



THE STATE OF THE ART ANALYZE ABOUT STEM EDUCATION PRACTICES IN BULGARIA

WP 2: State of the art analyze and joint strategy
development about Green STEM education practices

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STEM education

Modern world trends in education are primarily related to the forms, methods and means of teaching and learning, aiming at a diverse, dynamic, interesting and effective educational process. Therefore, the reforms that have been carried out in the last few years in school education in Bulgaria are in line with these global trends in education and require the modernization of traditional forms, methods and means of education by using new and diverse ones (Grancharova, 2019).

The exceptional and intensive development of science in recent years puts the knowledge of today's students to the test. They must know and be able to synthesize new information. The tasks that today's students face on a daily basis are becoming increasingly difficult and responsible. The previous methods used in training could not provide the necessary results and expectations for their solution. That is why teachers have to look for new, much more effective methods.

STEM learning based on integration and inclusion in the learning process of a real-life situation is a way to help students learn motivated. This training requires the implementation of a specific lesson activity in order to form students' skills to solve real-life problems using creative techniques and thus be easily integrated into working and social life. STEM education is what prepares students to keep pace with technological innovation.

STEM education is a type of integrated education with a focus on the formation and development of science literacy. This is because:

- the organization of this type of training is a reflection of the modern state of natural sciences and related technologies;
- the growth of worldwide interconnectedness (globalization), global environmental problems of pollution and environmental protection, and our obligations to find the right solutions require a direct connection of education with global issues;
- the formation and development of interdisciplinary and transdisciplinary skills and competences helps students to discover and clarify scientific and life problems and to apply the acquired knowledge and skills to solve them.



Integrated STEM learning is based on an integrated approach to traditional subjects that allows students to learn how to solve real-world problems. This training helps them to comprehensively understand the concepts, processes and laws in an integral society. There are multiple definitions of STEM integration. According to Sanders (2009), STEM integration occurs in teaching and learning between two or more STEM subject areas. It sees integration as consciously designed outcomes where at least one of the STEM subjects of study is well mastered through the help of another subject of study. For example, teaching mathematics and its relevance to science, how technology affects the development of engineering, etc. (Sanders , 2008). Moor and Smith (2014) describe integrated STEM education as an attempt to create a single course of study (a subject of study - STEM) that unites all STEM disciplines, or delivering lessons on real-world topics that combine knowledge of more than two STEM academic subjects (Moor & Smith, 2014). They further add that an integrated STEM curriculum may include STEM content and learning objectives focused on one subject, but the context may be from other STEM subjects. Integration in STEM education is also understood by some authors as focusing on the study of natural sciences and mathematics as separate subjects, in which content from technology and engineering is included (Breiner et al ., 2012). STEM integration is also achieved through common approaches to teaching and learning across the curriculum. Many of these teaching approaches promote the integration of STEM learning and STEM skill building activities . Carrying out practical and experimental activities in the teaching of STEM subjects builds a wide range of "soft" skills that are used by students in all subjects. In this way, the integration of STEM subjects creates a prerequisite for "rethinking education as a whole in an innovative way" (Peppler and Bender , 2013). Integrative STEM education typically involves multidisciplinary teaching and is aimed at developing students' problem-framing and problem-solving skills, as well as their ability to contextualize scientific knowledge concepts to real-life situations.

STEM education supports intellectual development, entrepreneurship and the development of an entire nation. Entrepreneurship is about people taking the initiative to make their dreams



come true and taking action. Entrepreneurship is a risk-taking process and also provides awareness and production skills.

Another goal of STEM education is to bridge the gap between different disciplines, namely to create full integration (Wang, 2012) and raise a generation with research skills, productive and inventive from kindergarten to university. STEM education aims to identify students' curiosity and research skills in primary and secondary schools and guides and encourages students in science, technology, engineering and mathematics departments of universities in general.

Science, technology, engineering, and mathematics (STEM) education plays a vital role in preparing students for the twenty-first century workforce because it encompasses the knowledge and skills needed for creative problem solving, critical thinking, and innovative solutions. It is an essential component of high-quality education and essential to national economic growth and prosperity. This report examines the current state of STEM education in Bulgaria, its challenges and recommendations for improving the results of STEM education.

STEM Report provides a comprehensive assessment of the current state of science, technology, engineering and mathematics (STEM) education in a country. The report includes a workforce analysis, policy recommendations and an assessment of the outcomes of STEM education in schools and universities.

In recent years, significant efforts have been made in Bulgaria to improve STEM education. The government is focusing on developing a national strategy to support STEM methodology and innovation, with plans to increase research funding and investment in STEM infrastructure. In addition, there are collaborations between schools, universities and industries to support STEM learning and create internship and work opportunities for young scientists.

In recent years, Bulgaria has also actively participated in international STEM competitions, in which it has taken first place in many international Olympiads in physics and mathematics.

However, there are still some challenges she faces to improve her results in STEM . One of the challenges is the unsatisfactory level of funding for science and technology education, resulting in inadequate training and insufficiently innovative materials for teachers and few



scholarships for students to pursue careers in science and technology. Another challenge is the lack of equipment and technology in some schools, which hinders the ability of students to carry out laboratory experiments or participate in project-based learning and cross-curricular integration.

Overall, the purpose of the National STEM Report for Bulgaria is to provide a more detailed picture of the current state of STEM education in the country and to identify key areas for improvement to support the growth and development of the STEM workforce.

The state of STEM education in Bulgaria

STEM education in Bulgaria has been gradually introduced in recent years as an absolute priority for the development of education. However, there is still much work to be done to achieve high quality STEM education in the country.

1. Funding: Funding for education in Bulgaria is generally insufficient, which has an impact on STEM education;

2. Insufficient teacher training: School teachers require additional training to achieve high quality STEM education. Without such training, they will not be able to guide their students properly in the STEM field;

3. Insufficient cooperation between universities and schools: The possibility of cooperation between universities and schools could help students get a better education in the STEM field;

4. Lack of opportunities for practical training: Opportunities for practical training in STEM education in Bulgaria are still limited. For this reason, students often cannot apply their theoretical knowledge in practice.

Despite these challenges, more and more schools in Bulgaria are introducing STEM education as a priority for their students. This will help prepare the next generation of STEM professionals in Bulgaria.



STEM and the Ministry of Education and Science

According to Bulgaria's national strategy, STEM education focuses on universal literacy skills. These skills are creative thinking, critical thinking, problem solving and collaborative learning. Students must achieve these skills. In this context, the role of teachers is to help students reach a higher level of thinking, product development, invention and innovation by leading but not teaching theoretical content knowledge in science, technology, engineering and mathematics. It is important to create a learning environment where students are not afraid of failure and are confident. Therefore, the role of teachers is to help students reach the level of higher-order thinking, product development, invention, and innovation by leading, but not teaching them, science, technology, engineering, and mathematics.

The idea of introducing the STEM methodology in Bulgarian education is not recent. In April 2018, Bulgaria became a member of the European STEM Coalition, which includes national STEM platforms and organizations responsible for the implementation of national STEM strategies. One of the most important tasks of the European STEM Coalition is to facilitate the interconnection of sharing good practices between different countries and to support the development of new educational platforms. In Bulgaria, one is about to be created with an emphasis on digital skills at all levels in school and higher education, discovering the technical talent of adolescents at an early stage and attracting expert teachers (www.mon.bg). The first steps were taken in the academic year 2018/2019, when schools began to organize and involve students in extracurricular activities that are based on the main STEM fields - science, technology, engineering and mathematics. "Building a school STEM environment" is a national program of the Ministry of Education from 2020, which aims to create new STEM school centers. They integrate various methodologies, with the focus being on the study and application of various key competencies in the field of natural and mathematical sciences in all schools in the country. According to the above-mentioned program of the Ministry of Education and Culture, each newly built school center will include the following parts - improvement of the internal architecture and furnishing of existing classrooms, information technologies, new and more innovative educational



content, different methods of teaching and managing the educational process in the classroom room. The program targets schools with innovative practices and those with the potential to develop innovations in the fields of natural sciences, digital technologies, engineering thinking and mathematics (STEM). The main goal in the implementation of the program is to motivate students to study natural sciences, mathematics and technologies, increase educational results, acquire a system of competences, permanent, comprehensive knowledge, key skills and attitudes oriented towards practice, development and career orientation of students, directing them to technological professions. The program is aimed at creating an integrated learning environment of a new generation in Bulgarian schools, which will encourage and support educational innovations in learning and teaching in the field of STEM, creativity and research. The investments will support the introduction of new teaching methods, increase the qualification of pedagogical specialists and create new educational content in the direction of integrating the subject areas of STEM. The purpose of the program is to invest in comprehensive integrated solutions for a new school creative environment with a focus on science, engineering, mathematics and technology (STEM), including different elements according to the specific need of the school and the school community: remodeling of existing spaces, technology , new teaching methods, new or integrated learning content, new organization of the learning process, supportive environment for students with special educational needs if necessary. The final product of the program will be technology centers in schools, which are an integrated collection of classrooms and other learning spaces in schools, creating a culture of innovation among school communities. Thus, the National Program will create "models" in part of the Bulgarian schools to prove the process of successful investment in a comprehensive idea, including learning environment, technologies, management, integrated content, qualification and teaching methods (<https://web.mon.bg/bg/101212>).



The main objectives of the program are:

- ✓ To increase students' motivation for learning natural sciences and mathematics;
- ✓ To create opportunities for project-based learning, integrative complex knowledge, understandable learning in natural sciences with modern scientific topics and change of educational paradigms;
- ✓ To increase students' engagement, skills and achievements, their digital literacy, creativity,
- ✓ To create skills to meet industry requirements,
- ✓ To form skills for solving real life problems, for creating technological solutions, teamwork, critical thinking, etc.);
- ✓ To stimulate students to create and improve modern technological solutions in the field of mechanics, programming and artificial intelligence;
- ✓ Skills for creating new technologies and their automation;
- ✓ To increase the number of students interested in university majors and jobs in the technology industries;
- ✓ To contribute to the growth of technology industries and their share of GDP.

The final products of the national program are the creation of innovative learning centers with a focus on STEM, which include a change in the educational environment, learning content, teaching, organization and management of school processes (<https://web.mon.bg/bg/100835>). .

Since 2020, progress has been noticed in Bulgaria in the implementation of more STEM forums and national conferences with the training of natural science and mathematics teachers. They share good practices in the field of STEM education, gather information about new resources and enrich the horizons of innovative teachers.

Unfortunately, even now in 2023, there are still no universities in Bulgaria that teach or start projects in the field of STEM education. Courses to increase STEM educational skills and teacher trainings in various organizations are absolutely insufficient. For the transition to STEM



education in Bulgaria, there is a need to create a new methodology offered in universities and more specifically in the faculties of natural sciences – Chemistry, Physics, Mathematics.

At the national level, we can summarize that the ideas and guidelines proposed by the European Union in terms of a plan for the recovery and sustainability of the Republic of Bulgaria are fully implemented. As one of the main goals are - informing the whole of Europe about projects related to STEM education in Europe, facilitating the distribution and sharing of materials and tools produced by STEM education projects, creating a web-based platform where European national congresses, conferences, seminars or STEM education projects can be announced across Europe, presenting educational materials suitable for inquiry-based learning and adaptable to science and mathematics courses, contributing to the training of STEM teachers through online and face-to-face training.

In the present and communication age, STEM education is extremely important and it is imperative to implement it in the shortest possible time to be able to achieve the necessary skills. Introducing the STEM methodology will increase students' interest in natural sciences and may help them choose a profession in the STEM field. STEM education will help prepare students for life in collaboration with the skills and competencies they need. In the future, their success will increase by using critical thinking, applying skills to develop innovative models.

In Bulgaria, there are several projects aimed at STEM education:

Project " STEM Centers and Innovations in Education" under the PVU Component 2 "Building a school STEM environment". This project envisages the creation of over 2,240 STEM centers in all schools by 2026. The main goals of this project are: building an educational STEM environment, developing students' STEM skills, increasing skills for professional realization on the labor market . The planned areas of the program are five - Natural Sciences, Green Technologies and Sustainable Development, Robotics and Cyberphysical Systems, Design and 3D Prototyping , Mathematics and Informatics.

➤ **Natural Science** - Chemistry, biology, physics and astronomy are part of the natural sciences. In the STEM laboratories, both traditional devices such as microscopes, telescopes,



multimeters, but also a **3D printer** for building models, a **smart display** for visualization and simulation through digital applications can be used. Exemplary experiments could be: dissociation of acids and bases, "silver mirror" and "golden rain"; study of pH of solutions; activity of metals, examination of sunlight by means of a prism; connecting electrical circuits; study of environmental factors through sensors, viewing 3D models of various organs of the human body, observation of tissues and microorganisms under a microscope, preparation of a herbarium with typical plants for the region, observation of objects in space through a telescope, study of constellations and galaxies in a VR environment. <https://web.mon.bg/bg/101212>

➤ **Green technologies** - Renewable energy sources (RES) supply energy in a natural way and are not exhausted, but constantly replenished. Renewable energy sources use solar, wind and geothermal energy, hydropower, biomass, etc. for the production of electrical energy. In hydrogen technologies, hydrogen is a universal energy carrier that can be used for almost anything that requires the use of energy. A fuel cell is an energy conversion device that can efficiently capture and use the energy from hydrogen through electrolysis. The use of RES reduces dependence on inorganic fuels, adds diversity in energy sources and reduces greenhouse gas emissions in the atmosphere. Hydrogen fuel cells are environmentally friendly and twice as efficient as traditional combustion technologies. Additional environmental protection measures: separate collection and recycling of waste, water and air purification, preservation of biological diversity; Types of RES: wind generators, hydro facilities, photovoltaics, biofuels.

➤ **Robotics** – Robots are used in almost every sphere of our daily life – personal assistant, medical robot, industrial robot, intelligence and space robot, gaming and racing robot. They can replace a person in an environment that threatens their health, perform repetitive actions or perform a very specific operation. **Cyber-physical systems** represent systems connecting information and software components with mechanical and electronic parts, allowing communication between them through a single infrastructure - for example, the Internet. Sample experiments in a STEM lab: programming a learning stationary robot, programming a learning mobile robot, connecting and programming a sensor system, connecting and programming an IoT system.



➤ **3D design and prototyping** - 3D printers build models using **additive technology** . 3D scanners create non - contact and non-destructive three-dimensional copies of objects. There are different technologies such as optical, tomography and structured light. In these technologies, the material is wound on a roll that is fed to the 3D printer head . 3D scanning is the process of analyzing a real-world object, person , or environment to collect data. The data contains the shape and color of the object. This data finds various applications such as dimensioning, modeling, reengineering, implementation and reconstruction: education, construction, marketing, art, medicine, automotive, architecture, science, engineering.

➤ **Mathematics and Informatics** – Mathematics includes numerous tools to address the integrative issues of STEM learning. Mathematical modeling is an essential element of STEM and is used to find patterns in data. These models can be used to model real and imaginary worlds. Informatics examines how information is transmitted, received, processed, stored, destroyed and presented in the computer world. Data abstraction has reached a high level and through Object-Oriented Programming (OOP) it enables real and imaginary worlds to be represented in the computer. Math is related to art, which is part of STEAM learning. Only by knowing proportion, perspective and symmetry can a work of art be created. The genius Leonardo da Vinci used a mathematical systematization of nature and introduced the term "Golden Section". The activity of the laboratory of mathematics and informatics covers: use of microprocessor systems, modeling, calculations, processing and presentation of data, programming languages C, C++, Python, C#, JavaScript and others, 2D and 3D modeling and data processing, artificial intelligence .
<https://web.mon.bg/bg/101212>

The other National Program developed in Bulgaria is called "Innovations in Action" - Module 5, which is aimed at supporting schools and teachers implementing innovative activities through the creation of an innovative learning environment in the classroom, innovative teaching methods, as well as schools with innovative practices and those with the potential to develop innovations in the field of natural sciences, digital technologies, engineering thinking and mathematics (STEM). <https://stem.mon.bg/project-methodology-stem-resources-description/>



Module 5 includes three main steps:

Activity 1 of the National STEM Center includes the development of recommendations and methodology for teachers to teach in a STEM environment in the fields of natural sciences and engineering, mathematics and technology, with the aim of increasing the educational results of students, acquiring a system of competences, development and career guidance of students, directing them to technological professions, the professions of the future, engineering sciences and natural and mathematical knowledge.

Activity 2 of the National STEM Center is aimed at developing criteria, indicators and methodology for implementation, analysis and evaluation of school teaching resources and toolkit for STEM . The application of criteria and measurable indicators for applicability of the created educational resources will contribute, on the one hand, to their more effective application, and on the other hand, to a more motivating environment of preparation for new educational resources in schools.

Activity 3 of the National STEM Center is about developing resources - models for STEM education and their promotion. The creation of educational resources-models aims to demonstrate the application of a common methodology for teaching integrated knowledge, and on the other hand - to create examples and incentives for the application of similar school resources.

<https://stem.mon.bg/project-methodology-stem-resources-description/>

Implementation of STEM projects in Bulgaria

In Bulgaria, various STEM projects have been implemented, aimed at fostering and enhancing synergy in education in the fields of science, technology, engineering, and mathematics.



In 2020, the Ministry of Education and Science of the Republic of Bulgaria launched its national program "Building a school STEM environment" through which to stimulate the creation of new school centers - an integrated set of specially created and equipped learning spaces with a focus on learning and applying competencies in the field of natural sciences in the state and municipal schools in the country. Each school center will include a change in the following elements: physical environment (improvement of the interior architecture and furnishing of existing spaces), technologies, learning content, teaching methods and management of the educational process. The program is aimed at schools with innovative practices and those with the potential to develop innovations in science, digital technology, engineering thinking and mathematics (STEM).

The program includes two main activities: Activity I: Large projects (up to BGN 300,000) and Activity II: Small projects (up to BGN 50,000). The first activity envisages the projects to be complete, unified centers with a specific focus (such as: Center for Young Researchers; Center for Technologies in Creative Industries; Center for Digital Learning Creators; Center for Science, Research and Innovation) which include several classrooms, as well as the adjacent common spaces. The total value of the project can include a combination of construction and repair activities for the transformation of existing spaces, furniture, equipment, teacher training, creation of integrated learning content and more. The second activity includes projects that will transform and equip smaller physical spaces - one or two classrooms or corners in an existing space. Although smaller in terms of funding, these projects have the same objectives as the larger ones: creating conditions for the development of skills related to creativity in digital technologies; experimental work; developing engineering thinking and problem solving skills; work on projects and assignments with practical orientation in science and technology. The total value of the project can include a combination of construction and repair activities, furniture, equipment, teacher training and more in the following type projects: Corners type "workshops"; Research laboratories; Classroom for creative digital creators.



The national program "Building a school STEM environment" aims to increase students' interest and achievements in the fields of science and technology by supporting the creation of school centers with a focus on STEM. These centers will provide all necessary conditions for conducting modern and high-quality STEM education in schools.

Young people will acquire the necessary knowledge and skills to succeed in future professions.

Students will be educated in an environment and through methods close to the business world and real-life situations. School education will encourage learning through creativity and the development of innovative solutions to real-world problems. More young people will choose to pursue education and careers in science and technology-related fields.

Young people can have a successful future and a decent life in Bulgaria.

Each school STEM center encompasses changes in four elements:

- Educational environment and technologies.
- Educational content.
- Teaching methods.
- Organization and management of school processes.

The results of scientific research in the field of STEM education are extensive and diverse.

Here are some of the key achievements and outcomes:

- Utilization of innovative teaching methods and approaches: Scientific research has facilitated the implementation of various innovative teaching methods and approaches in STEM education. This includes active and collaborative learning, problem-based learning, game-based learning, and virtual learning, which actively engage students and prepare them for the challenges of the modern world.

- Continuing professional development of teachers: Scientific research supports the professional development of teachers in the field of STEM. This involves providing current knowledge and tools, training on new technologies and methods, and enhancing teachers' communication and mentoring skills.



- Increasing interest and attracting more students: Scientific research helps identify effective ways to increase interest and attract more students to STEM education. This may include the use of stimulating educational materials, extracurricular activities, teacher or mentor programs, and promoting diversity and inclusivity in the STEM field.

- Development of key skills: STEM education, supported by scientific research, focuses on the development of key skills such as critical thinking, problem-solving, creative thinking, and communication skills. These skills are essential for successfully addressing challenges and thriving in the modern world.

Literature survey on STEM education in Bulgaria, conducted by the international Web of Knowledge database

Regardless of the faster flow of information and innovative technologies that affect each area of our live, the paradox between the technology advancement and the decreased interest of students in science subjects exists.

The data obtained from the international study of the science literacy of Bulgarian pupils in mathematics and natural sciences (from 4th grade and 8th grade) - TIMSS (https://www.copuo.bg/sites/default/files/uploads/docs/2020-12/TIMSS2019_resultati.pdf) and PISA (https://wp.flgr.bg/wp-content/uploads/2019/12/PISA-2018_First-Analysis_IRE.pdf) reveal that the results are below of the average values. The most significant is the decline in the field of natural sciences. According to PISA data, the average score of Bulgarian pupils dropped by 22 points in 2018 compared to 2015.

Recently, a national study about the science literacy was conducted amongst 105 teachers through an online questionnaire (with 15 questions) (Todorova, S., 2022). Survey results indicate that teachers apply different methods to build science literacy in students. Part of them knew for the results of PISA and TIMSS made in our country in 2015 and in 2019, but the others -were not familiar. They shared the need of additional methodical help and literature for acquiring further knowledge and skills to improve science literacy among students.

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The combination of interdisciplinary, practically oriented approaches to study both disciplines and the application of modern methods (Sabirova, F., et al., 2020) could lead to the formation of a scientific and technical elite.

The literature study that was conducted for searching the phrase „STEM education in Bulgaria” through Web of Science database was limited to find out of 17 publications (Fig. 1).

The results comprise the period between 2011 till May, 2023 and are listed in Appendix 1.



Fig. 1 Results of Web of Science Core Collection

In 2011, the research focus of Bairaktarova, D. et al. (Bairaktarova, D. et al., 2011) was aimed at development of leadership skills in the field of STEM education in Bulgaria.

At the core of STEM-leadership education is the need in:

- ☞ understanding the technological problems and questions that the society has faced;
- ☞ development of analytical abilities for solving of various problems;
- ☞ efficiency by working in teams and in groups with different origin, cultures and by academic disciplines.



Graham shares that "the mission statements of many undergraduate engineering degrees include aspirations to produce engineering leaders for the 21st Century" (Graham, R., 2009).

As an official discipline – STEM education on leadership is not included in Bulgarian higher institutions. All major engineering, technology and science universities offer management training in a Leadership/Management theory in partnerships with the university's business schools.

In view of leadership education, Bulgaria, as well as other European countries, are in a similar situation. These similarities affect the approach to STEM leadership training focusing on management between Bulgarian universities and one of the American developed programmes.

In order to integrate leadership education in Bulgarian higher institutions and STEM – different approaches such as: interdisciplinary engineering courses and academic technology disciplines; elective courses or leadership training; developing a model for peer learning; different projects with participation of international and global engineering teams. However, considerations must be taken into account - cultural components of leadership education that may influence the selection of the best practices with certain applicability at the local level.

Recently, the changes in educational methods have gained significant popularity, including the expanded use of innovative teaching methods:

➤ **Project-based learning** (PBL) (Wolpert-Gawron, H., 2015). This method provides an opportunity to encourage pupils/ students to learn skills and to apply their knowledge through project participation. They learn how to work in a team, and the important thing is not the achievement of the goal itself, but the path to it. The teacher's role is to facilitate and encourage students to take full control of their projects from the start to the end.

➤ **Problem-based learning** (Nilson, L. B., 2010)
There are similarities between this method and PBL, with the main difference here being that students have to analyze and evaluate the problem assigned to them. This requires a higher level of mental activity, as there is usually no single answer for the problem. This approach leads to creativity, teamwork and leadership, the idea being to stimulate students to create their own business plans to solve societal needs.



➤ **Inquiry-based learning** (Keselman, A., 2003) (Pedaste, M., et al. 2015) (de Jong, T. 2006) also involves active learning, where the role of students in the learning process is to be encouraged to ask more questions, and the teacher to arouse their curiosity and encourage them to think deeply. By this type of learning, the skills that are developed include critical thinking, questioning and problem solving.

A number of studies indicate that these innovative methods appear to be efficient and lead to improved learning outcomes. According to Connor, A.M., et al. (2015) the main characteristic of all these approaches is that they are focused on students, but the authors define them as initiated by information and communication technologies (ICT). To be able to implement innovative learning activities in a technological environment, teachers need a proper qualifications both in ICT and pedagogy. The research reveals that the majority of STEM teachers consider themselves as qualified enough to take advantage of the modern digitized classroom. Terzieva, V., et al., (2020) show that in a considerable part of Bulgarian schools, technology resources and tools such as computers, multimedia, projectors, and the internet have already been usual for classroom infrastructure but not always are adequate in quantity or technical characteristics.

Other statistics disclose that less than 1/3 of schools have enough technology equipment purchased for the last five years. Therefore, during the last four years, the re-equipment of the computer rooms with modern solutions has started. Thus, students can perceive science subject in a more attractive way. Data indicate that the use of innovative tools is increasingly expanding and has reached a higher level of integration. More and more teachers are already going beyond standard ICT applications and try to use more and more specific ones. Mainly students are those who will take a benefit from technological resources, whereas teachers should enable access through the modern teaching approaches (Terzieva, V., et al., 2020).

Survey

To establish the attitude of teachers and experts towards the introduction of STEM education, both the premise and the recommendations, it is proposed to fill in a survey with



questions (appendix 2). The survey includes 8 questions that are related to the use of STEM resources.

The goals are:

- to determine the attitude of teachers and experts towards *STEM education* ;
- to assess the role of *STEM classes* in doing science;
- to capture a shift in science and teachers' readiness to be innovators in STEM teaching with the help of ICT.

To the first question - *How often do you use audio/video materials when teaching STEM classes?*, the responses indicate that audio and video materials are used regularly in teaching STEM education. Almost half of the survey participants apply it to a significant degree. Only 16.7% of participants use them very rarely or not at all. This highlights the importance of visual representation of information in STEM learning.



Fig. 2 *How often do you use audio/video materials when teaching STEM classes?*

From the second question - *How do you usually learn about the STEM educational resources that you use in class?*, it becomes clear that the majority of respondents actively search for information on the Internet. It is noticeable that the help from the educational institutions is absolutely insufficient. From the above results, the following summary can be made: Only 5.6% of the participants found out about STEM learning resources through the educational authorities



in their country. This may indicate that not every country provides sufficient available and accessible resources through official channels. 33.3% of participants actively search for STEM learning resources in educational repositories such as Scientix. This indicates that these teachers are aware of existing resources and know how to find them. 66.7% of participants actively search for relevant learning resources on the web. This shows that teachers are willing to use a variety of online resources to find materials that are relevant to their curriculum. 33.3% of participants subscribe to the information channels of national and international STEM educational projects that are publicly funded. This may indicate that these teachers are actively involved in the STEM education process and follow the innovations and developments in this field. 16.7% of participants subscribe to the information channels of private companies that publish STEM education resources. This may indicate that these teachers are willing to use resources that are produced by private companies, such as software companies or publishers.

Summarizing these results, it can be said that teachers use various sources to find learning STEM resources, such as online resource repositories, national and international projects, and information channels of private companies, but unfortunately educational institutions provide almost no part of them.

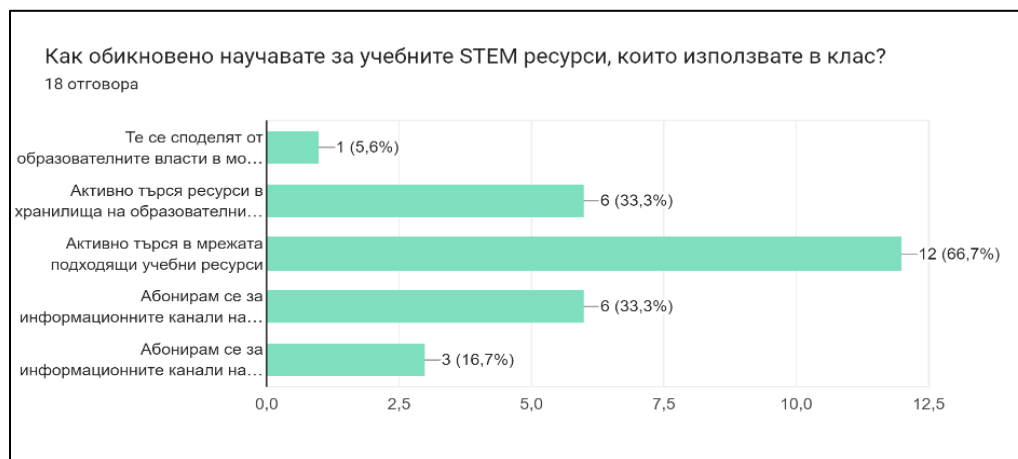
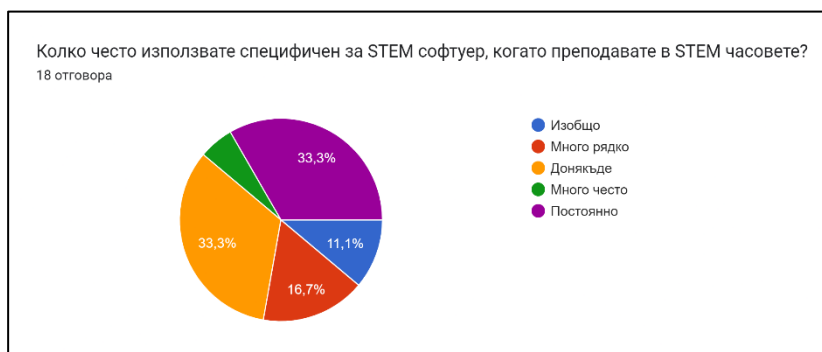


Fig. 3 How do you usually learn about the STEM learning resources you use in class?



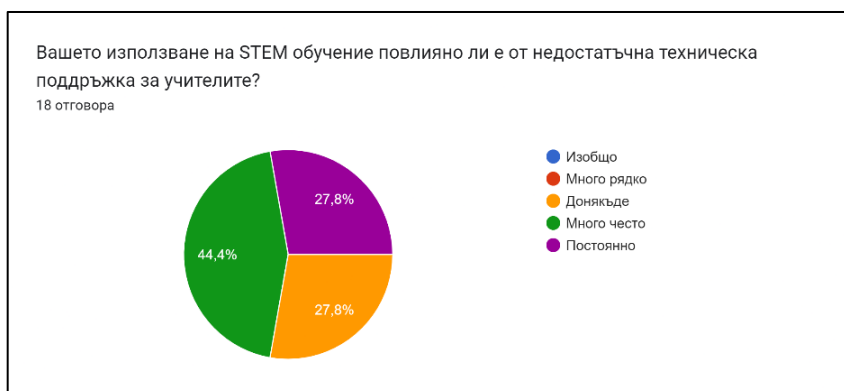
To the third question of the survey, 38.9% answered that they regularly use specific STEM software when teaching STEM classes. This may indicate that these teachers are familiar with



different types of software and know how to apply them effectively in the educational process. 11.1% of participants do not use STEM software at all when teaching STEM classes, 16.7% of participants use very rarely, 33.3% of participants only use it sometimes. This may be the result of a lack of knowledge about these tools, insufficient availability of resources, or the choice of other training methods.

Fig. 4 How often do you use specific software when teaching STEM classes?

The following graph shows the responses that indicate that insufficient technical support for teachers can have a significant impact on the use of STEM education. Almost three quarters of the survey participants (72.2% - constantly or very often, 27.8% - somewhat) face the problem of





lack of technical support. This highlights the need for appropriate technical resources and support for teachers to provide effective STEM learning.

Fig. 5 *Is your use of STEM learning affected by insufficient technical support for teachers?*

The answers to this question show that the lack of content in Bulgarian can have a significant impact on the use of STEM education. Half of the survey participants (50% - consistent) stated that this is a factor that influencing their STEM learning practices. More than a third of the participants (27.8% - very often) also expressed that the lack of content in Bulgarian affects their work. This highlights the need to have appropriate content in Bulgarian for STEM education in order to promote effective learning in these fields.

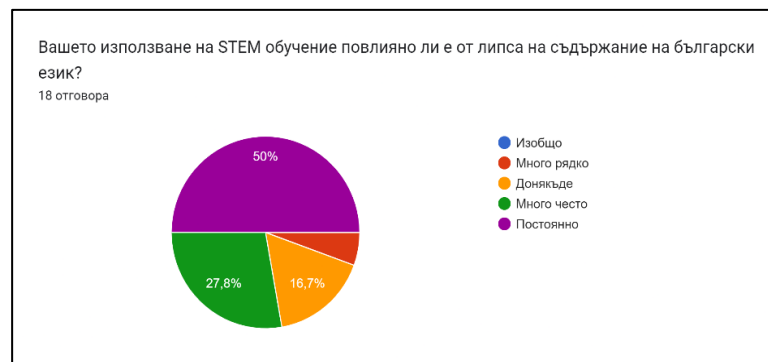


Fig. 6 *Is your use of STEM education affected by a lack of content in Bulgarian?*



A summary of the results of this question shows that the majority of teachers do not receive support from experts outside the school to improve their STEM teaching. 66.7% of teachers indicated that they received little or no support, while only 27.8% received mostly technical assistance. Pedagogical support was indicated by only 5.6% of teachers. Also, there is a very small percentage of teachers (5.5%) who very rarely receive technical or pedagogical assistance from experts outside the school. Overall, the results show a lack of expert support for improving STEM education.

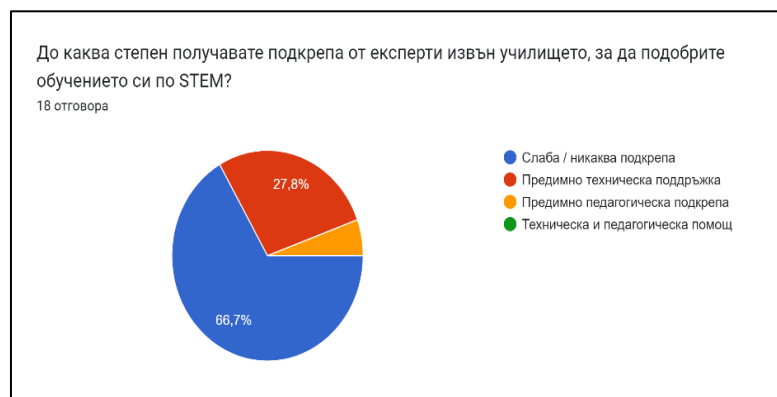


Fig. 7 *To what extent do you receive support from experts outside the school to enhance your STEM learning?*

Regarding the question of whether innovative STEM teaching has a positive impact on students' effort to learn, more than 80% of participants (61.1% extremely, 22.2% very much)





answered that there is such an impact. About 17% responded that it had some positive impact, and no one responded that innovative STEM teaching had very little or no positive impact on student motivation.

Fig. 8 *In your opinion, does innovative STEM teaching (using ICT and innovative pedagogical approaches) have a positive impact on students working harder?*

Summarizing the results of the question "Do you think innovative STEM teaching has a positive impact on students' understanding of what they are learning?" We can conclude that 77.7% of the participants believe that innovative STEM teaching has an extremely positive impact on making students understand what they learn more easily, and 22.3% respondents believe that it has a very positive impact on attitude. None of the participants responded that innovative STEM teaching has some, very little, or no positive impact on students' understanding of what they learn more easily.

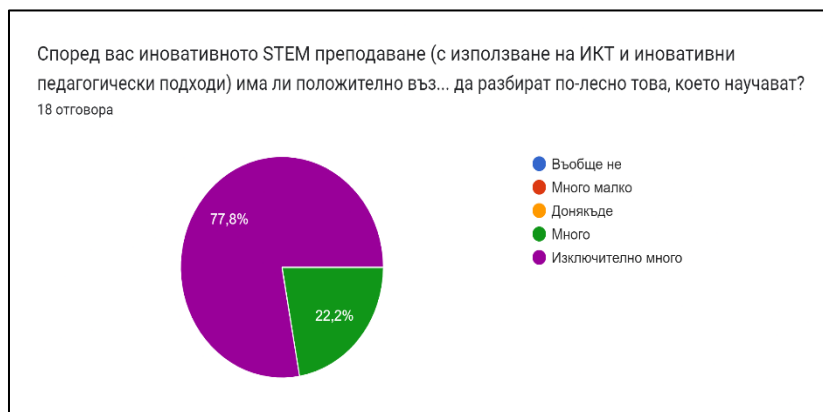


Fig. 9 *In your opinion, does innovative STEM teaching (using ICT and innovative pedagogical approaches) have a positive impact on making students understand what they learn more easily?*



With these answers, one can feel the pragmatic attitude of the teachers and their fatigue from the long-term superimposition of facts and formulas without real understanding. Visualization and use of the material taught are extremely important for current students.

Based on the survey results, the following conclusions can be drawn:

- There is an increased commitment to the studied natural science material when it is using STEM methodology;
- Student engagement increases when innovative STEM teaching is used and has an extremely positive impact on students;
- The lack of content in Bulgarian significantly complicates the development of STEM lessons for teachers;
- Summarizing the results, it can be said that although a significant part of the participants uses STEM software in teaching STEM classes, there are still quite a few teachers who do not use it or use it very rarely. This may mean that more training and resources are still needed to promote the use of STEM software in the educational process.

Recommendations

In order to improve the state of STEM education in Bulgaria, the following recommendations are suggested:

- Improving teacher training: Government should make STEM teacher training a priority and create initiatives that attract and retain qualified STEM teachers;
- Investments in STEM education: Increased funding should be directed to STEM programs, including providing equipment, laboratories, and technology;
- Collaboration with STEM professionals: Collaboration between STEM education stakeholders, educators, and STEM professionals should be increased to provide students with insight into STEM applications across industries;



- Increased access to STEM opportunities: Government should implement initiatives that ensure equal access to STEM education opportunities for all demographic groups.

Conclusion

STEM education is an integral part of an innovative education system and is essential to national economic growth and prosperity. By investing in teacher training, increasing funding, establishing collaborations and improving access to STEM opportunities, Bulgaria can improve its educational outcomes in STEM and prepare a skilled workforce for the twenty-first century.



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