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World Practices of STEM Education Implementation: Current Problems and Results

Abstract

The term “STEM education” has been clarified. It is well-founded that STEM education is a learning process that is based on interdisciplinary and practical orientation and provides the formation of skills to acquire theoretical knowledge, and master scientific methods for their use in solving specific practical tasks (not only in professional activities). A quantitative analysis of the results of the implementation of STEM education, presented in scientific publications, was carried out. A small percentage of publications dedicated to STEM education have been found. It has been established that in countries with developed economies, there are significantly more published scientific results regarding the implementation of STEM education. Practical cases of the implementation of STEM education in Ukraine and the world are highlighted. Among these are the organization of STEM education through solving problem situations in field conditions; basing classes on solving practical tasks in a certain professional field; examples of organizing and conducting lessons in high school on an interdisciplinary basis; cases for four scenario exercises; cases for solving practice-oriented tasks at home; and cases of inclusive education using STEM projects. A content analysis of modern practices of implementing STEM education on the basis of open educational resources such as Coursera, edX, Udemy, Prometheus, and EdEra was conducted. The analysis of open educational resources shows that there are too few courses that would focus on STEM education and on training teachers to implement STEM-oriented education. The basis for the research was scientific publications in publications indexed by the scientometric databases Scopus and Web of Science over the past 10 years, and dissertation research conducted in Ukraine.

K e y w o r d s: STEM education, forms of implementation of STEM education, practices of implementing STEM education, STEM education in Ukraine, teacher training for STEM-oriented education

Modern achievements of society, as a rule, are determined by the integration of various spheres of human activity. Such integration can be observed especially in relation to information technologies, which today tend to develop rapidly. Society consumes more and more technological products and services developed by scientific and technical specialists. There is more and more research in data processing, virtual and augmented reality, robotics, the Internet of Things, renewable energy, ecology, and more. According to these studies, the direction of STEM (**S**cience, **T**echnology, **E**ngineering, **M**athematics), which integrates natural sciences, technology, engineering, and mathematics was updated. Considering the importance of the combination of these industries for the technological development of each country, the question arises about the appropriate STEM education, which would provide the basic training of the younger generation to solve real-life problems on the basis of such integration.

At the same time, the perception of STEM education by teachers and scientists and the ways of its implementation in the conditions of certain educational institutions in different countries of the world are not established today. The authors of the article faced the problem of interpreting STEM education when the need for advanced training of teachers (mathematics, natural sciences, computer science) for its implementation in general secondary education institutions was actualized: in order to teach the future teacher to implement STEM-oriented learning, it is first necessary to understand its essence and characteristics. This means that today there is no single vision for providing the young generation with STEM education. Therefore, we see the following areas of scientific research: 1) clarification of the concept of “STEM education”; 2) quantitative analysis of the results of the implementation of STEM education presented in scientific publications; 3) highlighting practical cases of STEM education implementation; 4) analysis of modern practices of implementing STEM education on the basis of open educational resources.

Methodology of Research

The basis for the research was scientific publications in publications indexed by the scientometric databases Scopus and Web of Science over the past 10 years, and dissertation research conducted in Ukraine. We also used the content of educational online platforms for analysis.

To solve the first, second, and partially third tasks of the research, theoretical methods of scientific knowledge were used – analysis of the results of scientific research, their systematization, and generalization. To solve the third and fourth tasks of the research, a content analysis of online educational platforms such as Coursera, edX, Udemy, Prometheus, and EdEra was conducted and the content of individual online courses was studied. The choice of these educational platforms is due to the following reasons: according to ClassCentral (Shah, 2021), among the world leaders of popularity, the first places are occupied by platforms like Coursera, and edX; the Udemy platform today has the largest number of educational resources (about 200 thousand); the Prometheus and EdEra platforms are Ukrainian, and therefore they are the most acceptable for the average teacher in Ukraine.

Results of Research

A. Clarification of the concept of "STEM education"

We researched the publications in which the issue of STEM education was raised, with the aim of revealing the interpretation of the term "STEM education" by different scientists in the world. We found out that STEM education can mean:

- a study program that combines two or more fields (science, technology, engineering, and mathematics; for example, mathematics and engineering or physics and information technology, etc.) and is based on an integrated approach to their teaching, that is, the content of individual fields are not separated, but presented as one course (Yata et al., 2020);
- interdisciplinary learning that combines the study of science, technology, engineering, and mathematics based on problem-based scenarios (Qin & Fu, 2017);

- several academic disciplines, the mastery of which involves the use of information technologies and ensures the formation of skills to perform practical tasks that will be important for employment (Martyniuk, 2018; Balyk & Shmyger, 2017; Department of STEM education IMZO);
- the process of assimilation of knowledge, abilities, skills, and methods of activity, which involves interdisciplinary approaches in the construction of the content of education and the selection of methods and tools of education (Botuzova, 2018);
- technology for the development of personal qualities of young people, which ensures the ability to solve complex problems, think critically, and have cognitive flexibility and creativity (online: https://osvita.ua/legislation/Ser_osv/61444/);
- creative space for the formation of a child's worldview (Hom, 2022);
- pedagogical technology for the formation and development of mental, cognitive, and creative qualities of young people to ensure their competitiveness in the modern labor market based on the integration of the content and methodologies of natural sciences, technologies, engineering, and mathematics (Stryzhak et al., 2017);
- a method of teaching a subject for personalization of learning (Oliynyk et al., 2020);
- an educational strategy that follows project-based learning through a process of scientific research and engineering design for a team-based solution to a real problem situation (Zhao, 2015; Zhou & Li, 2021);
- an approach to learning that is based on the visualization of scientific phenomena, which "allows you to easily grasp and acquire knowledge based on practice and a deep understanding of processes" (online: https://uk.wikipedia.org/wiki/STEM);

The analysis and systematization of the above-mentioned and other interpretations of the concept of "STEM education" made it possible to distinguish more general approaches to its interpretation (Fig. 1).

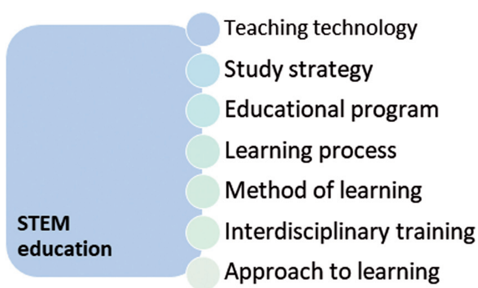

Figure 1. Approaches to the interpretation of the concept of "STEM education"

Source: Own work

The analysis of these approaches in the interpretation of STEM education revealed their dual basis (Fig. 2):

1. interdisciplinarity (or intersubject connections of natural sciences, technologies, engineering, and mathematics), which ensures the development of personal qualities of young people – critical thinking, creativity, transfer of knowledge and methods from one sphere of science or activity to another;
2. practical orientation (or the solution of life's (not far-fetched) tasks), which enables the formation of skills to use theoretical knowledge and methods in practice.

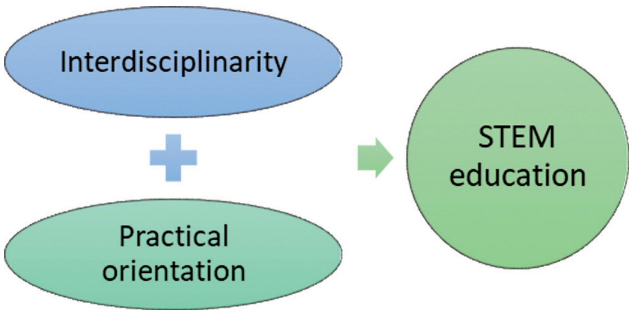

Figure 2. Important components of STEM education

Source: Own work

At the same time, certain approaches to the definition of STEM education have appeared to be debatable. Specifically, can STEM education be considered a technology or a curriculum? STEM education does not involve an established algorithm of actions, so it is not a technology or a curriculum. However, we are impressed by the idea that STEM education is a learning process that is based on interdisciplinary and practical orientation and provides the formation of skills to acquire theoretical knowledge, and master scientific methods for their use in solving specific practical tasks (not only in professional activities).

B. Quantitative analysis of the results of the implementation of STEM education, presented in scientific publications

We also assessed the importance of STEM education in the context of scientific and pedagogical research. In particular, we analyzed the data of the scientometric databases of Scopus and Web of Science, where a large number of scientific publications are concentrated. The analysis was carried out through filters and keyword searches. The obtained data are systematized by us in Figure 3 ("a" – matching by the keyword "STEM"; "b" – matching by the keywords "Education" (left) and "STEM Education" (right); "c" – matching by the keywords "Education in school" (left) and "STEM Education in school" (right); "d" – matching by the keywords “Education in colleges” (left) and “STEM Education in colleges” (right); “e” – matching by the keywords “STEM Education” (left), “STEM Education in school” (middle) and “STEM Education in colleges” (right); “f” is a left-to-right keyword mapping of “STEM Education in England”, “STEM Education in Germany”, “STEM Education in USA”, “STEM Education in India”, “STEM Education in Ukraine», “STEM Education in Finland”, “STEM Education in China”).

The analysis of the presented data confirms that:

1. the percentage of articles (2.1%) devoted to STEM education is insignificant in relation to the number of articles on education (58 042 vs. 2 750 865). This means that the ideas of STEM education are beginning to be actualized in the scientific environment, however, research on STEM education has not gained unconditional distribution and relevance;
2. the percentage of articles (2.8%) devoted to STEM education in secondary schools is insignificant in relation to the number of articles on school education (7 300 vs. 263 130). The percentage of articles (3.4%) devoted to STEM education in colleges, is relative to the number of articles on college and university education (2 734 vs. 29 304). At the same time, the comparison of absolute indicators still indicates a greater interest in the implementation of STEM education at the school level;
3. in countries with a developed economy, the number of scientific results on the introduction of STEM education is greater in relation to other countries all over the world. In particular, by country: USA – more than 12 000 publications, Germany – more than 3 000 publications, England – more than 2 000 publications.

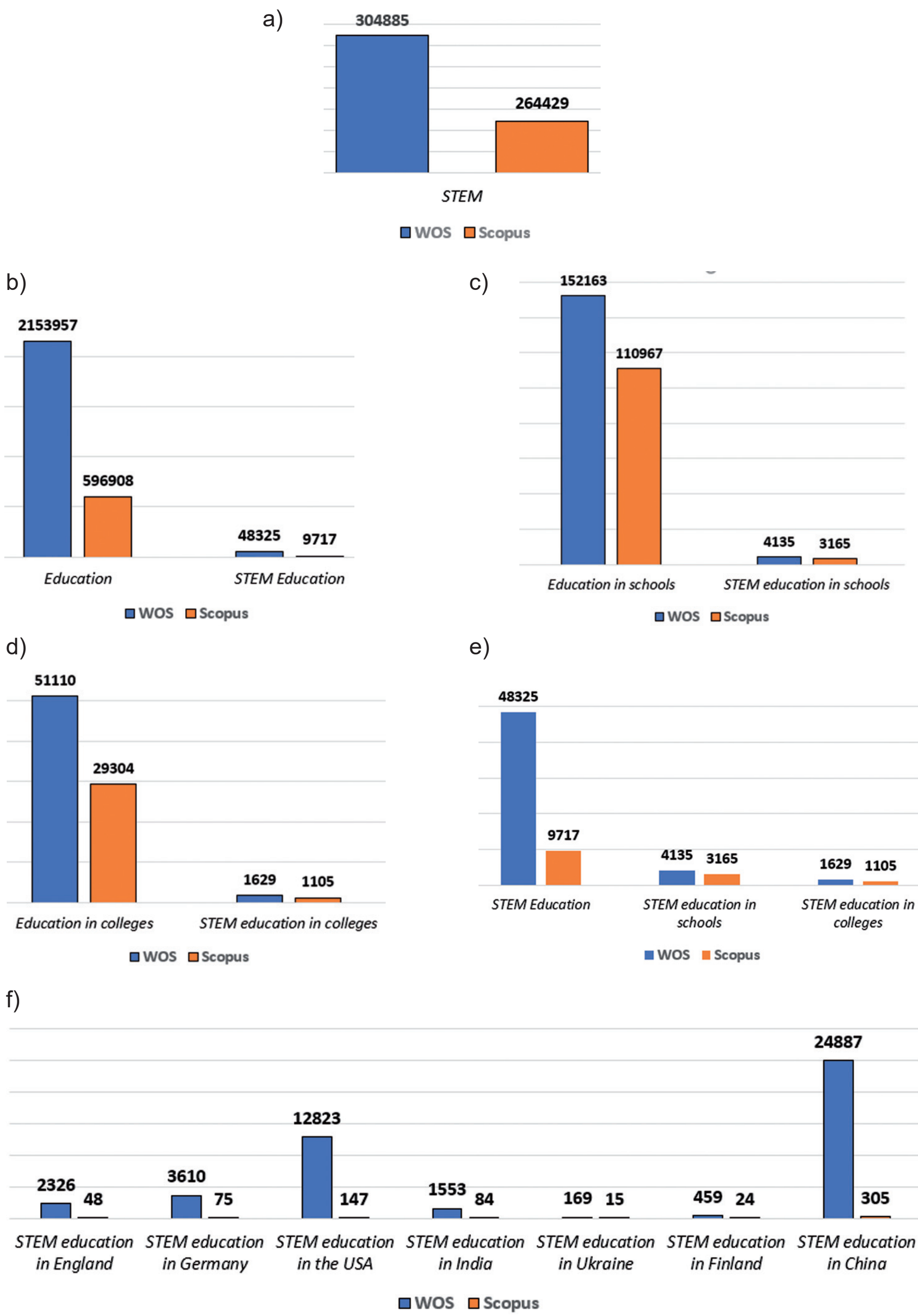

Figure 3. Number of publications by keyword

Source: Own work

C. Highlighting practical cases of STEM education implementation

In addition to the quantitative analysis of publications in the scientometric databases of Scopus and Web of Science, we investigated ways of implementing STEM education, which is described in scientific publications. In particular, we discovered:

- cases presenting the experience of organizing STEM education through the solution of problem situations in the field, and the leading teaching method in the game (Pig Game, Pit and Pendulum, Sociologists' Dilemma, etc.) with parallel coaching/curator support (online: https://activatelearning.com/meaningful-math/);
- cases, which describe the conduct of classes on solving practical tasks in a certain professional field, meeting with representatives of STEM professions, and excursions to STEM enterprises (online: https://www.facebook.com/groups/80589541236);
- examples of organizing and conducting lessons in a high school on an interdisciplinary basis, where the leading method of learning is solving practice-oriented tasks (Hsiao et al., 2022);
- cases for four scenario exercises in the form of a special course that integrates natural sciences, technology, engineering, and mathematics and is designed to identify "STEM talents" (Wang et al., 2022);
- cases for solving practically oriented tasks at home (Yan, 2017);
- cases of inclusive education using STEM projects (Skowronek et al., 2022).

The study of the Ukrainian experience of STEM education demonstrates the use of practice-oriented tasks and projects. It should be noted that STEM education in Ukraine is not characterized by systematicity and stability. It is implemented by enthusiastic teachers based on original projects and programs, often reduced to group project activities or solving applied problems. In most cases, STEM education is still perceived as an integration of science, technology, and mathematics subjects.

If we consider STEM education in Ukraine through the prism of training young people in informatics, mathematics, and physics, we should note certain trends in the shift of emphasis toward the study of technologies (while training young people not only as software users but also as developers of mobile applications), the establishment of mathematics and physics training. The information technology course provides solution of competence problems and the implementation of individual educational projects on an integration basis (mathematics, physics, chemistry, biology, geography, etc.). The analysis of the content of the physics course in the context of STEM education proves that since 2015, the developers of the curriculum for the 7th grade have provided only the implementation of educational projects (outstanding physicists; physics in everyday life, technology, production; observation of physical phenomena of the environment; diffusion in everyday life). The analysis of the tasks of the school mathematics course shows that they are oriented to a greater extent on the formation of computational and transformational skills. The formation of modeling skills or the applied use of mathematical knowledge is not systematic. According to the results of the analysis of the educational workload, we note that on average, the school has 3.5 lessons of mathematics, 1.5-2.5 lessons of physics, and 1.5 lessons of computer science per week.

D. Analysis of modern practices of implementing STEM education on open educational resources

The analysis of modern practices of implementing STEM education on open educational resources was carried out by us, taking into account their popularity. Today, there are a large number of educational platforms on the Internet. According to Class Central (Shah, 2021), more than 220 million students are registered in more than 19,000 courses. Among the world leaders in 2021, the Coursera and EdX platforms were noted (Shah, 2021).

We simultaneously studied Coursera, edX, Udemy, and Ukrainian platforms – Prometheus and EdEra. *Coursera* (coursera.org) – is an online learning platform that was founded in 2012 and today has more than 92 million listeners and offers more than 4 000 courses from 150 universities around the world (Riley de León, 2021). *edX* (edx.org) – is a platform with university-level online courses founded in 2012. The resource has more than 3 600 courses and 42 million registered users (online: https://impact.edx.org/hubfs/impact-report-2022.pdf). Udemy (udemy.com) – is an online platform that positions itself as a commercial provider of massive open online courses, founded in 2010. At the beginning of 2022, the platform had more than 52 million listeners, 196 thousand courses, and 68 thousand instructors who teach courses in more than 75 languages. During the history of the platform, more than 712 million courses have been registered on it (online: https://about.udemy.com/). *Prometheus* (prometheus.org.ua) – is the largest Ukrainian online educational platform, which has 2 million listeners and offers more than 250 online courses. Courses for both schoolchildren and adults are placed on the platform. *EdEra* (ed-era.com) – is a Ukrainian online education studio founded in 2014 that distributes free courses and develops projects for training employees of certain companies (Marchenko, 2019).

We investigated the quantitative content of online platforms. In particular, based on data from the Class Central company (Shah, 2021), it was found that the share of online courses in natural sciences, technology, engineering, and mathematics (all areas of STEM education) is a total of 39.9%: natural sciences account for 9.5% of all courses, technologies – 20.2%, engineering – 7.3%, mathematics – 2.9% (Fig. 4).

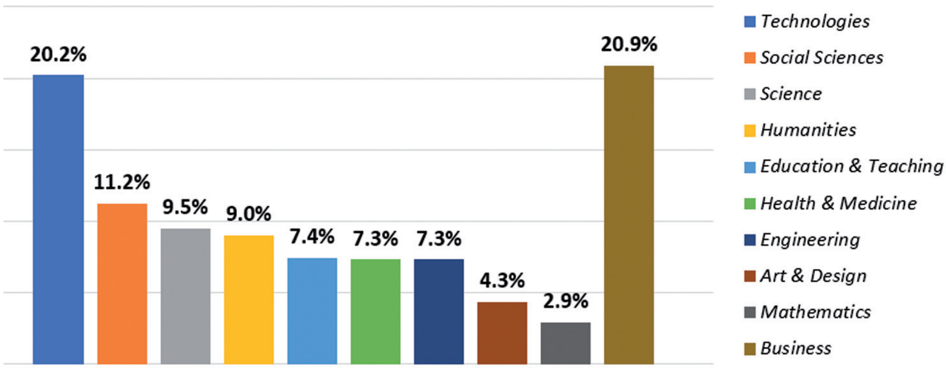

Figure 4. Distribution of courses in different subjects according to Class Central data

S o u r c e: Own work

It should be noted that the quantitative weight of mathematics courses in the context of the four directions of STEM education is insignificant in relation to all other directions of STEM (Fig. 5)

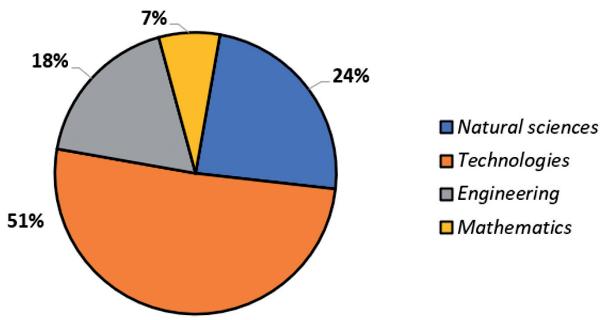

Figure 5. Distribution of courses by areas of STEM education

S o u r c e: Own work

At the same time, data on individual fields cannot provide STEM training and talk about the demand for STEM education. Therefore, we investigated the above-mentioned platforms for the availability of STEM education courses, that is, those that integrate the four directions in a certain way (Table 1).

Table 1
Quantitative indicators of STEM courses on Virtual Educational Resources

Virtual Educational Resources	Number of courses in which the concept of STEM is mentioned		Number of courses with the word STEM in their title	
		among them Ukrainian		among them Ukrainian
Coursera	1942	22	4	0
edX	888	0	7	0
Udemy	482	0	8	0
Prometheus	1	0	1	0
EdEra	0	0	0	0

S o u r c e: Own work

Based on the results of the analysis, we have that there is only one course related to STEM on Ukrainian educational platforms. The Prometheus platform offers a single course called "English for STEM (Science, Technology, Engineering, and Mathematics)" (online: https://courses.prometheus.org.ua/courses/course-v1:AH+ENG_STEM101+2020_T1/about), which is a copy of the course "English for Science, Technology, Engineering, and Mathematics" hosted on the Coursera platform (online: https://www.coursera.org/learn/stem).

Coursera has the largest number of courses that mention something about STEM. In particular, there are 1,942 courses on the platform that mention the word "STEM" either in the title, in the abstract, or in the course itself. Only 4 courses have the word STEM in the title.

To get an idea of the capacity (content) of STEM-related courses, we took individual courses on the platforms *Coursera, edX, and Udemy* into account.

On the *Coursera* platform, the course "Emprendiendo en STEM (Entrepreneurship in STEM)" was completed, which was developed by the teachers of the Australian University – Business School (online: https://www.coursera.org/learn/emprendiendo-en-stem). The course consists of six learning modules: "Entrepreneurs and the Entrepreneurial Process", "Opportunities, Value Generation and the Business Model", "Innovation Processes in STEM", "Startup Financing", "Marketing and Sales", "Teams, Leadership, and Social Capital". The content of the course includes many educational and methodological materials: video lectures, multimedia presentations, audio, mandatory and optional questions for self-examination, questionnaires, tests, training manuals, and forums for each week of training. We see the lack of specific examples of the implementation of STEM in entrepreneurship as a disadvantage of the course.

On the *edX* platform, there is a course "Advancing Learning Through Evidence-Based STEM Teaching (Improving learning through evidence-based STEM teaching)" (online: https://www.edx.org/course/advancing-learning-through-evidence-based-stem-teaching-5). Its developers are faculty from Vanderbilt University, Michigan State University, Northwestern University, and the University of Nebraska. The goal of the course is to master evidence-based educational practices. Pedagogical practices of active learning using modern STEM technologies in classes are analyzed during training (8 weeks): peer learning, problem-based learning, research laboratories, cooperative learning, flipped classrooms, and learning through diversity. The experience of the course teachers with the implementation of STEM lessons in the educational process is interesting.

The *Udemy* platform contains the course "Finding the Art in Engineering – STEM to STEAM" (online: https://www.udemy.com/course/art-in-engineering/). The course was developed by mechanical engineering and 3D design expert J. Devitry of the Utah State University Space Engineering Center. This course aims to demonstrate ways to expand your own creative thinking through the creation of original patterns, various forms, and artistic images using 3D modeling. The course consists of 30 educational videos that show how to create a project using knowledge from the fields of engineering and art.

Summary characteristics of STEM-related courses are presented in Table 2.

Table 2
Characteristics of STEM-related courses

Platform	Coursera	edX	Udemy
Course title	Emprendiendo en STEM	Advancing Learning Through Evidence-Based STEM Teaching	Finding the Art in Engineering - STEM to STEAM
Volume	6 weeks	8 weeks	2 hours
Language of teaching	Spanish	English	English
Tests	+	+	–
Practical tasks	+	–	–
Video lectures	+	+	+
Materials for self-study	+	+	–
Forum	+	+	–
Feedback from the teacher	–	–	–
Peer assessment	+	+	–
Providing a certificate	+	–	–

S o u r c e: Own work

According to the results of the analysis of courses on open educational platforms related to STEM education, it should be stated that the developers do not offer courses specifically for acquiring STEM education.

Discussion

The experience of implementing STEM education in Ukraine is not extensive, but it can be systematized and generalized. In particular, it should be stated that the development of STEM education in Ukrainian institutions of general secondary and extra-curricular education is identified with the development of natural and mathematical education, and natural sciences include sciences that study the phenomena of the surrounding world in living and non-living nature: physics, astronomy, chemistry, biology, ecology, geography, and medicine. This means that the term "STEM education" to a greater extent refers to the strategy in the education of Ukrainian youth.

STEM education in Ukraine is based on the Concept of the Development of Science and Mathematics Education (STEM Education) until 2027 (online: https://zakon.rada.gov.ua/laws/show/960-2020-%D1%80#Text). The concept defines a set of measures related to the formation and development of scientific research and engineering skills, invention, entrepreneurship, early professional self-determination, and popularization of scientific, technical, and engineering professions.

The plan included many activities, such as holding conferences, seminars, and symposiums on the use of the latest methods of STEM education for teaching and scientific-pedagogical staff, creation of databases or interactive maps of educational institutions implementing STEM education and their constant updating; conducting contests, tournaments, Olympiads, intellectual competitions, summer schools, and all-Ukrainian science festivals for education seekers, and teaching staff, conducting career orientation events for education seekers in the format of "Professions of the Future" projects, weeks on the popularization of STEM education, etc., improving the qualifications of teaching and scientific-pedagogical staff on the use of the latest methods of STEM education, creation of new STEM centers and STEM laboratories, expansion of their areas of activity, and equipping of science and mathematics offices in educational institutions, updating the design of school areas, promoting the functioning of institutions of specialized scientific education, introduction and support of sections of the scientific and technical direction of out-of-school education institutions, development and implementation of modern methods of distance learning of science and mathematics subjects, ensuring the replenishment of the libraries of educational institutions with high-

-quality popular science and scientific literature, conducting research and preparing recommendations using the methods of science and mathematics education (STEM education) in educational institutions, etc.

At the same time, taking into account our own experience and communication with fellow teachers, we note the fragmentation and non-systematic nature of the Ukrainian experience of implementing STEM education. In institutions of general secondary education, teachers use programs and textbooks that are not focused on STEM education, in particular, do not provide solutions to a sufficient number of interdisciplinary tasks and the use of information technologies for this. STEM projects are offered by enthusiastic teachers and in most cases in non-formal education settings.

The USA's experience in developing STEM education is interesting. S. Vakil and R. Ayers (2019) describe that in the USA, a special role is assigned to a two-year higher education in the STEM field, which is obtained in municipal colleges. This is due to experts' forecasts, according to which in the near future the need for graduates with bachelor's degrees who are knowledgeable in the STEM field will double the need for specialists who have not received an education in this field.

The effectiveness of a two-year higher STEM education requires high-quality scientific and teaching staff and the corresponding methodical base, which is the basis for high-quality training of students in a short time (an offer of training programs and methods, provision of personnel, etc.); the need of the private sector (organizations and firms) for specialists in the field of new, promising technologies (availability of demand for graduates); training students oriented to further study in intensive university programs; motivation of college graduates to continue their education combined with practical application of already acquired knowledge and skills in the field of STEM.

The experience of STEM education in the USA is systematized in the work by Park, Wu & Erduran (2020). The authors note that in the USA considerable attention is paid to the relationship between schools and universities. In particular, when evaluating applications for funding research projects from universities, the presence of proposals for the use of research results aimed at strengthening ties with the K-12 system ("outreach effect" criterion) must be taken into account in the projects.

As a part of the USA National Nanotechnology Initiative, six leading research universities have been selected to establish National Science Centers for Nanoengineering. These educational institutions, through connections with schools, help teachers to modernize educational programs through the development and implementation of new STEM disciplines. Learners are given the opportunity to study physics, chemistry, and the basics of nanoengineering and at the same time get acquainted with university laboratory research.

Within the framework of the project, several categories of participants. These include researchers who sometimes find it difficult to develop training materials that learners can understand; university faculties responsible for the development/organization of effective methods of teaching schoolchildren; schools that provide balanced training in all the necessary disciplines combined with additional subjects in nanotechnology.

Considering the experience of Great Britain, the authors S. Baselga, O. Garrido, and H. Buron drew attention to the period devoted to STEM education, namely from kindergarten to the end of school. STEM education is designed as a set of STEM disciplines that are mastered taking into account interdisciplinary approaches (Baselga et al., 2020). In the course of its implementation, considerable attention is paid to the relationship between schools and research universities. The forms of interaction of leading universities with schools are different. At the same time, the attention is paid to training not only schoolchildren but also their teachers.

In Great Britain, the need to change public opinion regarding technical and engineering professions has been recognized. In particular, a national campaign is being developed and launched to popularize engineering education, and its importance for society, and improvement of learners' attitudes toward engineering careers. At the same time, in Great Britain, at the national level, the problem that arose during the introduction of STEM education was realized. Some schools orient learners to a narrow list of subjects that are easier to study but do not provide the formation of a fundamental basis for further development in the engineering and technical fields of science.

Conclusions

1. According to the analysis of scientific and pedagogical research and the results of the comparison and generalization of approaches to the definition of STEM education, we consider, STEM education should be understood as a type of education that is based on the mastery of various branches of science (natural sciences, technology, engineering, mathematics) taking into account their interdisciplinary connections with the aim of forming a person's knowledge system and methods sufficient to solve current professional tasks. STEM education cannot be considered a learning technology, a certain academic discipline, or a separate branch of science.
2. Quantitative analysis of research results, which are presented in the world's leading publications, indexed by the scientometric databases of Scopus and Web of Science, shows the relevance of the problem of implementing STEM education, and it should be noted that in countries with a developed economy, there are significantly more scientific results regarding the implementation of STEM education. However, such materials have not acquired systematization

and generalization. To a greater extent, they describe either the implementation of a certain interdisciplinary project or their own experience of STEM-oriented training through solving case problems or existing positive practices of counseling in STEM-oriented training of young people. Among the scientific publications, there are not enough materials related to the preparation of teachers for STEM-oriented training.

3. The analysis of open educational resources shows that there are not enough courses that would focus on STEM education and on the preparation of teachers to implement STEM-oriented training. The courses offered promote the idea of integrating knowledge from different fields to solve professional tasks that cannot claim to solve the problem of providing STEM education. We explain this by the lack of established practices of successful STEM education, as well as the lack of a clear understanding of STEM education as a type of modern education.

The obtained results actualize other directions of scientific research, namely the study of the importance of various fields in STEM education at the "school, college, university" levels, the characteristics of the content of each of the STEM directions (natural sciences, technologies, engineering, mathematics), the determination of the most effective forms and methods STEM-oriented education.

References

Advancing Learning Through Evidence-Based STEM Teaching. (n.d.). edX. https://www.edx.org/course/advancing-learning-through-evidence-based-stem-teaching-5

Balyk, N., & Shmyger, G. (2017). Approaches and Peculiarities of Modern STEM Education. *Physical and Mathematical Education*, 2(12), 26-30.

Baselga, S.V., Garrido, O.M., & Buron, H.G. (2020). Drama-Based Activities for STEM Education: Encouraging Scientific Aspirations and Debunking Stereotypes in Secondary School Students in Spain and the UK. *Research In Science Education*, 52(2), 749. https://doi.org/10.1007/s11165-020-09968-0.

Botuzova, Yu. (2018). Geogebra Dynamic Models At The Mathematics Lessons As A STEM-Approach. *Physical and Mathematical Education*, 3(17), 31-35. https://doi.org/10.31110/2413-1571-2018-017-3-005

Department of STEM education IMZO. (n.d.). Facebook.com. https://www.facebook.com/groups/805895179541236

edx 2022 Impact Report. (n.d.). edX. https://impact.edx.org/hubfs/impact-report-2022.pdf

Emprendiendo en STEM. (n.d.). Coursera. https://www.coursera.org/learn/emprendiendo-en-stem

English for Science, Technology, Engineering, and Mathematics. (n.d.). Coursera. https://www.coursera.org/learn/stem

English for STEM (Science, Technology, Engineering, and Mathematics). (n.d.). prometheus.org.ua. https://courses.prometheus.org.ua/courses/course-v1:AH+ENG_STEM101+2020_T1/about

Finding the Art in Engineering - STEM to STEAM. (n.d.). Udemy. https://www.udemy.com/course/art-in-engineering/

Hom, E. J. (2022). What is STEM Education? *Live Science Contributor*. http://www.livescience.com/43296-what-is-stem-education.html

Hsiao, J., Chen, S., Chen, W., & Lin, S. S. J. (2022). Developing a plugged-in class observation protocol in high-school blended STEM classes: Student engagement, teacher behaviors, and student-teacher interaction patterns. *Computers and Education*, 178. https://doi.org/10.1016/j.compedu.2021.104403.

Marchenko, Yu. (2019). *Online education: Ilya Filipov about EdEra courses and why Western education is not better than ours*. https://platfor.ma/topics/nadlyudskyj-faktor/onlajn-prosvita-illya-filipov-pro-kursy-edera/

Martyniuk, O. O. (2018). STEM technologies as a means of forming the information and digital competence of teachers and students. *Collection of scientific works of the Kamianets-Podilskyi National University named after Ivan Ohienko. Series: Pedagogical*, 24, 18-22. https://doi.org/10.32626/2307-4507.2018-24.18-22

Meaningful Math. (n.d.). Activate Learning. https://activatelearning.com/meaningful-math/

Methodological recommendations for the development of STEM education in institutions of general secondary and extracurricular education for the 2018/2019 academic year. (2018, Jule 19). Osvita.ua. https://osvita.ua/legislation/Ser_osv/61444/

Oliynyk, B. B., Samoylenko, O. M., Batsurovska, I. B., & Dotsenko, H. A. (2020). STEM education in the system of training of future engineers. *Information Technologies and Learning Tools*, 80(6), 127–139. https://doi.org/10.33407/itlt.v80i6.3635

On the approval of the Concept of the development of science and mathematics education (STEM education). (2020, August 05). Verkhovna Rada of Ukraine. https://zakon.rada.gov.ua/laws/show/960-2020-%D1%80#Text

Park, W., Wu, JY., & Erduran, S. (2020). The Nature of STEM Disciplines in the Science Education Standards Documents from the USA, Korea and Taiwan Focusing on Disciplinary Aims, Values and Practices. *Science & Education*, 29(4), 899-927. https://doi.org/10.1007/s11191-020-00139-1.

Qin, J. R., & Fu, G. S. (2017). Stem Education: Interdisciplinary Education Based on Real Problem Scenarios. *China Educational Technology*, 4, 67-74. https://caod.oriprobe.com/articles/50888223/STEM_Education__a_Interdisciplinary_Education_Base.htm

Riley de León (2021). *Coursera files for IPO amid the online learning boom*. https://www.cnbc.com/2021/03/05/coursera-files-for-ipo-amid-online-learning-boom-.html

Shah, D. (2021). *A Decade of MOOCs: A Review of MOOC Stats and Trends in 2021*. https://www.classcentral.com/report/moocs-stats-and-trends-2021/

Skowronek, M., Gilberti, R. M., Petro, M., Sancomb, C., Maddern, S., & Jankovic, J. (2022). Inclusive STEAM education in diverse disciplines of sustainable energy and AI. *Energy and AI,* 7. https://doi.org/10.1016/j.egyai.2021.100124.

STEM education. (n.d.). Institute for Modernization of the Content of Education. https://imzo.gov.ua/stem-osvita/

STEM. (n.d.). Wikipedia. https://uk.wikipedia.org/wiki/STEM

Stryzhak, O. Y., Slipukhina, I. A., Polikhun, N. I., & Chernetckiy, I. S. (2017). STEM-education: main definitions. *Information Technologies and Learning Tools*, 62(6), 16–33. https://doi.org/10.33407/itlt.v62i6.1753.

Vakil, S. & Ayers, R. (2019). The racial politics of STEM education in the USA: interrogations and explorations. *Race ethnicity and education*, 22(4), 449-458. https://doi.org/10.1080/13613324.2019.1592831.

Wang, T., Wang, L., Fu, L., & He, L. (2022). *The novel STEM practice course and industrial robot educational platform via university-middle school collaboration*. https://doi.org/10.1007/978-981-15-8155-7_316.

We share knowledge with the world. (n.d.). Udemy. https://about.udemy.com/

Yan, M. (2017). Case study of STEM education in the family. Proceedings of the 2017 3rd *International Conference on Economics, Social Science, Arts, Education, and Management Engineering (ESSAEME 2017)*, Atlantis Press, 119, 2280-2284. https://doi.org/10.2991/essaeme-17.2017.463

Yata, C., Ohtani, T. & Isobe, M. (2020). Conceptual framework of STEM-based on Japanese subject principles. *IJ STEM Ed,* 7, 12. https://doi.org/10.1186/s40594-020-00205-8

Zhao, Z. J. (2015). *Progress of Stem Education Policy in the United States*. Shanghai: Shanghai Science and Technology Education Press.

Zhou, C. & Li, Y. (2021). The Focus and Trend of STEM Education Research in China —Visual Analysis Based on CiteSpace. *Open Journal of Social Sciences*, 9, 168-180. https://doi.org/10.4236/jss.2021.97011.

Artem Yurchenko, Kateryna Yurchenko, Volodymyr Proshkin, Olena Semenikhina

Światowe praktyki wdrażania edukacji STEM: aktualne problemy i wyniki

Streszczenie

Powszechnie uważa się, że edukacja STEM jest procesem uczenia się, który opiera się na interdyscyplinarnej i praktycznej orientacji i zapewnia kształtowanie umiejętności zdobywania wiedzy teoretycznej i opanowania metod naukowych do ich wykorzystania w rozwiązywaniu określonych zadań praktycznych (nie tylko w działalności zawodowej). Przeprowadzono analizę ilościową wyników wdrażania edukacji STEM, przedstawionych w publikacjach naukowych. Znaleziono niewielki odsetek publikacji poświęconych edukacji STEM. Ustalono, że w krajach o rozwiniętych gospodarkach publikowanych jest znacznie więcej wyników naukowych dotyczących wdrażania edukacji STEM. Podkreślono praktyczne przypadki wdrażania edukacji STEM w Ukrainie i na świecie. Wśród nich jest organizacja edukacji STEM poprzez rozwiązywanie sytuacji problemowych w warunkach terenowych; prowadzenie zajęć z rozwiązywania praktycznych zadań w określonej dziedzinie zawodowej; przykłady organizowania i prowadzenia lekcji w liceum na zasadzie interdyscyplinarnej; przypadki dla czterech ćwiczeń scenariuszowych; przypadki rozwiązywania zadań zorientowanych na praktykę w domu; przypadki edukacji włączającej z wykorzystaniem projektów STEM. Przeprowadzono analizę treści współczesnych praktyk wdrażania edukacji STEM na otwartych zasobach edukacyjnych Coursera, edX, Udemy, Prometheus i EdEra. Analiza otwartych zasobów edukacyjnych pokazuje, że istnieje zbyt mało kursów, które koncentrowałyby się na edukacji STEM i szkoleniu nauczycieli w zakresie wdrażania edukacji zorientowanej na STEM. Podstawą badań były publikacje naukowe w publikacjach indeksowanych przez scjentometryczne bazy danych Scopus i Web of Science w ciągu ostatnich 10 lat oraz badania dysertacyjne prowadzone w Ukrainie.

Słowa kluczowe: edukacja STEM, formy wdrażania edukacji STEM, praktyki wdrażania edukacji STEM, edukacja STEM w Ukrainie, szkolenie nauczycieli edukacji zorientowanej na STEM.

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Prácticas mundiales de implementación de la educación STEM: problemas actuales y resultados

R e s u m e n

Se ha aclarado el término “educación STEM”. Está bien fundado que la educación STEM es un proceso de aprendizaje que se basa en la orientación interdisciplinaria y práctica y proporciona la formación de habilidades para adquirir conocimientos teóricos y dominar métodos científicos para su uso en la resolución de tareas prácticas específicas (no solo en actividades profesionales). Se realizó un análisis cuantitativo de los resultados de la implementación de la educación STEM, presentados en publicaciones científicas. Se encontró un pequeño porcentaje de publicaciones dedicadas a la educación STEM . Se ha establecido que en los países con economías desarrolladas hay significativamente más resultados científicos publicados con respecto a la implementación de la educación STEM. Se destacan casos prácticos de la implementación de la educación STEM en Ucrania y el mundo. Entre ellos se encuentran la organización de la educación STEM a través de la resolución de situaciones problemáticas en condiciones de campo; impartir clases sobre la resolución de tareas prácticas en un determinado campo profesional; ejemplos de organización y realización de lecciones en la escuela secundaria sobre una base interdisciplinaria; casos para cuatro ejercicios de escenarios; casos para resolver tareas orientadas a la práctica en el hogar; casos de educación inclusiva utilizando proyectos STEM. Se realizó un análisis de contenido de las prácticas modernas de implementación de la educación STEM en los recursos educativos abiertos Coursera, edX, Udemy, Prometheus y EdEra. El análisis de los recursos educativos abiertos muestra que hay muy pocos cursos que se centren en la educación STEM y en la capacitación de maestros para implementar la educación orientada a STEM. La base de la investigación fueron las publicaciones científicas en publicaciones indexadas por las bases de datos cienciométricas Scopus y Web of Science en los últimos 10 años, y la investigación de tesis realizada en Ucrania.

P a l a b r a s c l a v : Educación STEM, formas de implementación de la educación STEM, prácticas de implementación de la educación STEM, educación STEM en Ucrania, capacitación docente para la educación orientada a STEM.

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Мировые практики внедрения STEM-образования: актуальные проблемы и результаты

А н н о т а ц и я

Уточнен термин “STEM-образование”. Обосновано, что STEM-образование – это процесс обучения, который базируется на междисциплинарной и практической направленности и обеспечивает формирование навыков приобретения теоретических знаний, овладения научными методами их использования при решении конкретных практических задач (не только в профессиональной деятельности). Проведен количественный анализ результатов внедрения STEM-образования, представленных в научных публикациях. Определен небольшой процент публикаций, посвященных STEM-образованию. Установлено, что в странах с развитой экономикой есть значительно больше опубликованных научных результатов относительно внедрения STEM-образования. Освещены практические примеры внедрения STEM-образования в Украине и мире. Среди них: организация STEM-образования через решение проблемных ситуаций в полевых условиях; проведение занятий по решению практических задач в определенной профессиональной сфере; примеры организации и проведения уроков в вузе на междисциплинарной основе; кейсы для четырех сценарных учений; кейсы для решения практико-ориентированных задач на дому; кейсы инклюзивного образования с использованием STEM-проектов. Проведен контент-анализ современных практик внедрения STEM-образования на открытых образовательных ресурсах Coursera, edX, Udemy, Prometheus, EdEra. Анализ открытых образовательных ресурсов показывает, что существует слишком мало курсов, которые были бы ориентированы на STEM-образование и на подготовку учителей для внедрения STEM-ориентированного образования. Основой для исследования послужили научные публикации в изданиях, индексируемых наукометрическими базами данных Scopus и Web of Science за последние 10 лет, и диссертационные исследования, проведенные в Украине.

Ключевые слова: STEM-образование, формы внедрения STEM-образования, практики внедрения STEM-образования, STEM-образования в Украине, подготовка учителей для STEM-ориентированного образования