experience in researches and projects, since not all O&O and NLT teachers have necessarily done this before in their studies. Instead of existing courses in individual subjects, courses specifically aimed at integrated STEM could attract more STEM teachers and increase their willingness to attend such professional development opportunities.

The topic of augmented reality in education is quite new and little studied for STEM education. In a study by V.V. Osadchyi, N.V. Valko and L.V. Kuzmich the publication on the research topic, described the concept of augmented reality, analyzed the technologies of augmented reality, which are adapted to the teaching of natural sciences and mathematics, were analyzed. The role of STEM approach with augmented reality in the educational process is determined. An example of the use of augmented reality in the robotics project is given [8].

Nina Bencheva's article examines EU and Bulgarian policies to promote out-of-class learning, including STEM and ICT education [9]. Some best practices of extracurricular science education in Europe are identified. Teachers of the Department of Telecommunications of the University of Ruse have implemented various projects to teach students of schools in Ruse outside of formal education in the field of ICT and STEM. The article presents some of the experimental projects of teaching outside the classroom of professionals of the Department of Telecommunications.

The researchers K. Pressick-Kilborn, M. Silk and J. Martin have studied STEM and STEAM education in Australian schools [10]. They identified several problems of the implementation of STEM, including the need for professional training to equip teachers with new skills and knowledge in the development and delivery of STEM education. Two specific issues identified as critical are (a) the potential contribution of STEM education to a sustainable future and (b) the importance of STEM education for social justice, in ensuring that all children and young people have equal access to learning opportunities.

M. Dubek and C. Doyle-Jones have investigated the preparation of future teachers for the application of STEM education using the model of coeducation [11]. The research questions included: "How do candidates feel and perceive the model of co-teaching with their teachers?" and "What elements of a teacher's experience in co-teaching reflect the cognitive learning model?" This study found that teacher candidates who taught with their teachers strengthened their understanding of STEM integrated education, including STEM content and Pedagogical

Content Knowledge. Making thinking visible through cognitive learning with the help of a collaborative learning model has led future teachers to develop an understanding of STEM education in their personal teaching practice and to develop their ability to become confident and resourceful STEM teachers.

The biological threats and anti-epidemiological measures caused by COVID-19 have also made adjustments to STEM education. A. Aykan and B. Yıldırım have investigated the integration of the Lesson Study Model into distance STEM education during the COVID-19 pandemic [12]. The study focused on six points: (1) STEM education in distance learning, (2) Lesson Study, (3) lesson planning processes, (4) lesson planning problems, (5) assessment and evaluation methods, and (6) strategies; methods and techniques. The researchers concluded that the Lesson Study Model, integrated with STEM education, leads to better planning and teaching of STEM lessons. Moreover, distance learning platforms are promising ways to ensure the professional development of teachers during a pandemic.

The use of virtual and augmented reality in STEM education is no exception. S.O. Semerikov, M.M. Mintii and I.S. Mintii developed and researched the results of the course "Development of Virtual and Augmented Reality Software" for STEM teachers [13]. It is established that the course promotes the development of competencies in the design and use of innovative learning tools. A survey of the course participants on their expectations and course results is provided. Reducing hours, detailed guidelines and increasing the number of practical problems, the amount of independent work, increasing the number of classroom-related STEM subjects are called potential opportunities for the course that need to be realized.

3. Research results

3.1. Examples of implementation of STEM projects in Ukraine

The relevance and practical significance of STEM education is best demonstrated through the description of the quantity and quality of practically implemented STEM projects. It should be noted that as one of the elements of the educational process of any educational institution STEM projects are much broader than just an educational system that uses interdisciplinary links to gain relevant skills today. STEM projects should be considered in terms of the educational process as an element that helps to create a mental system of students. Since these projects have different scales, it is better to systematize the description of practical implementation not on the principle of disciplines and subjects and their interrelationships, but on the principle of "globality" of specific results.

The simplest to analyze are the STEM projects implemented within a specific subject or discipline, or even a specific topic.

The process of learning a foreign language covers almost all types of daily activities in most types of human actions, so it allows you to use a variety of STEM technologies. In particular, project technology, interactive learning technologies, case technology, mental maps, web-quest technology, etc.

Examples of tasks that can be performed in English lessons are the following:

- Lego activities that develop reading and writing skills (Alphabet - using lego to build the alphabet; Post-reading activities using lego – stick words or sentences on Lego bricks to learn the content);
- Craft-sticks – writing on a stick a new word from English that he learned in everyday life and in groups during classes, children form sentences with them;
- Elaboration in writing – students are given colored stripes of different colors with words from which to form a chain and new sentences;
- Inside my head – improving monologue speech by creating an image of a person with the help of paper and cut from magazines, newspapers, image wrappers and their subsequent

description;

- 3D House – create a model of a modern or medieval city, future city or dream city and in the process of working on projects to learn the use of English verbs in different grammatical tenses with instructions in English, of particular interest because architecture is a great example of design combination. arts, technology and engineering thinking;
- Papier-Mache Globe - in preparation for a high school debate on Traveling, children make a globe out of newspapers, choose a country, and argue why they should travel there.
- Storytelling – based on the text, students recreate events using toys in their own cartoons, create their own film about school, pet, hobbies, etc., using computer animation programs, sounding them in English. Or, they are dubbing excerpts from feature films or cartoons and overlaying subtitles in English. The process of creating paper booklets in a foreign language with the help of graphic editors.

An example of the use of STEM projects in professional pre-higher education is the involvement of project approaches in the study of the course "Computer Design" at the College of Radio Electronics (Dnipro). In particular, involving students in the software used in their studies is a creative task of developing a personal logo using AutoCad, which is then used in the drawings to confirm the authenticity of the development and authorship. Mastering the interface, the main functions of AutoCad takes place in a creative atmosphere, effortlessly, which achieves a positive attitude towards the discipline.

In the following practical works, students are invited to create their own portfolio of the designer, consisting of different types of technical drawings. The student is offered a list of tasks of varying complexity for each type of work and everyone chooses for themselves whether it will be a few simple tasks with the appropriate level of assessment, or a complex drawing that will bring a significant assessment to the developer "portfolio".

At the end of the course, students are asked to develop a model of a reproducible drawing of an electrical circuit diagram using Sprint Layout 6 – a simple and effective program for manual design and drawing of printed circuit boards for electronic devices with a high degree of complexity. In this way, students go all the way from developing a drawing to creating a board for a specific device.

The next level for analysis is the integration of different disciplines, the use of interdisciplinary links. Implementation of STEM projects in terms of integrated classes shows good practical results. In this case, subjects or disciplines can be combined in a variety of combinations, the restriction of which is only the relatedness of the issues considered in the curriculum:

- integration of geometry, physics, biology and literature on the topic "Square of figures";
- integration of algebra and physics on the topic "Function. Properties of the function";
- integration of geometry and geography on the topic "Applied Problems" for the application of material on solving triangles;
- integration of geometry and art on the theme "Quadrilaterals on the left, quadrilaterals on the right";
- integration of geometry and labor training on the topic of "Quadrilaterals";
- integration of physics with biology as a series of classes dedicated to animals – "devices" that can predict weather changes, predict various natural phenomena: earthquakes, thunderstorms, volcanic eruptions as living barometers, compasses, seismographs.

It is necessary to indicate the type of activity that is associated with in-depth study of certain material and its more detailed study – group activities (writing works of the Academy of Sciences) separately. Today STEM, STEAM, STREAM are the recognized leading trends in pedagogical practice in the world that provide for the integration of natural sciences, new technologies,

research, engineering, mathematics and art, including oratory, skills to confidently and friendly conduct public discussions, to argue their scientific hypotheses, present the results of project activities. In classes on the basics of robotics and computer modeling at the Poltava Regional Academy of Sciences [14], students learn the technical and software capabilities of LEGO EV3, Arduino, learn to compose algorithms and write programs for robots, take photos and videos from quadcopters, learn modern 3D modeling technologies in the SolidWorks automated design system and print 3D models on a 3D printer. Poltava Regional Small Academy of Sciences has an official license to use the software product SolidWorks for educational purposes. The advantages of SolidWorks are versatility in achieving a certain goal at all levels of work (creation of planar and three-dimensional sketches, elements of details, conjugations in assemblies, etc.). SolidWorks also provides the ability to create design documentation, photorealistic images, video animations, engineering calculations. 3D printing capabilities, close interaction with Excel spreadsheets, teamwork on projects make SolidWorks a very effective tool for use in research and experimental activities.

Among the largest are STEM projects, the implementation of which is designed for a significant number of educational institutions in the country or is available internationally. For example, "STEM school for building modular origami" – in 2021 the program of this course was recommended by the Ministry of Education and Science of Ukraine. The course is designed for students in grades 7-9. The branches are natural, technological, mathematical, information, social (authors I.Yu. Nenashev, N.B. Godovana, T.A. Kravets, N.O. Kazachkova). The course program was developed by the authors in accordance with the State Standard of Basic and Complete General Secondary Education [15], the Concept of Development of Natural and Mathematical Education (STEM education) [16]. The novelty of this technique is that it not only solves design, mathematical and architectural problems, but also helps the student to solve research problems, forms students' scientific and critical thinking, develops creative abilities and focuses on emotional and cultural enrichment of youth.

All-Ukrainian projects include the Discover Ukraine curriculum developed in conjunction with the Kyiv-Mohyla Business School [17]. This is an educational gamified project that contains interactive instructions, teaching materials, inspiring success stories and much more for teenagers in grades 7-11 from small towns of Ukraine, in which they learn to implement their ideas and plans, changing schools, cities and all of Ukraine. In the form of games, participants work on such skills and abilities of the XXI century as team building, critical thinking, project management, communication, practice working with ideas.

Free online service "Kahoot!" allows you to create interactive educational games, quizzes, discussions, surveys, consisting of a series of questions with multiple choice answers. The service is designed for learning based on games, which makes it interesting and exciting to study any subject in any language on any device for any age. And also the service can be useful to the head and pedagogical collective of educational institution for realization of various forms of scientific, methodical and organizational work.

The game "Minecraft", which allows players to create and destroy various blocks and use objects in a three-dimensional environment, bought in 2014 by Microsoft, has become a universal learning platform – a course in programming for children. This resource (version for learning – Minecraft Education Edition) allows children to develop the competencies of the new Ukrainian school, promotes creativity, cooperation and problem solving in an exciting environment, where the only limitation is the player's imagination [18].

MozaBook software is software that diversifies school lesson tools with numerous illustrations, animations, and creative presentation features. Spectacular interactive elements and built-in applications promote skills development, facilitate experiments, and arouse students' interest. This is an indispensable tool for a STEM project.

Virtual STEM center of the Small Academy of Sciences of Ukraine – STEM laboratory

MANLab – a center of real and virtual educational research aimed at supporting and developing STEM education in Ukraine. As well as interactive simulations for science and mathematics (`https://phet.colorado.edu/`); POP-UP-figures – (paper mechanics) – develops spatial imagination, interdisciplinary connections, self-expression, mathematical, natural, digital competence; augmented reality (AR) is the complement of the physical world with digital data provided by real-time computer devices (smartphones, tablets and AR glasses) [8]; laptops, Google applications, cognitive YouTube channels, creating your own videos, dramatizations.

As an example of the use of STEM education in the educational process of students of pedagogical specialties can be considered a plan of project activities, which can be used during independent work in natural sciences and mathematics. According to the results of this work, in addition to processing the material of the discipline, the student has the opportunity to create their own case for further teaching. This case will contain indicative topics, interdisciplinary links, a list of theoretical questions from the relevant disciplines, a description of the results, the mechanics of execution, timing and resources that can be used to implement projects. That is a detailed description of the organization of project activities.

The analysis of research results, work done and our personal experience suggest that students involved in the preparation and implementation of educational projects are more motivated to research activities, as they as a result of such work "accumulates" carefully developed and meaningful theoretical material and self-made experimental material. Publication activity allows students to gain vast experience in the field of research and prepares them for independent course and final qualification works. It is also important that students in the process of studying in higher education institutions form their own portfolio of research papers, which gives an advantage when entering a master's degree and employment.

3.2. Ways to improve the skills of practicing teachers in the field of STEM

The professional activity of a teacher in the conditions of STEM education is primarily aimed at the formation and development of mental and cognitive and personal qualities of students of general secondary education, the level of which determines the possibility of their further mastery of promising specialty of STEM industry. It also involves the formation of the ability and readiness of the future graduate of general secondary education to solve complex problems, which is possible with the appropriate level of critical thinking, creativity, cognitive flexibility, teamwork and their ability to carry out research activities. All this should contribute to the formation of a holistic picture of the world, awareness of the practical value of knowledge in mathematics, physics, engineering and other subjects of STEM education, as well as the formation of "soft" skills necessary for the information society. That is why one of the most effective ways to implement STEM education in general secondary education is research activities that are implemented through the implementation of certain projects. In the course of such activities, students of general secondary education have the opportunity to independently search for information on the topic of the project, to analyze and systematize it, using a variety of information technologies. This gives them the opportunity to see and solve a problem that is essentially a research activity.

The process of teacher training in the context of the implementation of STEM education also has certain features. First, it is impossible to implement interdisciplinarity until the teacher acquires a thorough knowledge of the disciplines in which the integration takes place, so in the program of training teachers to use STEM technologies basic disciplines must precede all others, and their mastery must be given enough time. Secondly, it is the need for practical experience, in particular in the implementation of project activities. This experience is gained by the teacher during a variety of exercises, through independent work in laboratory and practical classes, in various types of repetition, as well as through the implementation of project activities during training, which encourages them to think about problems related to their learning. Due to this,

teachers gain experience of teamwork and research approach to learning about the world around them, thus forming the appropriate components of the studied readiness.

Therefore, project activities should permeate the entire process of preparing teachers for the use of the STEM technologies. Third, it is very important to socialize and adapt the teacher in the professional circle, which will allow them to form an appropriate professional behavior, compare themselves with other teachers as well as provide an incentive to continue learning. Therefore, in the process of preparing teachers for the use of STEM technologies it is necessary to ensure the appropriate social interaction in the professional environment. Fourth, the effectiveness of the teacher training process depends entirely on the level of formation of its value-motivational sphere. Therefore, in the process of preparing teachers for the use of STEM technologies it is necessary to create an appropriate motivational background, stimulating their psychological readiness to learn as well as forming an active and positive attitude to technology in professional activities based on existing knowledge and experience.

3.3. Certificate training program

According to the Institute for Modernization of the Content of Education in Ukraine, the curriculum is a normative document that defines the range of basic competencies that must be mastered by those who study in a particular subject (discipline) and the system of knowledge, skills and abilities they must master [19].

The curriculum should include: an explanatory note, a list of topics of the material studied, recommendations on the number of hours for each topic, distribution of topics and time spent on the whole course, the amount of knowledge, skills and abilities in this discipline, a list of illustrations and literature for learners, guidelines and literature for learners, criteria for assessing knowledge, skills and abilities in each activity, etc.

STEM program is considered to be one that meets the main criteria: relevance and innovation of content; comprehensibility of the program implementation process (what do the learners do specifically, what conditions and equipment are necessary for effective implementation); availability of methods that allow you to use the program in any educational institution; achievement of educational and pedagogical result and availability of tools for its measurement. STEM programs are developed in the following main areas: integrated, interdisciplinary curricula; robotics and engineering; "Smart devices" of the Internet of Things; 3D modeling, etc.

The process of preparing teachers for the application of STEM education is possible during self-educational activities and through activities during refresher courses. For this purpose, the Donbas State Pedagogical University has developed and is implementing a certificate program "Implementation of STEM education in educational activities." The purpose of the certificate program is to form students' skills to implement STEM education in a scientifically sound and critical way; widely use interdisciplinary interaction; to introduce methods and means of STEM education in professional activity. The target audience of the program is future and practicing teachers of general and pre-higher education.

The developed certificate program contains five content topics. The first of the proposed topics "STEM education: the state of implementation and prospects for development" aims to provide an overview of the STEM approach and current trends for the near and long term. Historical overview of STEM education, starting from the principle of clarity, allows to distinguish the genesis of STEM development, to trace the stages of formation and influences on STEM education, from related and opposite approaches to learning. Currently, there is a sufficient regulatory framework both at the state level and at the interstate level. Mastering the regulatory framework forms the basis for the confident application of STEM. In addition to the lecture material for the course participants, an essay on "What I know about STEM" is offered.

The second proposed topic of the certificate course "Organization of STEM oriented

educational environment" forms the theoretical basis of the STEM approach to learning. Various aspects of the STEM learning environment, inherent tools, forms and methods of learning, etc. are considered. To consolidate the studied material, it is proposed to create a structure of STEM oriented educational environment using mental maps. Self-educational activities on this topic are aimed at studying educational systems and their components, the functioning of systems in the educational environment, examples of the creation and operation of STEM oriented educational environment.

The third topic "Use of STEM equipment in research projects" considers first of all a typical list of teaching aids and equipment for classrooms and STEM laboratories. Depending on the field of education, the list of equipment may differ significantly. The Ministry of Education and Science of Ukraine approved the "Standard list of teaching aids and equipment for classrooms and STEM laboratories" [20]. It determines the requirements for teaching aids and equipment, classrooms of biology, geography, mathematics, physics, chemistry and STEM laboratories of state and municipal institutions of general secondary and vocational education. These institutions provide a complete general secondary and pre-higher education, taking into account the requirements of the latest educational technologies and teaching methods. The result of training on this topic is the acquisition of skills in the use of STEM equipment, which is possible through the practical use of equipment. Since the main form of training in the certificate course is distance, the students get acquainted mostly with the emulation of equipment or with a visual representation of the stages of use of equipment. The practical part of the study of the topic is to choose from a typical list of teaching aids and equipment needed for the educational field taught by the student and a comparative analysis of its parameters and characteristics. Self-educational activities include an overview of the capabilities of equipment and tools and study examples of their use.

The fourth topic of the program "Network resources to support students' research activities" is devoted to the implementation of STEM education through network resources. These can be virtual labs, simulators, cloud storage services and their analysis, means of visualization of the received data and creation of infographics, etc. The practical part of the study of this topic involves the creation of an electronic educational resource designed to study the topic of knowledge of students, taking the STEM approach into account.

The fifth topic is aimed at studying the methodological aspects of the implementation of STEM education in the educational process. First of all, the peculiarities of the implementation of STEM education depending on the field of knowledge are considered. Each field of knowledge has its own characteristics related to the research activities, in accordance with which the field and the specifics of the study of disciplines in this field of knowledge are built. The specifics of the industry require the definition of methodological aspects of the implementation of STEM education, which must meet the requirements of training in the field and modern global challenges to education. The practical part of the study of the topic involves a detailed development of the lesson with the preparation of all necessary materials for it. Self-educational activities involve the development of best practices in their field of knowledge with the preparation of guidelines for the implementation of STEM approach in education. The consideration of each topic is planned at levels corresponding to Bloom's taxonomy. Students learn basic knowledge of the topic, connect it with existing ones and try to apply them according to their field of knowledge. The result of the application, depending on the topic, may be new visual aids, including in digital form, the development of fragments of training sessions, tasks, including for self-educational activities that have practical significance, and so on. These stages allow us to form a basic knowledge of the topic, but this will not be enough for us. Through group work, learners begin to test their own work on their colleagues. The results of the approbation, the conducted survey, the discussion in the groups of the performed own developments are used for carrying out their efficiency. The last step is to improve your own development and make it

available to the public.

4. Conclusions

The introduction of the principles of STEM education in the learning space contributes to the creation of a fundamentally new model of learning with new opportunities for teachers and students. Using an interdisciplinary approach, integration of school subjects, practical orientation, research and project activities during classes, focusing on the concept of STEM, we can build a modern, economically stable, smart and happy society with the high level of technology.

The ongoing professional training of practitioners allows to adjust the educational trends, learning technologies and scientific approaches in teaching. The proposed certificate course for practicing teachers, which, by the way, can be taken by the future teachers, allows you to adjust the knowledge of STEM approach in teaching, expand knowledge of interdisciplinary interaction in teaching, improve scientific teaching of teaching materials, learn to form a scientific approach and widely use project training.

ORCID iDs

V E Velychko https://orcid.org/0000-0001-9752-0907
N V Kaydan https://orcid.org/0000-0002-4184-8230
O G Fedorenko https://orcid.org/0000-0002-1897-874X
V P Kaydan https://orcid.org/0000-0003-2008-3539

References

[1] Ministry of Education and Science of Ukraine 2020 Plan of measures for implementation of the concept of stem education development until 2027 URL https://mon.gov.ua/ua/news/oprilyudneno-plan-zahodiv-shodo-realizaciyi-koncepciyi-rozvitku-stem-osviti-do-2027-roku
[2] Nistor A Jiménez-Iglesias M and el 2016 Introducing new stem topics in the curriculum URL http://www.scientix.eu/observatory
[3] McOwan P 2016 Teaching enquiry with mysteries incorporated URL https://cordis.europa.eu/docs/results/321/321403/final1-temi-final-report-en.pdf
[4] European Comission 2021 Digital Education Action Plan 2021-2027 URL https://education.ec.europa.eu/sites/default/files/document-library-docs/deap-factsheet-sept2020_en.pdf
[5] Li Y and Anderson J 2020 *Developing Teachers, Teaching, and Teacher Education for Integrated STEM Education* (Cham: Springer International Publishing) pp 353–360 ISBN 978-3-030-52229-2 URL https://doi.org/10.1007/978-3-030-52229-2_19
[6] Kim M S and Keyhani N 2019 *Research and Practice in Technology Enhanced Learning* **14** URL https://doi.org/10.1186/s41039-019-0103-6
[7] Vossen T, IHenze, Rippe R, Driel J V and Vries M D 2021 *Research in Science Education* **51** 891–911 URL https://doi.org/10.1007/s11165-019-9840-1
[8] Osadchyi V, Valko N and Kuzmich L 2021 *Journal of Physics: Conference Series* **1840, No. 1, p. 012027**
[9] Bencheva N 2020 *Proceedings of University of Ruse* **59, Book 3.2** 84–88
[10] Pressick-Kilbornand K, Silk M and Martin J 2021 STEM and STEAM Education in Australian K-12 Schooling URL https://doi.org/10.1093/acrefore/9780190264093.013.1684
[11] Dubey M and Doyle-Jones C 2021 *The Teacher Educator* **56:4** 445–465 URL https://doi.org/10.1080/08878730.2021.1930310
[12] Aykan A and Yildirim B 2021 *Technology, Knowledge and Learning* URL https://doi.org/10.1007/s10758-021-09564-9
[13] Semerikov S, Mintii M and Mintii I 2021 *CEUR Workshop Proceedings* **2898** 159–177 URL http://ceur-ws.org/Vol-2898
[14] Poltava Small Academy of Sciences URL http://poltava.man.gov.ua/
[15] State Standard of Basic and Complete General Secondary Education URL https://cutt.ly/7IhSf6n
[16] The Concept of Development of Natural and Mathematical Education (STEM-education) URL https://cutt.ly/7IhSf6n

[17] "Discover Ukraine" is an educational project for students in grades 7-11 from all over Ukraine URL https://vidkruvai.com.ua/
[18] Fedorenko E G, Kaidan N V, Velychko V Y and Soloviev V N 2021 *CEUR Workshop Proceedings* **2898** 107–118 URL http://ceur-ws.org/Vol-2898
[19] Institute for Modernization of Educational Content, STEM programs URL https://imzo.gov.ua/stem-osvita/programi-stem/
[20] Ministry of Education and Science of Ukraine, On approval of the Standard list of teaching aids and equipment for classrooms and STEM laboratories URL https://zakon.rada.gov.ua/laws/show/z0410-20/#Text