E-learning and STEM Education
Scientific Editor Eugenia Smyrnova-Trybulska
"E-learning", 11, Katowice-Cieszyn 2019, pp. 631-642
DOI: 10.34916/el.2019.11.39

STEM EDUCATION: PRACTICE-ORIENTED TOOLS FOR TEACHERS OF MATHEMATICS

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Abstract: *The article is devoted to the study of the possibility of realization of STEM education in Ukrainian schools, selection of appropriate tools of modern pedagogical and information technologies for organizing STEM education in the mathematics classroom, methodological training for mathematics teachers to this activity, development of innovations, readiness to use IT technologies in the realization of inter-subject links, development of the individual's creative potential, their pre-service training.*

Keywords: STEM education, teaching mathematics, methodical teacher training, inter-subject links.

INTRODUCTION

The pace of technology development contributes to the increasing demand for engineering and IT-specialists, professionals of high-tech enterprises. Accordingly, there is an increasing interest in scientific and technical components at all levels of education. (Morze, Gladun, Dzyuba, 2018)

The activation of STEAM education is one of the ways to solve a number of educational problems. Now in Ukraine, teachers work in the conditions of updating of the educational model as well as the implementation of new approaches and teaching technologies, including STEM and STEAM education within the all-Ukrainian project "STEM School" on the platform of the Ukrainian project "Quality of Education" (InnovatsIyniy proekt «STEM-shkola», 2017, Nakaz MON Ukrayini, 2018)

In these conditions, the training of teachers, who are capable and ready to solve interdisciplinary tasks, to implement project-oriented activities, to apply innovative teaching methods is of particular importance. It is useful to provide such training in higher education institutions even while training future teachers.

However, despite the increased interest of modern researchers in the field of pedagogy, didactics and mathematics teachers, the technology of STEAM education is being introduced into the educational process of secondary schools of Ukraine rather slowly. Given the above, an important task of higher pedagogical educational institutions is the targeted preparation of students - future mathematics teachers - for the implementation of this technology in their future professional activities.

The purpose of the article is to highlight the results of a study of the attitude of teachers and students to the problem of using STEAM education technology in the educational process of a comprehensive school.

Research methods: analysis of the problem in the pedagogical and methodological literature regarding STEAM education, a survey of practicing mathematics teachers and students of the Faculty of Physics and Mathematics.

1. IMPLEMENTATION OF STEM EDUCATION IN UKRAINE

The support of STEM education in Ukraine, as well as in the USA, Japan, South Korea, Israel, Great Britain, and others, is at the state level. Since 2016, systematic work on its implementation with the aim of "the innovative development of the subjects of the natural-mathematical cycle, research work in educational institutions" has begun. (Nakaz MON Ukrayini, 2016)

Over the past few years, much has been done for this: a "Web-STEM school" has been created, the tournaments are held, the All-Ukrainian "Robotrafic" competition and grants are played out, scientific and methodical materials are developed for teachers to implement and develop STEM education in the institutions of the general secondary and out-of-school education. By STEM education we mean the relevant pedagogical technology of formation and development of critical thinking, cognitive and creative qualities of school students, who are able and ready to solve complex tasks, cooperate, and implement innovative activities. At the same time, we consider STEM education in mathematics as a purposeful process of transferring and mastering knowledge, skills and methods of cognitive activity of a person, based on the interdisciplinary approaches in the creation of educational programmes at various levels, individual didactic elements, studying the phenomena and the processes of the surrounding world, solving problem-oriented tasks. This approach to studying contributes to the popularization of engineering and technical professions among young people and the formation of sustainable motivation in the study of the disciplines of the natural-mathematical cycle.

The idea of using methods of diversified development in education is not new. For example, there is the SEL concept, which implies the development of children's social and emotional skills, the method of phenomenon-oriented training and teaching PBL, similar to STEM in the way we attempt to combine

different disciplines when studying a particular topic. (Anisimova, Shatunova, Sabirova 2018)

In Chicago (2011), for example, the Scientists for Tomorrow (SfT) initiative has been supported. The SfT initiative is aimed at using the education program, based on STEAM. Within its program, young people of different ages, in their free time, master various educational modules, such as "Alternative energies", "Physics of sound and mathematics of music", "People and plants", "Robotics" and "Astronomy". (Caplan 2017)

In our country, the relevance of STEM education implementation is no less interesting (D. Vasilyuva, K. Dmitrenko, E. Patrikeeva, O. Lozovaya, S. Gorbenko, N. Goncharova, O. Kovalenko, etc.); general aspects, basic concepts, problems and prospects of STEM education (I. Vasilashko, N. Morse, O. Stryzhak, I. Slipukhina, N. Polisun, I. Chernetsky, V. Sharko, etc.); methodical approaches to STEM training (V. Bagashova, L. Gned, L. Danilenko, N. Yakobchuk, L. Yakovleva, etc.); the use of information technology in teaching mathematics (M. Zhaldak, V. Korolsky, T. Kramarenko, O. Semenikhina, M. Burda, V. Klochko, G. Mikhalin, and others). Consideration is also given to the training of teachers of higher education institutions and secondary schools in using STEM technologies, as well as using interdisciplinary strategies in their work. (Segura, 2017. Chanthala, 2018). The received results of STEM training demonstrate raising of achievement and self-esteem of high school students and university students in the study of physical and mathematical disciplines. In our country, such research is still rare.

2. SELECTION OF TOOLS FOR IMPLEMENTATION OF STEM-EDUCATION

Since 2017, Ukrainian schools have been gradually switching to a new programme. In the 2018-2019 school year, most of the country's first grades of primary schools switched to the programme of the New Ukrainian School (NUS). Ukrainian Ministry of Education and Science regulated the requirements for the educational space of such classes, both for primary school and for subject classrooms of all educational branches. (Zasobi STEM-osviti)

At the same time, STEM tools are considered ~~as~~ a set of equipment, ideas, phenomena, and methods of actions, that ensure the implementation of experimental, design and research activities in training. The selected tools must carry out informational, practical, creative and control functions. Institute of the modernization of the content of education in Ukraine recommends using:

- printed methodological (textbooks, electronic textbooks, teaching aids, training instructions and algorithms),

- visual aids of various types: natural (equipment, tools, samples), figurative (photos, posters, reproductions of paintings), sign-symbolic (sign models, graphs, charts, tables);
- technical: informational (computers, multimedia, overhead-projectors, copy-boards, interactive boards, document cameras, video-conferencing systems, projection desks, etc.), and controlling (simulators, devices for process diagnostics). (Zasobi ta obladnannya STEM)

The market is full of various offers of tools for education. It would be wrong to assume that the previously mentioned tools were not used by teachers in our country. The project method, interactive boards, programs "Stereometry", "Trigonom", "Mathematica", "Geometry", simulators for performing actions with fractions, etc. Currently, the range of offers and opportunities has increased significantly. Technical equipment of educational institutions allows using these resources in the organization of STEM-education. Only for primary school in mathematical educational field 55 different sets and simulators are offered under the NUS program (for the formation of calculating and computing skills, for working with geometric figures and bodies, for studying the concepts of area and volume, working on tasks, etc.). Leading global companies are also ready to offer their products to teachers. For example, Microsoft Store for Education offers free and paid tools. It includes OneNote notebook for organizing assignments and assessments, and STEM programmes for engaging each student to work in a lesson, and tools for organizing a Microsoft Teams, Sway lesson for creating publications, interactive training materials, presentations, projects, etc., a well-known application – GeoGebra dynamic math field, interactive digital training tools with visual models from the Sesavis Visual Learning Tool, the WeDo 2.0 LEGO® Education. Unfortunately, only a small part of them has versions in Ukrainian (EV3 Programming, GeoGebra Classic, GeoGebra Graphing Calculator) or Russian (Sensavis Visual Learning Tool, Polyup, GeoGebra Geometry, FMath, MyBookMachine Player, FluidMath, EquatIO, Matific) languages.

Most of them are very useful in the study of computer science, some in the study of physics, and only a few may be interesting for teachers in mathematics lessons. We considered the listed teaching tools in the context of their use mathematics teaching. We opted for free applications, the use of which is allowed in Ukraine. Let's characterize them without touching the system requirements for software applications of Sensavis Visual Learning Tool. Teachers can use it to create visual models in the classroom, to simplify and analyze complex concepts, not only in the field of mathematics, but also in biology, chemistry, physics, geography, technology and others. School students can study the material and cooperate with their peers, as well as create their own videos. The writing tool for custom visualization allows the teacher to write directly on the screen using a digital whiteboard – without leaving the application.

Polyup makes it possible to develop logical and critical thinking in the process of solving mathematics puzzles and design algorithms.

- *EV3 Programming* is the official programming application from LEGO® Education. The app is complementary to the LEGO MINDSTORMS Education EV3 education concept, which supports teachers through a special platform and guided lessons, related to the education program. It is designed to simplify school students' access and participation in a wide range of subjects, including computer science, science, technology, engineering, and mathematics.
- *GeoGebra* is the world's leading software for dynamic mathematics that supports STEM education and innovation in the field of teaching and learning. It can be adapted to any education programme or project. The GeoGebra Geometry version allows measuring lengths and areas of flat figures. It can also be used for control. A variant of the GeoGebra Graphing Calculator program allows building graphs of functions, transforming them with the help of sliders, including parametric curves and given polar coordinates. To solve equations, find special points of functions (zero points, minima, maxima, intersection points), find derivatives and integrals. GeoGebra Classic combines geometry, algebra, spreadsheets, graphics, statistics and calculus in one easy-to-use package.
- *FMath* is a graphing application, but its first version is available only for a quadratic function.
- *MyBookMachine Player* allows integrating text, pictures, photos, video, audio, graphics, etc. into one multimedia file. In addition, each object can have an additional function (a link that opens a YouTube video, a Word document, related to a specific issue, the launch of an additional interactive exercise, for example, MasterTool, GeoGebra, students can access several different libraries from the tables of this program or only teacher's books, which the teacher uploads to this server, etc.). This, according to the authors, is the easiest way to allow someone to use a digital book in the author's personal book cloud. For such access, permission from the author has to be obtained.
- *FluidMath* is the first handwriting-based educational math application, designed for secondary and high school teachers and students. The popularity of this application is in its ease of using. It allows teachers and students to create standard mathematical situations, to compose and solve mathematical and physical tasks, using their own handwriting. For teachers, it is useful in creating dynamic learning materials for the audience. It is convenient for students to explore concepts in mathematics and natural sciences.

- *EquatIO* allows any mathematical expression, written on the keyboard or touch screen, as well as a formula, dictated aloud, to turn into clear and precise formulas on the screen. It ignores unwanted non-mathematical words, so it can be used in mathematics lessons and other STEM subjects.
- *Matific* develops skills in mathematical mastery and problem solving through game interaction. This application is intended only for school students and teachers who own the Matific service. Matific is a multidisciplinary online resource in mathematics, which is designed to provide teachers with optimal support in an effective and entertaining presentation of mathematical concepts. The content of Matific is carefully localized and compared with the education programme of each country. The Matific application combines a rich list of interactive games, differentiated for each student, which makes it an ideal means of teaching and learning. Mathematics is presented in an entertaining and simple form, children can do the tasks at their own pace, improve their abilities and skills, and also evaluate the use of mathematics in life.

In the conditions of the Ukrainian modern school, the organizational, educational and methodical work of teachers, their creative initiative, flexibility in the selection of educational material, as well as in the implementation of teaching methods and tools, is not limited by new standards and education programs. The transition to the competence-based model of STEM education and the implementation of the new methodological approaches causes a shift in focus on competence-oriented forms and methods of training, a system-activity approach, the implementation of innovative, game-based teaching technologies, case-study technologies, interactive methods of group training, problem techniques for development of critical and system thinking of school students. This is where the question arises about the readiness of our teachers to use such a technological arsenal.

3. READINESS OF MATHEMATICS TEACHERS TO USE STEM EDUCATION TOOLS

We have analyzed a number of studies aimed at exploring the learning environment, learning outcomes, learning tools, research on the STEM subject. The fullest review of research on the introduction of STEM education has been done by Devkan Kaleci, Özge Korkmaz. (Kaleci, Korkmaz 2018)

In their opinion, the number of formal learning environments for applications is quite large, but they are most often used as data collection tools. It is noted that research is conducted with the future teachers of natural sciences in selected groups. They argue that it demonstrates lack of the system research, conducted in the disciplines of STEM. When examining STEM subjects, it turns out in research, that the opinions of students and teachers are mainly collected,

but the effectiveness of STEM is investigated in the students' career. The researches are mainly explained the definitions of STEM, STEM education, and STEM integrated training. The research on the organization of STEM training and the readiness to use them in the professional activities by school teachers practically weren't conducted.

During the 2018-2019 school year, experimental work was carried out with 32 teachers of mathematics in Odessa, who had internships, and 34 students of bachelor's and master's programmes at the K. D. Ushinsky South Ukrainian National Pedagogical University (Odessa), of the specialties 014 Secondary education. Mathematics, Computer Science, Physics. The research was aimed at indicating the level of readiness for STEM training, familiarizing with educational means, web resources that are applicable in STEM training.

The experimental work included the organization of an interview of the senior students of the Faculty of Physics and Mathematics and Odessa teachers who work on new programmes.

The questionnaire includes a number of open questions (the answer is given in free form), direct questions (the content of the question includes the information, which is interesting for the researcher), scaled questions (the questions, to which the respondent chooses one of the clearly formulated answers, presented to him). Separate questions are divided into blocks for the ease of filling, further processing and analysis. The main blocks of questions:

1. General information (qualification, gender and age of the respondent).
2. Professional activities of the respondent (type of the educational institution, present position, work experience, qualification category).
3. Questions, relating to the evaluation of training for STEM education of the interview participants.
4. Suggestions for improving the content of education programmes and organization the educational process in the context of STEM education.
5. Suggestions for improving the content of education programmes and organization of the educational process.

During questioning, some listeners did not fill out all the columns of the questionnaire; if the number of the completed questionnaire columns exceeded 60%, the questionnaire was accepted for processing, but unfilled columns were not included in the statistics. Therefore, data are presented in percentage terms.

The average age among the respondents was slightly over 40 years old, the percentage of women was 77.0%, and only 23.0% were men. 48.4% of the respondents from the number of listeners work in educational institutions, 41% are 4th year bachelor students, and 10.6% are 1st year master's degree students of the specialties of mathematics teacher, computer science

teacher, physics teacher. (Figure 1) The majority of the respondents among the teachers are teachers of the highest category (62.5%), the second category are 37.5%.

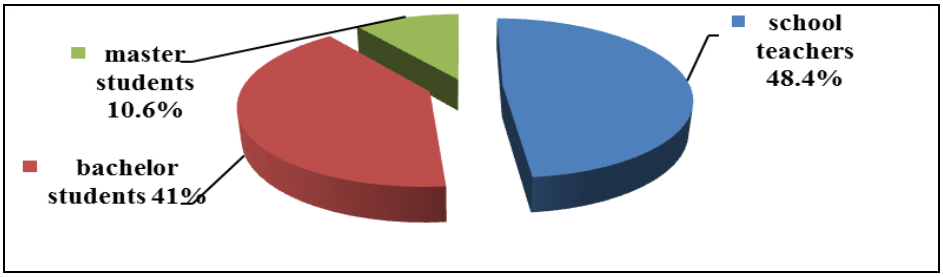

Figure 1. Qualification category of specialists
Source: Own work

The questioning involved the students, who are just starting their professional activity (work experience up to a year – 10.6% of the respondents), and with a short work experience (from 1 year to 5 years – 7.5%, from 5 to 10 years – 13.6%) and specialists with more than 10 years of professional experience (27.3%) (Figure 2). Assessing the need of training (Figure 3), improvement of the professional skills during all life, 57.5% of the respondents are interested in the continuous professional development. They believe that teachers who provide training, should be aware of modern pedagogical trends, maintain their pedagogical competence at the required level, constantly improving their pedagogical skills, which will make it possible to increase the effectiveness of training.

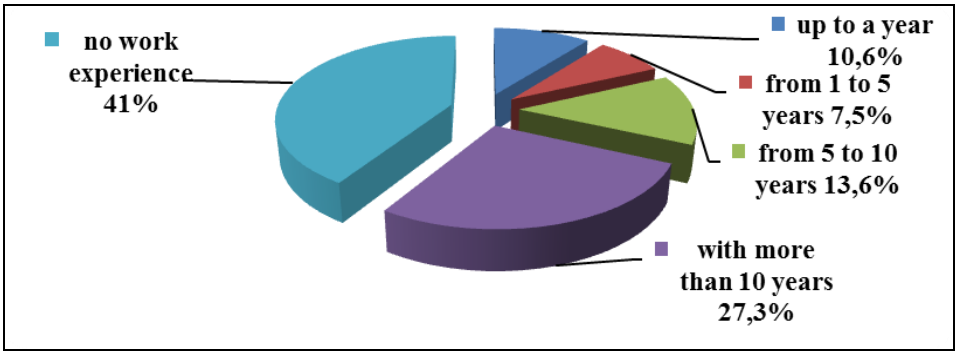

Figure 2. Work experience
Source: Own work

As for active teaching methods (training, research projects, problem tasks of an interdisciplinary nature), 71% of the respondents note that in the process of modern education they should prevail. The questionnaire also offered the questions on identifying the pedagogical competence of a modern teacher.

The answers of the respondents show that they consider an ideal mathematics teacher to be a highly qualified practitioner with excellent theoretical background, able to combine theory and practice, use modern pedagogical technologies, apply advanced information and computer technologies. Answering the questions about STEM education, the respondents gave the following results: 25.2% of the respondents had an idea about this technology, 27% attended conferences and seminars on STEM education. Most of them were teachers and only 5% were students.

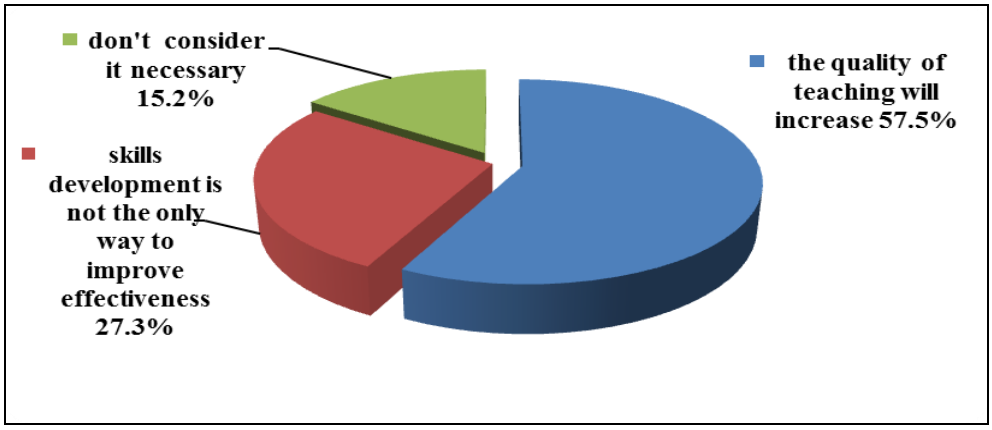

Figure 3. The need for continuous skills development of teachers
Source: Own work

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Among the online resources that can be used in STEM education the following were mentioned: interactive boards, electronic textbooks, educational software, own designs of tables, figures for geometric and textual tasks, simulators for controlling computational skills. 12% of the respondents use the interactive whiteboard actively, 17% use programs for creating dynamic models of geometric shapes and graphs, 15% apply their own electronic design to the lessons. Unfortunately, these results show only practicing teachers.

From the listed STEM education tools (EV3 Programming, GeoGebra Classic, GeoGebra Graphing Calculator, GeoGebra Geometry, Sensavis Visual Learning Tool, Polyup, FMath, MyBookMachine Player, FluidMath, EquatIO, Matific), only 6% of the interviewed teachers used GeoGebra Geometry in their practice, 17.6% of students worked in the classroom with GeoGebra Geometry, 3% with Polyup.

It should be noted that 7.5% of the respondents had special vocational training for the realization of innovations in education, all of them from among the students, studying in the specialty 014. Secondary education. Computer science. Answering the question about the professional position on information technologies and their application in the educational process, 16.7% think that this is a distant future, 36.3% answered that nothing will change, since there are no conditions for their use, 27% are interested in new software tools and find their use useful in solving interdisciplinary tasks. (Figure 4)

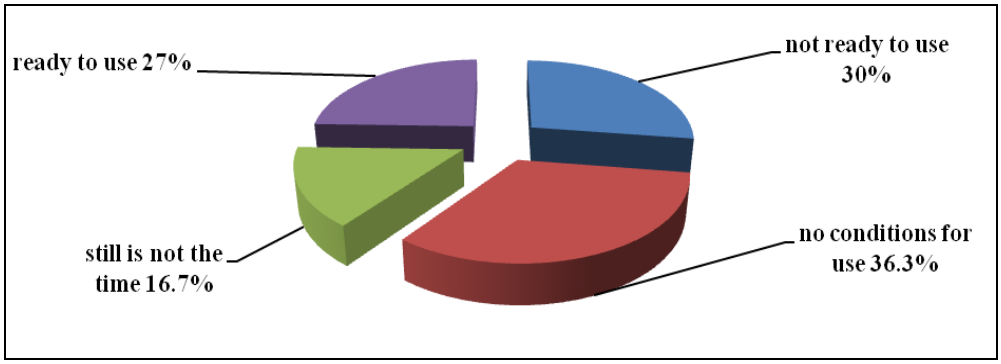

Figure 4. Readiness for use of IT technologies
Source: Own work

CONCLUSION

In our opinion, the lack of motivation for innovative activity among teachers, problems with technical equipment at educational institutions is the reason for obtaining such research results. The interviewed respondents think that the most effective form of classroom work is practical exercises with the use of modern educational technologies, web resources, simulators, and project activities. Independent classroom work, in their opinion, should include self-learning material for further discussion with the teacher (43% of the respondents) and independent work on doing the individual practical tasks and projects (29% of the respondents). Their views on STEM education state that they see the advantages and effectiveness of STEM education compared to other technologies, at the same time the majority (87%) stated the need to have special courses to master the STEM training method. Summarizing the aforesaid, it can be noted that the formation of teachers' readiness for using modern educational

technologies, namely STEM education, should be carried out, starting from pedagogical universities, specially and purposefully in the process of studying psychological, pedagogical and special disciplines and special courses, focused on learning the basics of STEM training. It is advisable to adopt foreign experience of special training, to introduce new subjects. The teachers should monitor fast-growing scientific and technological innovations. Their role is not to transfer theoretical knowledge to school students in science lessons, technology, engineering and mathematics, but to raise their level of thinking to a high level, so that the school students were ready to learn throughout their lives. The implementation of STEM education in our country should be aimed at ensuring that students, future teachers of mathematics, acting teachers develop their abilities to research, solve methodological problems and develop products with an interdisciplinary view of mathematical disciplines, and are ready to work with STEM teaching tools.

Our further research will be devoted to studying the practical application of STEM tools in the educational and research activities of students of pedagogical universities.

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