https://doi.org/10.53656/ped2026-5.06

Research Insights
Изследователски проникновения

PEDAGOGICAL DIMENSIONS OF STEM EDUCATION – A SURVEY

Aleksandra Tencheva,
Elitsa Chorbadzhiyska
South-West University "Neofit Rilski" (Bulgaria)

Abstract. Nowadays, technological advances and scientific discoveries shape the future of society, the importance of education in the fields of science, technology, engineering and mathematics is constantly growing. This is why STEM education (Science, Technology, Engineering, Mathematics) has become a critical factor in preparing young people for future professions and challenges. This survey explores the pedagogical dimensions that shape effective STEM teaching and learning, including interdisciplinary integration, inquiry-based learning, project-based instruction, and the use of technology-enhanced environments. This article examines issues related to the essence of STEM education, its nascency, applications and advantages, the skills it develops in students. A survey was conducted among Bulgarian teachers and an analysis was made regarding their knowledge and understanding and applicability of STEM education in the Bulgarian school.

Keywords: STEM in education; survey research; pedagogy; inquiry-based learning; interdisciplinary teaching

1. STEM – an innovative teaching method

In recent decades, STEM education – an integrated approach to teaching and learning in Science, Technology, Engineering, and Mathematics – has gained global recognition as a cornerstone of 21st-century education (Terlemezyan, Zapreva, 2025). The growing demand for innovation, digital literacy, and problem-solving competence in a rapidly changing world has driven policymakers, educators, and researchers to re-envision how STEM subjects are taught and learned. Traditional disciplinary silos are being replaced by pedagogical models that emphasize interdisciplinary integration, hands-on learning, and real-world problem solving, reflecting the authentic nature of scientific and technological inquiry (Johnson, Czerniak, 2023).

In the context of ever-evolving technologies, STEM education is becoming extremely popular and central to the education system (Kirilova, 2020). Despite

the different opinions of the authors regarding the time period of the appearance of STEM education, most of them unite around the name of Dr. Judith Ramaly, as the person who introduced the term (Kozuharova, Zhelyazkova, 2021). The STEM approach covers teaching skills and subjects in a way that resembles real life. The pedagogical dimensions of STEM education encompass a range of instructional strategies, learning theories, and contextual factors that shape learners' cognitive, social, and emotional development. Such skills are created and thinking is developed that are applicable in real life, ie. the student prepares for real life, he does not just accumulate knowledge, but knows how to use and apply it (Khurma, Darayseh, 2022). Effective STEM pedagogy extends beyond content mastery to include inquiry-based learning, project- and design-based learning, collaborative problem solving, and the use of technology-enhanced environments. Students understand and know why they should study a subject and how it will benefit them in life. STEM recognizes the fact that the continuous advancement of technology is changing the way children learn, connect with others, and interact with each other every day. This is what necessitates the increasingly frequent use of STEM education in the education system. Through STEM education, the integration of theory into practice can be achieved, creating an environment where the learner can be their own teacher, researcher and traveler in the fields of science. In this approach, there are no exact boundaries between the individual subjects, but on the contrary, the connection between them is sought, they complement each other, and this helps students to more easily perceive, understand and apply the learned information. Interdisciplinarity is of particular importance in our modern times, which is why there is a need to teach children how different scientific disciplines integrate and work together. Students should be able to search, find, process, work with the information, with the knowledge they have access to, and not just memorize (Mamadiyorova, 2025). It is important that they can think critically and analyze information. Through this approach, children can develop their creative skills, learn to work in a team, communicate in different ways, learn in a fun and interesting way, learning becomes something easy - like child's play. Learning through play and simulating real situations is subject to many educational principles. The key thing about STEM is that all learning activities are based on solving real-world problems and emphasize project-based learning. This, in turn, leads to an increase in the desire to learn (Alali, 2024). These approaches are rooted in constructivist and experiential theories of learning, which position students as active participants in constructing knowledge through exploration and reflection. Education needs to respond to a dynamic reality, and the jobs of the present and the future increasingly involve artificial intelligence, working with algorithms, invention and engineering (Khushk, Zhiying, 2023). STEM fields are among the fastest growing and most in demand on the market of labor. Students who receive a STEM education are better prepared for high-skilled, well-paying occupations.

2. Application of STEM

The application of STEM in science education, in real-world settings as well as in online teaching, is essential. Despite the increasing emphasis on STEM education worldwide, challenges remain in translating its philosophy into classroom practice (Tsvetanova, Terziyski, Mladenova, 2021). Variability in teacher preparedness, limited access to resources, rigid assessment systems, and fragmented curricula often hinder the implementation of innovative pedagogies. Central to integrating STEM learning are the environment, content, technology, and teacher skills. The environment in which learning takes place, the educational environment must match the learning needs. In addition, it should be cozy, interesting and beautiful, so that students willingly visit it. Learning content should also be tailored to students' interests, presented in a way that interests and motivates them, etc. (Alexieva, 2024). The learning process is not only giving and receiving information. Learning becomes a search for information, research and analysis of problems, situations and proposing possible solutions for them, development of projects. The modern world is tied to the progress of information technologies, they are in every sphere of our life. Today's students are a generation that lives and develops with electronic, information and communication devices and technologies, for them a world without technology is unthinkable. This also requires a change in the attitude of the teachers, in the methods they use. Training is needed so that teachers can quickly master and be able to more easily and successfully integrate STEM technologies into teaching.

The application of STEM in science education is essential to create an environment that promotes the integration of science, technology, engineering and mathematics through the development of student creativity. Understanding the pedagogical foundations that underpin effective STEM instruction is therefore essential to addressing these challenges and promoting inclusive, high-quality education (Levterova, Tagareva, Sivakova, 2024).

Teaching science and technology in primary schools provides an opportunity to use innovative approaches based on STEM (Mafugu, Tsakeni, Jita, 2022). The world is realizing the need for science, technology, engineering and mathematics to be combined (Mirkomilovna, 2025). Integrating STEM disciplines into unified lessons and courses helps students see how knowledge from different fields can be combined to solve complex problems in real-world situations. STEM integration has its roots in the progressive education movement of the early 1900s. There are two different ways to integrate content and engineering thinking: context integration and content integration. Content integration refers to the integration of engineering thinking and mathematics/science content when involving multiple domains (Moore, Smith, 2014). The application of STEM in the real environment encompasses many aspects that can enrich students' learning and show them how theoretical knowledge is translated into practical application. An integrated learning

environment refers to the learning context in which students learn more than one discipline, as well as the multidisciplinary practice of problem-solving knowledge. The integrated learning environment can occur in a lesson, module, course or through hands-on problem solving. Students who learn in a real environment can become more innovative and creative. However, there are challenges associated with designing and implementing such a real-world environment. First, traditional disciplinary boundaries must be developed in order for it to effectively tap into multiple disciplines (Shanableh, Aderibigbe, 2022).

Technologies are developing more and more rapidly and are increasingly used in production and everyday life, and they also affect education. It is logical to look for and develop new educational approaches that improve the understanding of the taught material, while at the same time speeding up the learning process and creating the necessary habits and skills in the learners (Kostovska, 2024). STEM education is based on an integrated approach and methodology that places the student at the center of learning and promotes learning through project-based learning, through experience, creativity and experimentation. STEM is based on learning by doing.

In STEM, students try to solve real-world problems by applying knowledge.

All this is related to the preparation of students for the so-called „professions of the future", with building skills and competencies necessary for the modern student to be a successful leader, professional (Petrova, 2021). According to Radloff and Guzey, video information plays an important role in advancing the learning process and improving STEM methodology. Online courses can include the use of YouTube videos, as well as dedicated videos published in cloud resources with organic access, recorded classroom lessons on STEM methodology (Liu, Chubarkova, Kharakhordinna, 2020). Artificial intelligence in education is an emerging interdisciplinary field. An example of an AI system is Mozaik Education, which is used worldwide in schools. On the Mozaweb platform can be found a range of educational applications and tools that can be used both on a tablet and on a phone, the Mozabook; mozaMap; mozaLog; Euclid, Euler3D, Matek, Fizika, LabCamera, which enable learning through play, which is also applicable to younger students (Calalb, Bostan, 2023). Online simulations and modeling are a very good way to explore and visualize lessons. Virtual labs, for example Labster (https://www.labster.com/)[1], the PhET Interactive Simulation platform, offer the ability to perform lab experiments in an online environment, which is particularly useful for conducting research when a physical visit to a lab may be be difficult. ExploreLearning Gizmos (https://www.explorelearning.com/)[2] online experiments and resources provide tools to visualize math and science concepts, helping students put their knowledge into practice.

Using educational videos and online resources is also essential. Websites such as YouTube [3] and TED-Ed[4] offer visual and interactive lessons on STEM topics that supplement learning and provide new perspectives. Platforms such as Coursera[5]

and edX[6] offer courses and lectures in STEM disciplines available online that help students deepen their knowledge and engage with new topics.

These resources and tools provide a variety of ways to integrate STEM into online learning, offering students the opportunity to engage with the material in innovative and interactive ways.

3. Benefits of STEM education – skills

The implementation of STEM activities in the educational system provides an opportunity to develop skills necessary for adaptation in a dynamically developing technological environment. Children are preparing for real life.

There are various studies aimed at determining the skills necessary for success in the world of the XXI century (Beers, 2011). But the commonality of most of them is that the use of STEM develops in students' key skills such as: teamwork, creative and critical thinking, initiative, communication, collaboration and mutual assistance, search and analysis of information, effective use of technology, increase of common culture, cultural awareness and recognition of cultural differences, and last but not least, development of life skills (Kozuharova, Zhelyazkova, 2021).

Creativity and innovation, creative thinking

Students develop skills for creating new ideas and approaches to solving existing problems, tasks, challenges, situations. They learn to experiment and think outside the box of traditional solutions, which is key to innovation.

Communication and cooperation, teamwork

It is expressed in the ability to effectively communicate and work in a team, mutual assistance and cooperation. Development and work on various projects related to sustainable development and solutions to social problems. Students learn to share ideas, listen to each other, understand and be aware of cultural differences related to understandings and perception of the world, learn to work in a team.

Improving learning motivation and commitment, initiative

Practical and project-based tasks make learning more interesting and connected to the real world. Students are more motivated and engaged when they see the application of their knowledge and skills. Students are encouraged to take initiative.

Self-learning and adaptability

Ability to constantly learn, improve and adapt to new situations and technologies.

Integration

STEM learning seeks to integrate science, technology, engineering, and mathematics to demonstrate their interconnectedness and applicability to real-world situations. The integration of science, technology, engineering and mathematics in STEM education is a key aspect that allows students to see how these disciplines are interconnected and how they can be applied in the real world (Becker, Park, 2011). This in turn increases mathematical literacy and algorithmic thinking.

Inclusive education

STEM education strives to be inclusive and provide equal opportunities for all students, regardless of their socioeconomic status, gender, or ethnicity. This includes developing programs to attract and retain diverse groups of students in STEM fields.

Critical thinking, critical analysis

STEM education emphasizes the importance of critical thinking, critical analysis, and problem-solving skills. Students are encouraged to analyze complex situations, explore different possibilities and find innovative solutions to problems (Topsakal, Yalcin, Cakir, 2022).

Multidisciplinarity

Multidisciplinarity is an aspect of STEM education that brings together different scientific and technical disciplines into an integrated curriculum. This approach not only prepares students for complex real-world problems, but also stimulates their critical thinking and creativity. Such integration allows students to understand how different disciplines are interrelated and how they can be applied to solve complex real-world problems (Kumar, 2025).

Practical applicability

Lessons in STEM education seek to have practical applicability in real-life situations to prepare students for future professional challenges. Teamwork is an essential aspect of STEM projects, supporting the development of communication skills, leadership and collaboration among students. This approach encourages the sharing of knowledge and skills and helps students learn how to work together to solve complex problems.

Strengthening scientific and technological culture

STEM education fosters an understanding and respect for the science and technology that underlies STEM learning. Technical skills are developed, students get practical skills to work with technologies and tools that are important for the modern world. They learn to program, work with different software and use technical equipment.

Increasing digital literacy

In today's world digital literacy is essential, STEM education helps students navigate the digital environment and use technology effectively, safely and ethically.

These advantages make STEM education an important part of modern education, providing students with the necessary knowledge, competencies and skills for successful integration and implementation in a rapidly changing world. STEM education plays an important role in preparing students for their future roles in a technologically advanced society by providing them with the necessary tools to understand and participate in the science and technology around them (Tavdgiridze, Didmanidze, Khasais, Sherozia, Dobordginidze, Akhvlediani, Akhvlediani, 2024).

Social-emotional skills

STEM education leads to the development and formation of social-emotional skills in students, a sense of belonging to a given group, satisfaction from a job well done, etc.

4. Challenges

STEM education offers many benefits, both to students and to society as a whole, but there are also a number of challenges and difficulties that must be addressed in order to successfully use STEM in education.

One of the main challenges is insufficient resources and equipment, which can drastically limit quality STEM education as well as opportunities for hands-on activities. Many schools and educational institutions do not have the necessary financial means to purchase modern equipment, that is why at this stage the state helps by allocating funds for the construction of STEM - centers in schools.

Another major drawback is the absence or insufficient training of teachers. Despite the desire of many teachers to teach using STEM, they often lack the necessary training and qualifications. This is why teacher professional development is key. While innovative models such as inquiry-based learning, design thinking, and computational thinking show promise, their integration into classroom practice remains inconsistent. Teachers may face difficulties aligning these pedagogies with curricular standards or may lack institutional support to experiment with new approaches. Additionally, the rapid evolution of technology and STEM industries demands continuous adaptation of teaching methods – a challenge for educators already constrained by workload and systemic limitations. In Bulgaria, within 5 years, 14,000 teachers will be trained in terms of these pedagogies and the use and application of STEM in education[7].

It is also necessary to promote the interest and motivation of students, using innovative teaching methods and connecting the learning material with the real world. Another problem is that not all students have equal access to STEM education, especially those from vulnerable groups or low-income areas, leading to differences in the quality of learning.

The main factor for the successful implementation of STEM technologies in education remains the teacher. He is the one who has to integrate several disciplines into one, which is undoubtedly a complex task. It is the teachers who must develop interdisciplinary lessons and projects that connect the different fields. They should also develop new forms of assessment to include project-based learning and practical tasks.

On the other hand, ever-increasing technological progress requires flexibility and adaptability, constant updating of pedagogical practices, methods, materials, curricula, content, etc. Technological equipment also requires regular maintenance and renewal, which is associated with additional costs on the part of the school.

These challenges require a concerted effort by schools, teachers, parents, and society expanding the pedagogical dimensions of STEM education.

5. Survey – results and discussion

The article examines a survey conducted among teachers, about the specifics of the training, and their opinions about its application and effectiveness in Bulgarian schools. It is the teachers' opinion about this pedagogical approach that is essential for its successful implementation and development.

The aim of the study is to investigate the opinions of teachers regarding the specifics of STEM-based education, as well as their assessment of its application and effectiveness in Bulgarian schools.

The subject of the study is the attitudes, assessments and professional experience of teachers in relation to the application of this pedagogical approach in educational practice. The variables of the study are the teachers' professional experience, type of school (primary, primary, secondary); qualification, assessment of the effectiveness of the approach; opinion on its applicability in school practice; attitudes towards its use in education; perceived benefits and difficulties in implementation. The study was conducted through a questionnaire survey among a sample of teachers from Bulgarian schools (secondary, primary, vocational schools), selected on the principle of voluntary participation and targeted selection – according to the thematic focus of the study.

Bulgarian teachers who teach at different educational levels and in different subjects took part in the survey. In recent years, there has been a lot of talk about implementing STEM education in early childhood (Fafunwa, Aisiku, 2022). It is precisely for this reason that we developed the survey also available to primary teachers and sought their opinion as well. Fig. 1 presents the distribution of the surveyed teachers by school.

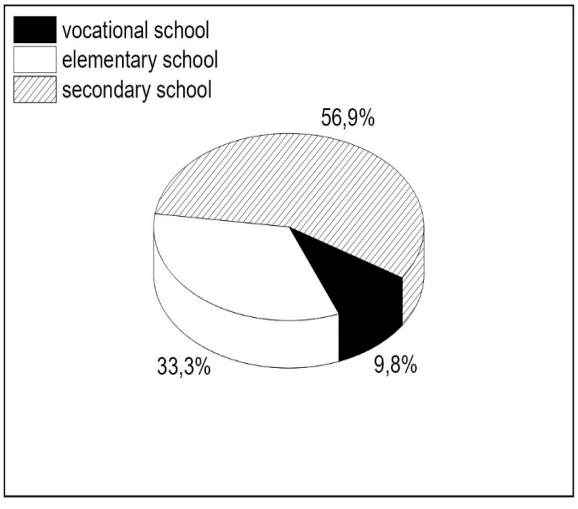


Figure 1. Distribution of teachers by school

Teachers working in secondary schools (56.9%)

The largest group is of teachers working in secondary schools. It is in these schools that individual subjects are differentiated and the need for STEM education is greatest. The need to show the connection between individual subjects and how this helps in learning the new material.

Teachers working in primary schools (33.3%)

This group is one third of the respondents. It is no coincidence that these teachers showed interest in the survey, considering the young age of their students and the need to apply different methods of holding attention, using different role-playing games, etc. STEM education in young students would be welcomed with greater ease, in view of its proximity to computing and innovative technologies.

Teachers working in vocational schools (9.8%)

The least participants in the survey are teachers working in vocational schools. There, the students are the largest and oriented in terms of what exactly they want to study. This may partly explain the lower motivation of these teachers towards STEM education.

The following figure (Fig. 2) shows the distribution of teachers in terms of their pedagogical experience.

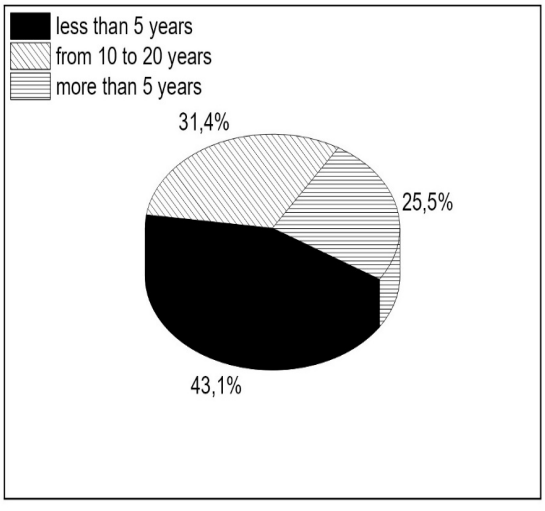


Figure 2. Distribution of teachers by pedagogical experience

Less than 5 years (43.1%)

Most of the surveyed teachers have less than 5 years of teaching experience, i.e. we can say that teachers who recently practice this profession are inclined to the application of new methods and approaches in education. These teachers are closest in years, time and understanding to their students, which contributes to building a more stable relationship between student and teacher, creates trust and understanding. This, in turn, facilitates the learning process and the application of innovative approaches.

For the next group - with a pedagogical experience of 10 to 20 years, we can say that these are teachers in their career maturity and have enough professional experience and at the same time a desire for innovation, such as the integration of STEM education. The share of teachers with more than 5 years of teaching experience, but less than 10, is also not small. These are ambitious teachers with motivation for work and striving for excellence.

In Bulgaria, the main problem is the lack of teachers in general and in natural sciences in particular. 92.2% women and 7.8% men participate in the survey, i.e. in the results, the women's opinion prevails (Fig. 3).

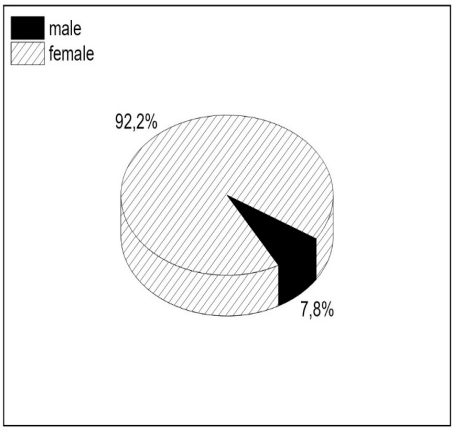


Figure 3. Distribution of teachers by gender

Of the respondents, the largest percentage are elementary teachers (27.5%), followed by those who teach Chemistry and Man and Nature (15.7%), and the smallest number are mathematics and physics teachers. From the obtained results, we can conclude that a greater part of the respondents teaches natural sciences (Fig. 4).

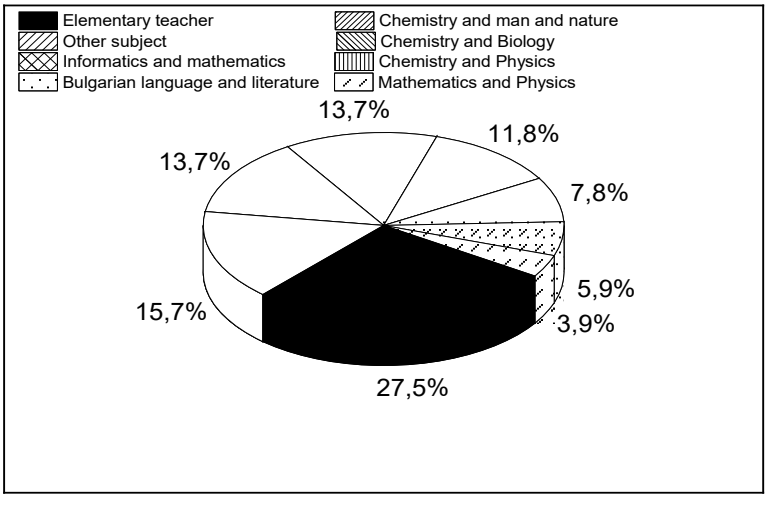


Figure 4. Distribution of the subjects taught by the respondents

Regarding whether STEM education in Bulgaria will be effective (Fig. 5), over half (59.2%) of the respondents believe that it will be effective, 34.7% answered rather yes, and 6, 1% can't judge. This result testifies to a high readiness of teachers to implement STEM in education. This is also an expression of support and increased interest in innovative educational practices and the understanding that the effective use of time during school hours has a key role in better assimilation of acquired knowledge and skills, and understanding of educational material.

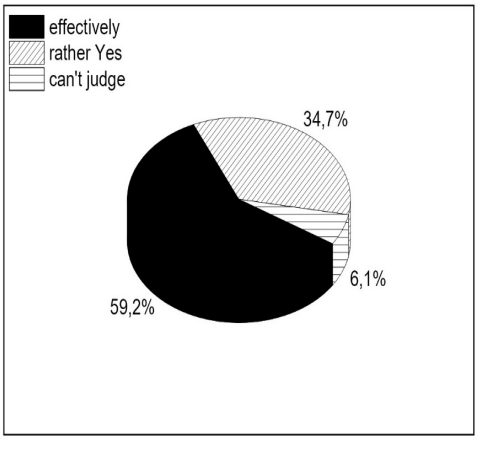


Figure 5. Distribution of answers to the following question:
How do you think STEM education will be effective in Bulgaria?

However, unfortunately, not all schools have yet built STEM centers (Fig. 6). Only about 20% of respondents said they already have a STEM center in place. The rest say they don't exist or are under construction. Possible reasons could be lack of knowledge about STEM, insufficient resources or lack of support from the state administration, various institutions. Teachers in such schools need specialized training and support to overcome barriers and learn about the benefits of STEM education. In Bulgaria, the Ministry of Education and Science, through various projects, greatly supports the process of building STEM centers in the country, as well as providing the necessary training for teachers. It is planned until 2026 in Bulgaria, every school should have a STEM center[7].

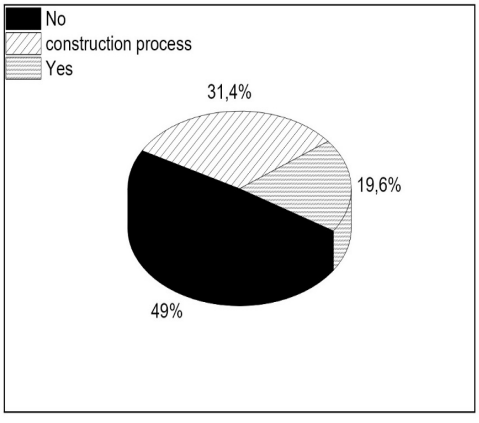


Figure 6. Does the school where you work have a STEM center?

On the other hand, to the question "Would you visit the STEM center in your school?", all respondents answered "Yes" (Fig. 7). This is a positive indicator of the use and benefits of STEM education, as well as the motivation of teachers to increase students' interest in science.

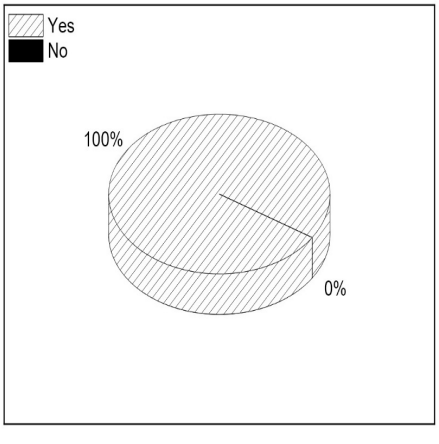


Figure 7. Would you attend the STEM center at your school?

The following graph (Fig. 8) presents results regarding the frequency with which teachers would visit the STEM center. Along with the answers every week (18.8%) and every hour (8.3%) there is an answer with a fairly high percentage – 72.9% – I don‘t use it. This result is again caused by the lack of a STEM center in these schools. Some of the reasons, as already mentioned, can be lack of sufficient resources to build such a center, lack of resources to purchase specific equipment and software, need for various trainings, not good organization, etc.

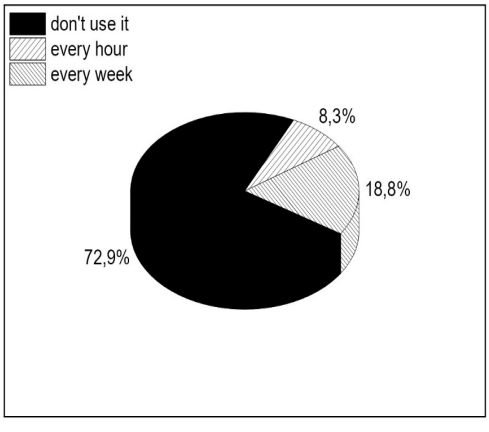


Figure 8. How often would you visit the center at your school?

Despite the problems and challenges surrounding STEM education, all respondents agree that its use will increase interest in natural sciences (Fig. 9). The decline in interest in natural sciences observed in recent years is also due to the way they are taught in modern Bulgarian schools. Often part of the material remains misunderstood, the general logical connection in the studied subjects and the opportunities for the formation of natural science literacy are not sought (Bellová, Melicherčíková, Tomčík, 2018).

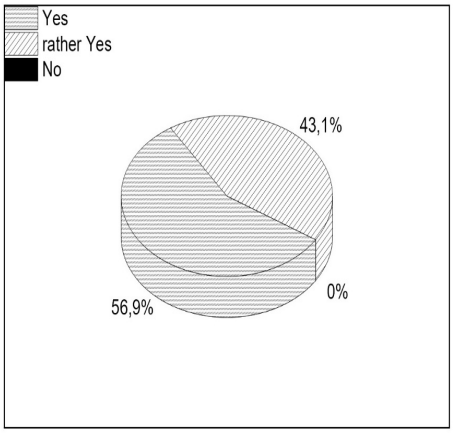


Figure 9. Do you think that interest in science will increase when it is taught through STEM education?

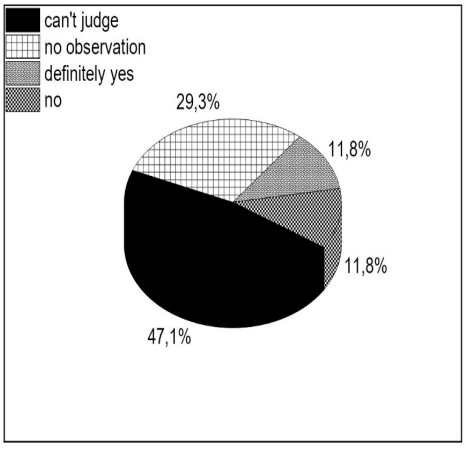


Figure 10. How do you think students and their parents perceive this type of education? Is there a generational conflict?

Regarding how students and their parents perceive this type of learning, the results obtained are quite heterogeneous (Fig. 10). The largest percentage of respondents answered that they still cannot judge (47.1%), and the next largest group – 29.3% – have no observation, with equal percentages of "Yes" and "No"

answers, respectively. This means that these teachers, students and parents need more information and examples of the benefits of STEM to form their opinions. The lack of sufficient information leads to a misunderstanding of a given problem, situation, innovation, etc.

Based on the categoricalness of the respondents regarding the effectiveness of STEM training, it was interesting to find out what they think this type of training develops in students. The question was asked with the possibility of choosing several answers. The results of the graph (Fig. 11) are presented as the number of choices for a given skill, ability.

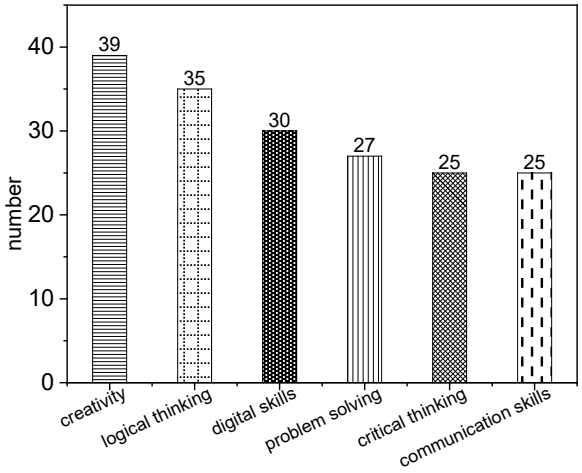


Figure 11. What do you think STEM education develops in students?

A large proportion of teachers surveyed see STEM as a key element in preparing students for the future. They understand the importance of technological and scientific skills in today‘s world. Most are aware of the benefits and what abilities, competencies, etc. can shape the students‘ STEM education and give them a successful start, as well as prepare them not only for their future professional, but also personal realization. Teachers believe that STEM education is very important. They are convinced of the importance of STEM for the future of their students and actively support its integration into the educational process. Some respondents indicated more than one answer.

That is why 92% of the surveyed teachers wish to take a course related to STEM education (Fig.12). The remaining two groups, which are a very small percentage and answered that they could not judge or answered „No“ need more information about the benefits of STEM education or are teachers with longer experience, older

who they see no point in upgrading their qualifications at this stage. As for what to include in the given course, the suggestions are for both theory and practice, which includes working with an interactive display, sensors, 3D printer, etc. ie. aspirants want to master STEM technologies as much as possible (Fig.13).

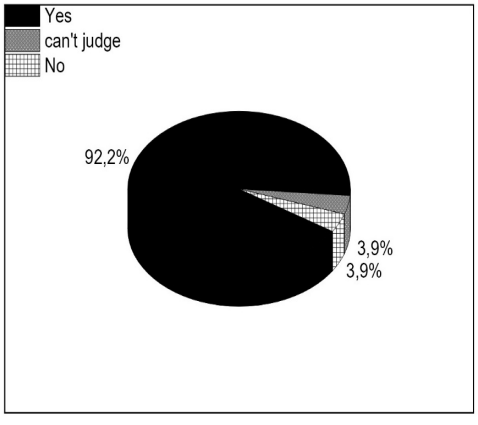


Figure 12. Would you like to take a course related to STEM education?

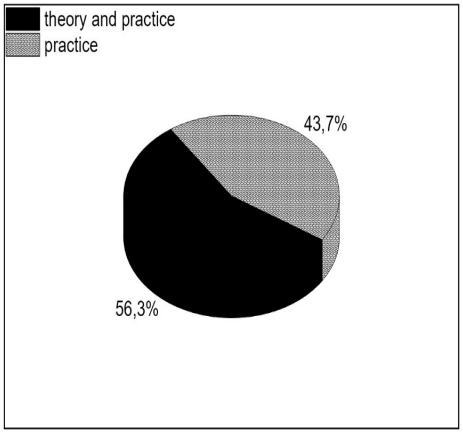


Figure 13. If you were to pursue STEM training, what Would you like it to include?

The results of the next question (Fig. 14), namely: "What do you think about the following statement: ‚The idea is that young people through the playful and fun moment enter serious science' – is it true or false?" show that a large proportion of teachers are ready to meet the challenges of STEM education. 94.1% of the respondents answered that it is true, and only 5.9% – that it is wrong.

The majority consider that through the game, through the so-called a game approach can easily reach the student and he can understand and master the material, without stress, which undoubtedly leads to understanding and longer-term retention, rather than learning for the sake of testing, learning for assessment. Through STEM education, learning is achieved for the sake of knowledge itself and an understanding of its need in the future, in real life. Learning itself does not consist in memorizing information, but in developing various skills, competences and abilities.

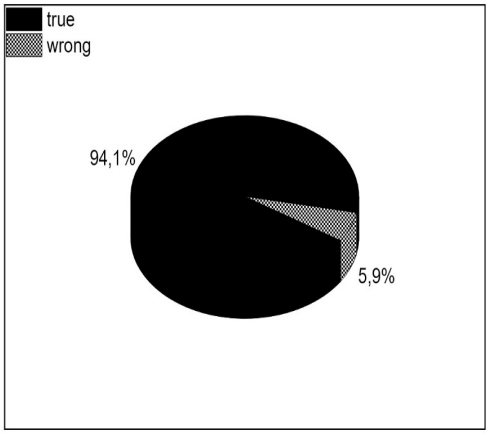


Figure 14. What do you think of the following statement:
"The idea is for young people to enter serious science through the playful and fun moment"

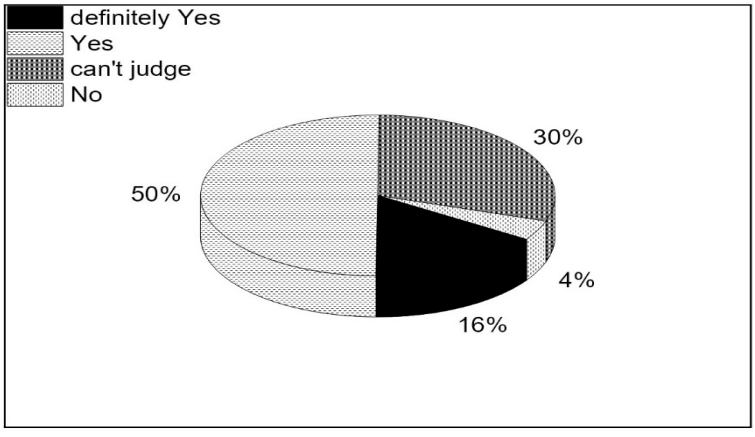


Figure 15. Do you think that STEM education will increase the success of children with special educational needs?

Half of the surveyed teachers believe that STEM education will definitely increase the success of children with special educational needs, 16% answer with "Yes", 30% cannot judge, which again speaks of insufficient awareness and the need for trainings and seminars to promote STEM education and its benefits and 4% answered No.

An open question was also asked: "Are you optimistic about the future of innovative approaches in the educational process?". Among the Bulgarian teachers there were the following answers:

– Yes (75.1%)
– Absolute (2.3%)
– Every new practice is a step forward in education (2.3%)
– Yes, innovative approaches will help children, but they need to learn hard work and discipline (2.2%)
– Yes, but they must be applied in the right way (2.3%)
– Yes. They will occupy an increasing part of the learning process (2.3%)
– Yes, I am optimistic, although the changes are happening extremely slowly (2.3%)
– Maybe yes (2.2%)
– No (2.2%)
– Rather yes (2.3%)
– Yes. They will occupy an increasing part of the learning process (2.3%)
– Average optimist (2.2%)

With few exceptions (2.2%), the respondents are optimistic and positive about innovative approaches in the educational process, they expressed their positive attitude towards the introduction of innovations and new technologies in the educational process. Innovation can lead to improvements, but it is also change that is at the heart of innovative approaches. Innovative practices refer to modern and creative approaches to teaching and learning that go beyond the traditional.

Innovation in the context of education still seems to be an abstraction rather than a reality. Nowadays, students do not have the necessary patience, desire to learn, it is difficult for the teacher to keep their attention, this is where innovations come in – they can be a solution to these problems.

In 2021, an analysis of a survey on the introduction of STEM education in Bulgarian schools was made (Kozuharova, Zhelyazkova, 2021). The article examines the essence of STEM education - its origin, definitions and skills that students develop. From the analysis, it is observed that at that time, a large percentage (61%) do not know what STEM is (31.2% do not know what STEM is, and 29.7% rather do not know). Now, three years later, 19.6% already have a STEM center built, 31.4% are under construction (Fig. 6) and all responded that they would use it when it was built in their school (100%) (Fig. 7).

Regarding the question "What do you think STEM education develops in students?", as well as in the questionnaire conducted in 2021 (Kozuharova, Zhelyazkova, 2021) first in the choice of teachers is "creativity". To the question: "Do you think it is appropriate to implement STEM education in Bulgarian education?" (Kozuharova, Zhelyazkova, 2021), 86.3% answered yes, only 5.9% answered that they could not judge. While now about 94% (Fig. 5) support STEM education (59.2% already think it will be effective and 34.7% answered rather yes). This brief comparison of the results between the two surveys shows how much STEM education has developed in just three years, indirectly these results also show us the advantages and benefits of this new learning methodology, in which the student is at the center.

6. Conclusion

This study explores the pedagogical dimensions that underpin effective STEM education, emphasizing the importance of interdisciplinary learning, hands-on experimentation, and collaborative problem-solving. These pedagogical approaches are deeply rooted in constructivist and experiential learning theories that place learners at the center of knowledge creation and encourage active engagement in real-world challenges. However, the successful implementation of STEM pedagogy depends on overcoming some systemic and practical challenges.

From the survey conducted, we can conclude that teachers consider the introduction of STEM education to be effective and appropriate. A large percentage of them want to take a training course that includes both theory and practice in order

to improve their competences. The teacher could not provide a full-fledged training if he himself did not have a solid theoretical and practical training. STEM education will also improve students‘ skills, such as creativity, logical thinking, digital skills, etc., which are necessary for the 21st century. The creation of pedagogical guidelines and textbooks, the equipping of more and more classrooms in schools, and why not in kindergartens, will in the future lead to a successful and effective increase in the quality of education. STEM is an innovative teaching method that integrates different disciplines into a comprehensive and hands-on learning experience. This helps students see the connections between them and apply their knowledge from one area to another, stimulating critical thinking and problem-solving skills. It encourages innovation, develops important skills and prepares students for future challenges. Students receive the necessary knowledge and skills that will help them adapt and succeed in the rapidly changing modern world.

Strengthening the pedagogical foundations of STEM education is essential to preparing learners to cope with the complexities of today's world. Future directions in STEM pedagogy should focus on integrating emerging technologies, principles of sustainability, and interdisciplinary collaboration, ensuring that education keeps pace with societal and technological changes.

Acknowledgments and Funding

This study was supported by National Program "Young Scientists and Postdoctoral Researchers – 2", 2024 and the project RP-A2/25.

NOTES

1. https://www.labster.com
2. https://www.explorelearning.com
3. https://www.youtube.com
4. https://ed.ted.com
5. https://www.coursera.org
6. https://www.edx.org
7. https://greenstemlearn.swu.bg

REFERENCES

Aleksieva, M. (2024). *Multidisciplinary innovations for social change: STEM learning as a catalyst for transformation in education.* Burgas University.

Alali, R. (2024). Enhancing 21st century skills through integrated STEM education using project-oriented problem-based learning. *Geo Journal of Tourism and Geosites, 53*(2), 421 – 430.

Becker, H., & Park, K. (2011). Integrative approaches among science, technology, engineering, and mathematics (STEM) subjects on students' learning: A meta-analysis. *Journal of STEM Education: Innovations and Research, 12*(5).

Beers, S. (2011). *21st century skills: Preparing students for their future.* STEM.

Bellová, R., Melicherčíková, D., & Tomčík, P. (2018). Possible reasons for low scientific literacy of Slovak students in some natural science subjects. *Research in Science & Technological Education, 36*(2), 226 – 242.

Calalb, M. & Bostan, C., (2023). *Using Mozabook in the creation of interactive lessons.* Senatului Universității Pedagogice de Stat Ion Creangă.

Fafunwa, B., & Aisiku, U. (Eds.). (2022). *Education in Africa: A comparative survey.* Taylor & Francis.

Johnson, C. & Czerniak, M. (2023). Interdisciplinary approaches and integrated STEM in science teaching. In: *Handbook of research on science education* (pp. 559 – 585). Routledge.

Khushk, A., Zhiying, L., Yi, X., & Zengtian, Z. (2023). Technology innovation in STEM education: A review and analysis. *IJERI: International Journal of Educational Research and Innovation*, *19*, 29 – 51.

Khurma, O., Al Darayseh, A., & Alramamneh, Y. (2022). A framework for incorporating the "learning how to learn" approach in teaching STEM education. *Education Sciences, 13*(1), 1.

Kirilova, M. (2020). STEM education of the future. *Vocational Education, 22*(4).

Kostovska, V. (2024). The future of education in the conditions of the invasion of digital technologies. *Before Education and Young Educators in the 21st Century*, (116).

Kozuharova, D. & Zhelyazkova, M. (2021). Essence of STEM education. *Pedagogical Forum*, 19 – 28.

Kumar, V., (2025). Integrating multidisciplinary approaches in education: Enhancing learning across disciplines. *Innovative Journal for Advances in Education, Science, Commerce & Multidisciplinary Learning, 1*(1).

Levterova-Gadzhalova, D., Tagareva, K., & Sivakova, V. (2024). *Smart technologies in education – current and promising aspects.* Burgas State University

Liu, Z., Chubarkova, E., & Kharakhordina, M. (2020). Online technologies in STEM education. *International Journal of Emerging Technologies in Learning*, (15).

Mafugu, T., Tsakeni, M. & Jita, C. (2022). Preservice primary teachers' perceptions of STEM-based teaching in natural sciences and technology classrooms. *Canadian Journal of Science, Mathematics and Technology Education, 22*(4), 898 – 914.

Mamadiyorova, S. (2025). New approaches to integrating disciplines in professional education for a comprehensive learning experience. *Dialogue, integration of sciences and cultures in the process of scientific and professional education, 1*(1), 423 – 425.

Mirkomilovna, N. (2025). STEM technologies in primary education: A modern scientific analysis. *Educator Insights: Journal of Teaching Theory and Practice, 1*(6), 40 – 52.

Moore, T., & Smith, K. (2014). Advancing the state of the art of STEM integration. *Journal of STEM Education: Innovations and Research, 15*(1), 5.

Petrova, A. (2021). STEM learning science through online classes with experiments. *Pedagogical Forum*, (3), 29 – 46.

Shanableh, A., Aderibigbe, S., Omar, M., & Shabib, A. (2022). Challenges and opportunities of multi-disciplinary, inter-disciplinary and trans-disciplinary research. *Higher Education in the Arab World: Research and Development*, 311 – 325.

Tavdgiridze, L., Didmanidze, I., Khasaia, I., Sherozia, N., Dobordginidze, D., Akhvlediani, D., & Akhvlediani, Z. (2024). STEM teaching in contemporary education. *Challenges to National Defence in Contemporary Geopolitical Situation, 1*(1).

Terlemezyan, H. & Zapreva, M. (2025). Challenges and advantages of implementing STEM/STEAM projects in school education in Bulgaria. *Foreign Language Teaching, 52*(2).

Topsakal, İ., Yalçin, S., & Çakir, Z. (2022). The effect of problem-based STEM education on the students' critical thinking tendencies and their perceptions for problem solving skills. *Science Education International, 33*(2), 136 – 145.

Tsvetanova, V., Terziyski, M., & Mladenova, M. (2021). *Application of STEAM technologies in educational environments (international experience)*. BPOS.

✉ **Dr. Aleksandra Tencheva**
ORCID iD: 0000-0003-2135-592X
Department of Chemistry
South-West University "Neofit Rilski"
Blagoevgrad, Bulgaria
E-mail: al.tencheva@swu.bg

✉ **Dr. Elitsa Chorbadzhiyska, Assoc. Prof.**
ORCID iD: 0000-0002-0434-6960
Innovative Center for Eco Energy Technologies
South-West University "Neofit Rilski"
Blagoevgrad, Bulgaria
E-mail: elli_e1@swu.bg