TRANSNATIONAL REPORT

Green STEM

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

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INTRODUCTION

The extensive advancements in science in recent years challenge the knowledge of today's students. They must possess the ability to comprehend and synthesize new information. The daily tasks confronting contemporary students are progressively becoming more complex and demanding. Traditional teaching methods have proven inadequate in delivering the desired outcomes, prompting educators to seek more effective approaches.

STEM education, centered on integration and inclusion within real-life scenarios, offers a means to motivate and engage students. This educational approach necessitates the execution of specific learning activities to cultivate students' problem-solving skills through creative techniques, facilitating their seamless integration into professional and social spheres. STEM education equips students to stay abreast of technological innovation.

STEM education fosters intellectual growth, entrepreneurship, and the advancement of the entire society. Entrepreneurship entails individuals taking initiative to actualize their aspirations and taking calculated risks. It also enhances awareness and production skills.

Science, technology, engineering, and mathematics (STEM) education play a pivotal role in preparing students for the demands of the twenty-first century workforce, as it encompasses the knowledge and competencies essential for creative problem-solving, critical thinking, and innovative solutions. It is a cornerstone of high-quality education, vital for national economic growth and prosperity. This report assesses the current state of STEM education, its challenges, and recommendations for enhancing its outcomes.

The STEM Reports from Bulgaria, Türkiye, Slovenia and Greece offers a comprehensive evaluation of the existing state of science, technology, engineering, and mathematics (STEM) education. This report includes an analysis of the workforce, policy recommendations, and an appraisal of STEM education's outcomes in schools and universities.

Today, it is widely acknowledged that science, technology, mathematics, and engineering are fundamental components of a nation's development. As a result, many nations are investing in the STEM approach to nurture future generations in these fields. In this context, various reports and documents have been prepared by the responsible educational institution, laying the groundwork for the implementation and dissemination of the STEM approach. These reports and documents

have underscored the importance of STEM education, drawing the attention of education experts, institutions, and the business community.

In relation to STEM education, the educational institution has actively participated as a national support entity in the Scientix Project, a collaborative project for science education in Europe, led by the European Schoolnet since 2014. This project encourages and supports Europe-wide collaboration among STEM (science, technology, engineering, and mathematics) teachers, education researchers, policy makers, and other STEM education professionals. The project aims to promote the use of technology and best practices in science education across Europe through the establishment of teacher communities.

One of the initial reports produced to promote STEM education in Türkiye is the "STEM Education Report" prepared in 2015 and hosted by Istanbul Aydın University. This report has underscored the need for STEM education and outlined a roadmap for its implementation.

The core of the report focuses on a comprehensive examination of the current state of green STEAM education in the country. Although green transition and sustainability are partially integrated into various educational stages, their most robust integration is observed in tertiary education and research institutions. Nevertheless, there is a notable absence of systematic incorporation of green technologies and sustainability into educational frameworks. Encouragingly, numerous initiatives are underway at different educational levels to address this gap on a national scale.

Through green STEAM education, individuals should be equipped with the knowledge and skills required to address environmental challenges and establish a sustainable and resilient world. By promoting the application of arts, technology, and scientific principles in an environmentally conscious manner, we inspire the next generation to become environmentally responsible innovators.

STEAM education has gained significant attention and recognition in recent years, representing an interdisciplinary learning approach that nurtures creativity, critical thinking, problem-solving, and collaboration among students. The government, educational institutions, and various non-governmental organizations are actively championing STEAM initiatives to foster innovation and prepare the next generation for a technology-driven and rapidly evolving world.

CURRENT STATE AND TRANSNATIONAL ANALYSIS FROM THE NATIONAL STEM REPORTS

STEM Approach in Bulgaria's Education System:

The state of STEM education in Bulgaria has emerged as a top priority for educational development in recent years. However, there is still considerable work needed to establish high-quality STEM education in the country. Several key challenges include:

1. Funding: Insufficient funding for education in Bulgaria has a direct impact on the quality of STEM education.
2. Inadequate Teacher Training: Teachers in Bulgarian schools require additional training to effectively deliver high-quality STEM education. Without this training, they may struggle to guide students in the STEM field.
3. Limited University-School Collaboration: Greater collaboration between universities and schools could significantly enhance the quality of STEM education by providing students with a more comprehensive learning experience.
4. Shortage of Practical Training Opportunities: Practical training opportunities in STEM education are limited in Bulgaria, preventing students from applying their theoretical knowledge effectively in real-world scenarios.

Despite these challenges, an increasing number of schools in Bulgaria are prioritizing STEM education, which will help prepare the next generation of STEM professionals in the country. The initiative began in the 2018/2019 academic year when schools began organizing extracurricular activities based on STEM fields such as science, technology, engineering, and mathematics. The "Building a School STEM Environment" program, initiated by the Ministry of Education in 2020, aims to establish new STEM school centers.

According to this program, each new school center will involve improving classroom infrastructure, introducing innovative educational content, and implementing diverse teaching methods. Additionally, Bulgaria has various projects focused on STEM education:

- The "STEM Centers and Innovations in Education" project, part of the "Building a School STEM Environment" initiative, aims to establish over 2,240 STEM centers in all schools by

2026. The project's goals include building an educational STEM environment, developing students' STEM skills, and enhancing their readiness for the job market.

- The "Innovations in Action" program, Module 5, supports schools and teachers in implementing innovative activities, fostering an innovative learning environment, and promoting innovative teaching methods. It focuses on natural sciences, digital technologies, engineering, and mathematics (STEM).

STEM Approach in Türkiye's Education System:

In Türkiye, the 2013 Pre-School Education Program serves as the foundation for pre-school education. While it doesn't explicitly emphasize STEM education, it includes achievements and indicators related to cognitive development that align with STEM education principles. Several universities in Türkiye, such as METU, YTU, and Bahçeşehir, conduct training programs for preschool teachers to raise awareness and knowledge about STEM practices.

In secondary school curricula, STEM education is not explicitly mentioned in STEM courses (Physics, Chemistry, Biology, Mathematics, and Computer Science). The applications of STEM are either absent or receive minimal attention in the curriculum.

In university and faculty of education curricula in Türkiye, there has been a growing focus on STEM education. Universities conduct various activities, including teacher training, integrating STEM courses, and organizing scientific events to promote STEM. However, the undergraduate curricula do not include direct STEM education courses, with some exceptions in Science and Primary School Mathematics Teaching departments.

STEM Approach in Slovenia's Education System:

The education system in Slovenia consists of primary, secondary, and tertiary education, with provisions for adult and special needs education. The primary education cycle includes subjects like Mathematics, Fine Art, Music, and Fundamentals of the Environment, which align with STEM education principles. The curriculum of the Fundamentals of the Environment course also covers green technologies.

In the secondary education cycle, the spectrum of STEM subjects expands to include Mathematics, Fine Art, Music, Natural Science, Natural Science and Technology, and Engineering and Technology, all of which incorporate references to green technologies. Technical courses delve

into four interconnected domains: Technical Resources, Technological Processes, Organizational Dynamics, and Economic Considerations.

In the third educational cycle, subject-specialist teachers lead instruction, offering a comprehensive exploration of STEM courses. Students can choose from a range of elective courses, some of which have direct or indirect connections to green technologies.

Upper secondary education in Slovenia includes both general education and technical and vocational education. The general education curriculum includes compulsory STEM subjects and a variety of STEM electives, allowing for more advanced study in Biology, Physics, Chemistry, Mathematics, and Informatics. Technical and vocational education provides specialized STEM courses, delving into various technical and natural fields. It offers an in-depth understanding of technical and scientific disciplines and introduces specialized courses related to Green STEM.

In summary, while both Bulgaria,Türkiye and Slovenia face challenges in implementing STEM education, they are actively working on initiatives to improve the quality and availability of STEM education. In contrast, Slovenia has made substantial progress in incorporating STEM principles and green technologies into its education system, starting from the early stages of primary education and continuing through upper secondary education.

STRATEGY AND PLAN FOR IMPLEMENTING A MODEL FOR TRAINING STUDENTS AND TEACHERS TO APPLY THE GREEN STEM STRATEGY

STEM education places a strong emphasis on universal literacy skills, including creative thinking, critical thinking, problem-solving, and collaborative learning. Students are expected to attain these skills, and teachers play a pivotal role in guiding students to achieve higher-order thinking, product development, invention, and innovation. Rather than merely imparting theoretical content knowledge in science, technology, engineering, and mathematics, teachers create a supportive learning environment where students feel comfortable exploring without fear of failure. Thus, teachers lead by example, nurturing students' confidence and creativity.

The primary goals of this program encompass:

1. Enhancing students' motivation for natural sciences and mathematics, making learning more engaging.
2. Facilitating project-based learning, integrating complex knowledge, and shifting educational paradigms toward a more comprehensive and contemporary approach.
3. Increasing student engagement, skills, achievements, digital literacy, creativity, and industry-relevant competencies.
4. Equipping students with problem-solving skills, fostering technological solutions, teamwork, and critical thinking.
5. Stimulating students to innovate and improve modern technological solutions, particularly in the fields of mechanics, programming, and artificial intelligence.
6. Developing skills for creating new technologies and automating existing processes.
7. Attracting more students to university majors and careers in technology-related industries.
8. Contributing to the growth of technology industries and their share of the GDP.

In the digital age, STEM education is of paramount importance and should be swiftly implemented to cultivate essential skills. Introducing the STEM methodology not only sparks students' interest in natural sciences but also guides them toward careers in STEM fields. This educational approach equips students with the skills and competencies necessary for a successful

future, emphasizing critical thinking and the application of these skills to create innovative solutions.

Survey to gauge the attitudes of teachers and experts in Bulgaria regarding the introduction of STEM education and its associated premises and recommendations, a survey with eight questions (Appendix 2) has been developed. This survey seeks to achieve several objectives, including:

- Assessing the overall attitude of teachers and experts toward STEM education.
- Evaluating the role of STEM classes in practical science education.
- Understanding the shift in science and teachers' readiness to embrace innovation in STEM teaching with the support of ICT.

The survey results lead to the following conclusions:

- STEM methodology increases students' engagement with natural science topics.
- Innovative STEM teaching positively impacts student engagement and performance.
- The absence of adequate Bulgarian-language content complicates the development of STEM lessons for teachers.
- While a significant portion of participants utilize STEM software in STEM classes, some teachers do not use it or use it infrequently. This indicates a need for more training and resources to promote the use of STEM software in education.

State-of-the Art Research Initiatives in the Web of Science (WoS) and TR-Indexed Papers. Our analysis delved into 226 papers on STEM education indexed in WoS and TR. We used specific criteria to identify articles conducted within Turkish universities, schools, and institutions. Data collection encompassed various aspects of the papers, such as titles, objectives, methodologies, participants, and results. The information was compiled into a structured database for further analysis. This analysis aimed to identify patterns, trends, and relationships among the papers by summarizing key findings and categorizing them for a more systematic understanding.

A search strategy was devised to locate pertinent keywords related to STEM education, resulting in the collection of theses from official databases (YÖK Thesis). These theses were selected to extract information about research objectives, methods, findings, and participants, and the data was organized for a descriptive analysis. This analysis revealed the frequency of STEM education topics, research methods, and the involvement of various participants.

STEM centers are integral to STEM education initiatives in Türkiye. These centers, typically associated with universities, research institutions, or other organizations, play a vital role in advancing STEM education. Their roles encompass:

1. Developing and implementing STEM education activities aligned with national standards, promoting hands-on learning opportunities.
2. Providing training and professional development for teachers to enhance their STEM teaching skills.
3. Offering valuable STEM resources, including books, journals, software, and hardware, for both students and teachers.
4. Supporting research in STEM education, aiming to create evidence-based teaching and learning strategies.
5. Collaborating with industry partners to expose students to real-world STEM experiences and insights into STEM careers, creating industry-academia alliances.

Green Education and Research at University of Ljubljana Slovenia, particularly the University of Ljubljana, is a proud member of the EU STEM Coalition, a network dedicated to advancing STEM education throughout Europe. This coalition focuses on crafting and implementing STEM education policies and strategies, aiming to drive economic growth, create opportunities, and improve overall well-being. By collaborating with policymakers, educational institutions, and industry stakeholders, the coalition seeks to innovate educational delivery and share evidence-based solutions addressing skill mismatches in STEM fields.

The University of Ljubljana is actively involved in initiatives to nurture STEM talent. These initiatives include collaborative efforts through Quadhelix partnerships, engagement in STEM activities within MakerLabs and FabLabs, and the organization of summer and winter schools, along with CAMPs for students in elementary and secondary education. The university also plays a significant role in formulating a comprehensive national STEM strategy and offers specialized training sessions for students, parents, and educators.

Research ventures conducted by the University of Ljubljana address critical issues such as Sustainable Innovation, Climate Change Mitigation, Environmental Awareness, Cross-disciplinary Collaboration, Green Career Opportunities, Resilient Communities, and Global Impact. Additionally, the university's faculties offer study programs focused on Delivering the European Green Deal, aiming to transform the economy and society. Projects are also undertaken to bridge

the gap between theoretical concepts and practical implementation, and these ventures contribute to sustainable progress, both locally and globally.

By actively participating in the EU STEM Coalition and pursuing numerous initiatives and research projects, the University of Ljubljana plays a pivotal role in advancing STEM education, fostering innovation, and addressing critical environmental and societal challenges.

CONCLUSIONS AND RECOMMENDATIONS

Recommendations

To enhance the status of STEM education in Bulgaria, the following recommendations are proposed:

• Enhancement of Teacher Training: The government should prioritize STEM teacher training and initiate programs to attract and retain qualified STEM educators.

• Investment in STEM Education: Increased funding should be allocated to STEM initiatives, including the provision of equipment, laboratories, and technology.

• Collaboration with STEM Professionals: Strengthen collaboration between STEM education stakeholders, educators, and STEM professionals to offer students insights into the real-world applications of STEM across various industries.

• Expanded Access to STEM Opportunities: The government should implement initiatives ensuring equal access to STEM education opportunities for all demographic groups.

Conclusion

STEM education is a fundamental component of an innovative educational system and plays a crucial role in a nation's economic growth and prosperity. By investing in teacher training, increasing financial support, fostering collaborations, and improving access to STEM opportunities, Bulgaria can enhance STEM education outcomes and prepare a skilled workforce for the challenges of the twenty-first century.

In summary, an analysis of academic research, reports, and studies conducted within STEM centers underscores a wide array of applications, projects, and workshops aimed at advancing STEM education in Turkey. Additionally, supportive initiatives for newly established centers are evident. Valuable educational resources, including books and brochures, are being developed to assist both teachers and students in their pursuit of academic excellence. These endeavors underscore the significance of STEM education and the commitment of Turkish institutions to cultivating a thriving culture of scientific exploration and technological innovation.

Nonetheless, the path ahead is still evolving, and this notable progress lays a strong foundation for an ongoing journey of improvement. As educational systems continuously adapt and the demands of the modern world undergo transformation, the relentless pursuit of excellence remains a guiding principle. This unwavering dedication to nurturing critical thinking, problem-solving, and creativity within students ensures that Slovenia is poised to maintain its distinguished position in the realm of Green STEAM education. This, in turn, significantly contributes to a future characterized by remarkable technological advancements and enriched insights in vital areas such as Sustainable Innovation, Climate Change Mitigation, Environmental Awareness, Resilient Communities, and Global Impact.

STEAM education in Slovenia is unquestionably charting a positive trajectory, reinforced by a resolute commitment to equipping students with essential skills, comprehensive knowledge, and an adaptable mindset essential for success in a technology-driven society. At the core of this educational transformation lies a strong emphasis on experiential learning, weaving together various disciplines to facilitate holistic comprehension. By fostering an environment where hands-on exploration flourishes, Slovenia nurtures fertile ground for students to grasp complex concepts through tangible engagement.

Furthermore, Slovenia's strategic partnerships with industries amplify the practical applicability of education. By bridging academia and industry, students gain access to real-world insights, cutting-edge developments, and the opportunity to work on projects mirroring actual professional scenarios. This mutually beneficial relationship enhances the quality of education and prepares students to make meaningful contributions as they transition into the workforce.

In essence, Slovenia's dynamic approach to STEAM education is a strategic investment that goes beyond producing proficient graduates; it shapes proactive problem solvers and forward-thinking innovators. This transformative education doesn't confine itself to national borders; it resonates globally. The solutions incubated within Slovenian classrooms have the potential to address not only local challenges but also a broader spectrum of global issues, from environmental sustainability and resource management to healthcare advancements and technological breakthroughs. Slovenia is forging a path towards systematically introducing sustainability and green transition in education that extends far beyond the classroom, shaping a future where knowledge and ingenuity act as driving forces for progress.

Notably, the educational landscape in Bulgaria, Türkiye, Slovenia and Greece thrives on interdisciplinary approaches, transcending traditional course boundaries. This approach not only mirrors the dynamics of the real world but also cultivates in students the ability to connect ideas across seemingly unrelated domains. As a result, learners are prepared to tackle multifaceted challenges by approaching them from diverse perspectives, fostering an innovative mindset with immense potential.

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

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 scince 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 PISSA (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 PISSA 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 PISSA 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.

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 effecient 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.

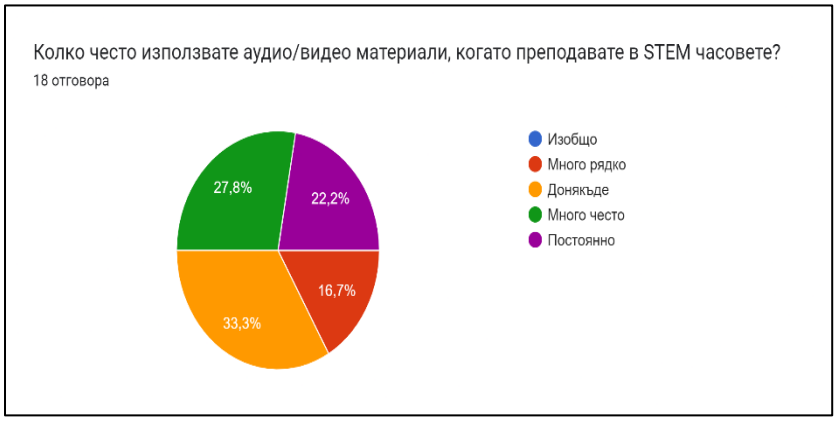


Fig. 2 *How often do you use audio/video materials when teaching STEM classes?*

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.

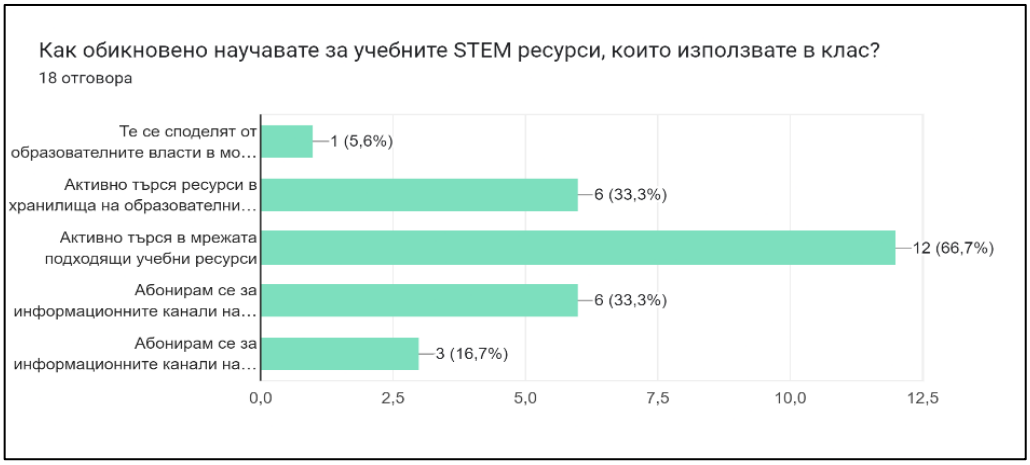
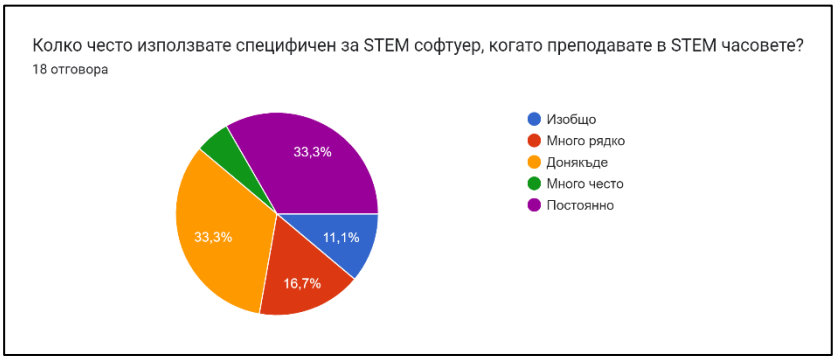


Fig. 3 *How do you usually learn about the STEM learning resources you use in class?*

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.

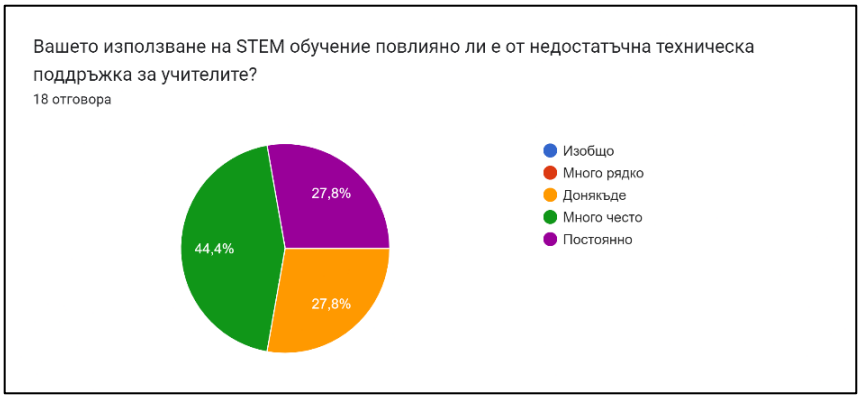


Fig. 5 *Is your use of STEM learning affected by insufficient technical support for teachers?*

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.

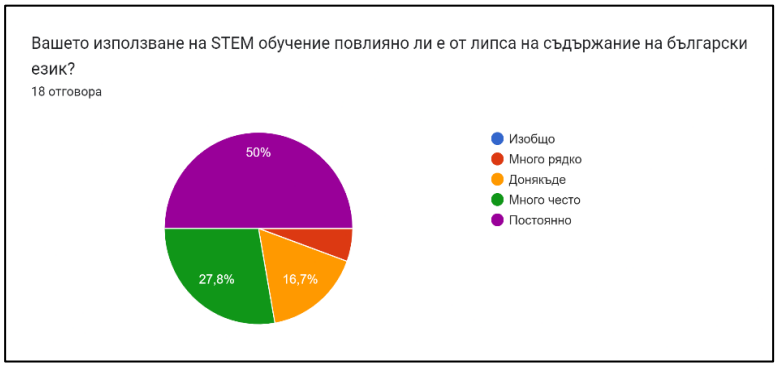


Fig. 6 *Is your use of STEM education affected by a lack of content in Bulgarian?*

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.

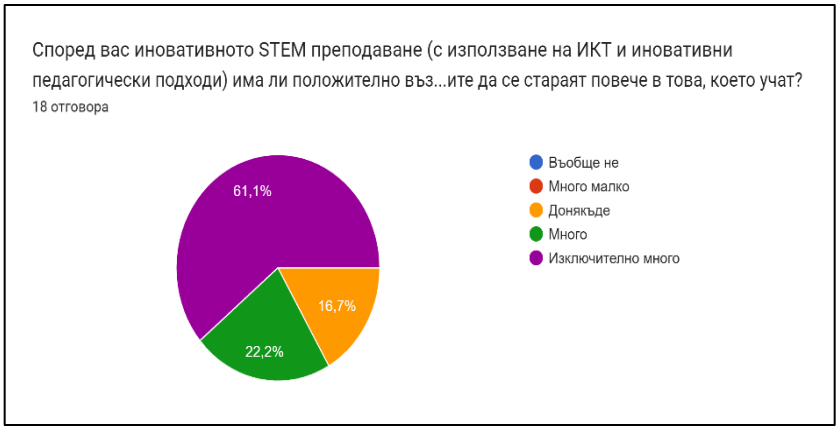


Fig. 8 *In your opinion, does innovative STEM teaching (using ICT and innovative pedagogical approaches) have a positive impact on students working harder?*

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.

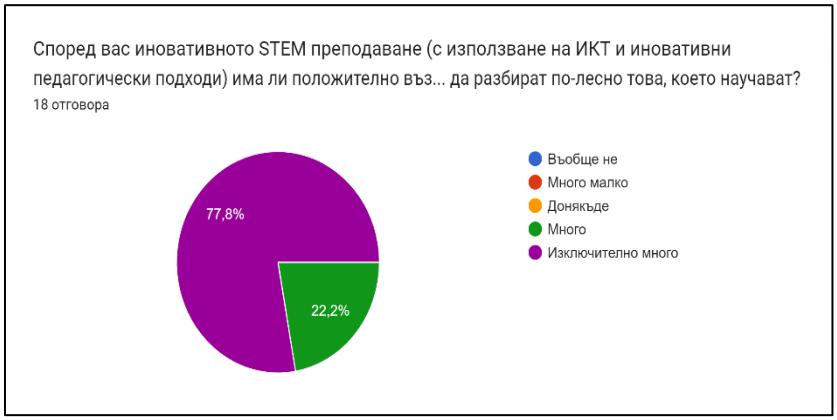


Fig. 9 *In your opinion, does innovative STEM teaching (using ICT and innovative pedagogical approaches) have a positive impact on making students understand what they learn more easily?*

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

Forefront

This report presents a comprehensive overview of the Turkish STEM Initiatives, compiled by a team of researchers with expertise in the fields of STEM Education and STEM fields.

Prof. Dr. Eylem BAYIR

Eylem BAYIR has been working as Prof. Dr. at Trakya University in Science Education Department and as head of the department since 2015. Her fields of research is STEM education, inquiry-based science leraning, nature of science, educational games on science, professional development of science teachers. She has many national and international projects, articles and book chapters on these subjects. She was the coordinator of "Bridge from Türkiye to the World: STEM Education" project carried out with the support of the Turkish Cooperation and Coordination Agency –TIKA. She provided STEM training for teachers from seven different countries from Asia and Balkans in 2018 and 2019 in this project with her colleagues.

Prof. Dr. ŞebnemSelen İŞBİLİR

Sebnem SELEN ISBILIR received Ph.D. in biochemistry from Trakya University and has been working in Trakya University, Natural Science Faculty, Chemisrty Department since 1998. She has been working as Professor since 2019 and head of the Department of Chemistry since 2021. Her research is focused on the antioxidant activity assays, secondary metabolites, enzyme isolation and enzyme inhibition. In particular, she studies on the obtaining plant extracts, the determination of antioxidant activity in these extracts by various methods, and the analysis of secondary metabolites such as phenolic substances, flavonoids, anthocyanins, and tannins. She took part in foundational supported projects and directed four postgraduate theses.

Assoc. Professor Dr. Hüsnüye Durmaz

Dr. Hüsnüye Durmaz, an associate professor and full-time researcher at Trakya University, is passionate about promoting STEM education and socio-scientific issues. His research focuses on improving science education by enhancing the professional development of science teachers and integrating innovative technologies into their lessons. He also develops hands-on and inquiry-based STEM activities for elementary and middle school students, and conducts professional development programs for teachers. Dr. Durmaz's

work is essential for improving the quality of STEM education and inspiring the next generation of scientists, engineers, and innovators.

Assoc. Professor Dr. HasanÖzyıldırım

HasanÖzyıldırım graduated from Ege University, Faculty of Science, Department of Chemistry. After teaching at state schools for a while, he started working at the Faculty of Science at Trakya University. In this process, he completed his master's and doctorate studies in organic chemistry at Trakya University. In these studies, he mainly worked with the synthesis of polymers and organic molecules. Since 2002, he has been working as an assistant professor at Trakya University, Faculty of Education, Department of Mathematics and Science. While working at Trakya University Faculty of Education, he was interested in out-of-school learning and STEM education and made some academic studies and practices. Taking part in national and international education some projects for STEM education teachers and students, HasanÖzyıldırım still continues his chemistry and education studies.

Assist. Professor Dr. EmrahOğuzhanDinçer

Dr. Emrah OĞUZHAN DİNÇER is a full-time assistant professor at Trakya University who is actively engaged in researching the integration of science, mathematics, and physics teaching. Her primary focus is on assisting science teachers in incorporating technology-based teaching methodologies into their lesson plans. With a background in mechanical engineering, Dr. OĞUZHAN is well-equipped to design and implement STEM activities suitable for middle school students.

Assist. Professor Dr. SertaçArabacıoğlu

Dr. Sertaç Arabacıoğlu, a full-time assistant professor at Trakya University, is actively involved in promoting STEM education through various research and outreach activities.One of Dr. Arabacıoğlu's main areas of research is the continuing professional development of science teachers. He understands that teachers play a critical role in shaping students' attitudes and interests towards STEM subjects. Dr. Arabacıoğlu is also involved in the development of STEM activities for elementary and middle school students. These activities are designed to be hands-on and inquiry-based, allowing students to explore and learn about scientific concepts in a fun and interactive way. Additionally, he organizes professional development programs for teachers, including guided teacher camps and interactive workshops. These programs enable teachers to learn new teaching techniques and share best practices with their colleagues.

Our team studied the various sources of information available to provide an in-depth analysis of the current state of STEM initiatives in Türkiye. Thus, the first step in preparing a Turkish STEM Initiatives Country Report was to identify the sources of data. And we decided various sources, including government-

funded, university-led, and industry-led organizations. Additionally, we've consulted research papers published in journals indexed by Web of Science (WoS) and Türkiye (TR), as well as master's and PhD theses. We also considered STEM activity workshops, such as those held at STEM centers, science museums, and interactive exhibits.

We analyzed to identify trends and patterns, as well as challenges and opportunities in Turkish STEM initiatives by looking for common themes and patterns in the last 5th years data. The first section of the report aimed to provide a calibrated perspective on STEM education within the consortium by presenting a general approach to STEM education and reflecting the partner country's understanding of STEM education through methods and activities. The second section provides a comprehensive analysis of research reports, articles, theses, and other science and society activities related to STEM education. Finally, an overview on the challenges and opportunities awaiting the project stakeholders is presented. We hope that this report will be a valuable resource for those interested in understanding the current state of STEM initiatives in Türkiye.

Project Cordinator

Prof. Dr. Eylem BAYIR

Index of abbreviations

Ministry of NationalEducation (Turkiye)	MEB
Turkish Scientific and Technical Research Council	TÜBİTAK
Turkish Industry and Business Association	TUSIAD
Ministry of Development	KB
Science, technology, engineering, and math	STEM
İstanbul Aydın University (PrivateUniversity)	IAU
Programme for International Student Assessment	tpacktpack
Technological Pedagogical Content Knowledge	TPACK
Information and Communication Technology	ICT

STATE-OF-THE-ART STEM EDUCATION INITIATIVES IN TÜRKİYE

Foundational Sources and National Context for Country Report Coverage

To foster a skilled workforce and spur economic growth, STEM education has been recognized as a crucial field of focus. In order to gain insight into the present status of STEM education in Türkiye, we have compiled information from several sources (refer to Table 1), which encompass reports from government-funded, university-led, and industry-led organizations. Moreover, we have scrutinized research papers published in journals listed in Web of Science (WoS) and Türkiye (TR) to discern patterns and trends in STEM education. We have also evaluated master's and PhD theses to gain a more profound understanding of the research in this domain. Finally, we have analyzed STEM activity workshops such as STEM centers and STEM-related interactive exhibits and workshops in Science Centers and Museums to fathom the practical experiences that are being offered to students. By combining these diverse data sources, our objective was to provide a comprehensive comprehension of STEM education in Türkiye and to identify possible areas for improvement.

Table 1.
Source of data for Country Report

Sources	Number of sources
Reports	
Government-funded	7
University-led	2
Industry-led	2
Published Papers from Journals	
WoS indexed studies from Turkey Country/Region	129
TR indexed studies from Turkey Country/Region	104
Master's and PhD Thesis	230
STEM centers and workshops	
STEM centers	13
STEM-related interactive exhibits and workshops in Science Centers and Museums	7

Reports Laying the Foundations for the Implementation and Dissemination of the STEM Approach in Türkiye

Today, it is known by everyone that science, technology, mathematics and engineering constitute the main components of the development of countries. For this reason, many countries are investing in the STEM approach, which enables future generations to grow up in these areas. In this context, some reports/documents have been prepared by MEB as the institution responsible for education, laying the foundations for the implementation and dissemination of the STEM approach in Türkiye. With the prepared reports/documents, the necessity of STEM education has been revealed by the education experts and institutions and the business world, and Türkiye's need for this approach has been brought to the agenda.

In the "Vision 2023 Strategy Document", prepared in 2004, it was stated that "Developing the creativity and imagination of the individual; observing and evaluating individual differences, each individual can develop himself at the highest level in line with his characteristics; freed from time and space constraints, created his own unique learning technologies and renewed himself with the flexibility of change. The vision in the field of education is "to have a learning and people-oriented education system that has the power to learn". At the same time, being able to dominate the technologies of the future and the fields of science that supports these technologies requires having trained manpower; and this manpower includes R&D personnel and people who have received science and engineering education in the aforementioned science and technology fields; therefore, it was stated that all levels of the education system should be taken into account in order to train people with these characteristics (Turkish Scientific and Technical Research Council [TÜBİTAK], 2004).

In 2010, "Science and Technology Human Resources Strategy Document" was published by Scientific and Technological Research Institution of Türkiye (TUBITAK) and this document includes adding project-oriented science and technology trainings to the curriculum in primary and secondary education, increasing curiosity, raising creative and entrepreneurial mindsets; Some strategies have been determined, such as increasing the interest in scientific activities by increasing popular science activities for primary and secondary education, adding projects and popular science subjects to the curriculum of the education faculty, and disseminating R&D project competitions among primary and secondary school students (TUBİTAK, 2010).

“The Tenth Development Plan” published in 2013 is the twenty-first century; it is pointed out that it will be the century of countries that can produce new knowledge by using global knowledge, transform knowledge into economic and social benefits, integrate this process with information and communication

technologies, and adopt a human-oriented development approach, in addition to raising qualified human power. In this plan, the main purpose of the education system is; It is stated that it is the training of productive and happy individuals who have developed thinking, perception and problem solving skills, have self-confidence and sense of responsibility, entrepreneurship and innovation, are prone to the use and production of science and technology, equipped with the basic knowledge and skills required by the information society (Ministry of Development[KB], 2013).

In the report titled "Demand and Expectations Research for STEM-Educated Workforce" published by the Turkish Industry and Business Association (TUSIAD) in 2014, the critical role of STEM education in the economic and technological development of countries was emphasized, and in the future, STEM education, that is, different disciplines combined. It is revealed that learned brains will be needed in the whole. It has been determined that there are differences in the contributions of those who graduated from STEM fields and those who graduated from other fields in companies. As a result of the report, it was stated that it is of great importance to make necessary reforms in the curriculum, education methods and teacher training in order to raise individuals who think creatively, innovatively, analytically and critically, and have high problem-solving skills, and that it is necessary to aim to increase STEM skills at all levels of the education system (TUSIAD, 2014).

Regarding STEM education, MEB has been involved as a national support point in the Scientix Project (the community project for science education in Europe) carried out by the European Schoolnet since 2014. Within the scope of this project, Europe-wide collaboration between STEM (science, technology, engineering and mathematics) teachers, education researchers, policy makers and other STEM education professionals is encouraged and supported. The project aims to disseminate the use of technology and good practices in science education in Europe with the teacher communities created.

The first report in Türkiye, which is one of the studies carried out for the dissemination of STEM education outside MEB, is the "STEM Education Türkiye Report" prepared in 2015 hosted by Istanbul Aydın University. In the report, the need for STEM education in Türkiye has been revealed and suggestions have been made by determining a road map for its implementation (Akgündüz et al., 2015).

With the “2015-2019 Strategic Plan” published by MEB in 2015, it started with studies on STEM education in Türkiye. It is stated in the plan that it is aimed to raise individuals who are creative, entrepreneurial, innovative, open to communication and learning, self-confident and responsible by gaining the knowledge, skills, attitudes and behaviors required by the age. In the plan, MEB has paved the way for the integration of STEM education into our education system by including strategic objectives that reveal the necessity of using STEM education, thus, studies on STEM education throughout the country have accelerated (MEB, 2015).

In 2016, MEB published the STEM education report, and an action plan was prepared that includes the issues that need to be done in order to integrate this approach into the Turkish education system and to spread it throughout the country by revealing the situation regarding STEM education. The STEM Education Action Plan was formed from the following steps: 1. Establishment of STEM Education centers, 2. Conducting STEM education research in cooperation with universities in these centers, 3. Training teachers to adopt the STEM education approach, 4. Updating the curriculum to include STEM education, 5. Creating teaching environments and providing course materials for STEM education. The report has a critical importance in the adoption and dissemination of the STEM education approach in our country. As a matter of fact, STEM education started with the Science Curriculum published by MEB in 2018. In the Science Curriculum, starting from the 4th grade, the component "Science, engineering and entrepreneurship practices" has been included in order for students to establish the connection between engineering and science and to understand the interdisciplinary interaction (MEB, 2018).

The critical role of STEM fields was also mentioned in the report titled "STEM Needs in Türkiye Towards 2023" prepared by PwC and TUSIAD in 2017, and the 'savior abilities' of the 21st century (critical thinking and problem solving, entrepreneurship and developing cooperation between systems and people, taking initiative, effective oral and written communication, analytical skills, continuous learning, curiosity and creativity) will increase. In the report, it was emphasized that the steps required for the development of STEM education and STEM workforce should be addressed at the national policy level and supported by the public, action plans should be implemented with the cooperation of the public, education and business world, and the progress should be followed closely.

In the "2023 Education Vision" document published by MEB in 2018, it is planned to establish STEM workshops within the scope of "Design-Skill Workshops" in all schools for the development of children's interests, talents and temperaments. These workshops are defined as "workshops where activities aiming at transforming theoretical knowledge into practice, product and innovative inventions, enabling students to see the information they learn in science, technology, engineering and mathematics courses as parts of a whole" (MEB, 2018).

In the "Integration of STEM Education into Curriculum: Workshop Report" prepared as a result of the "Workshop on the Integration of STEM Education into the Curriculum" hosted by Istanbul Aydın University in 2018, the problems raised by teachers, experts and academics regarding the integration of STEM education into the curriculum were identified and the problems were divided into 11 themes. has been collected. Suggestions for solutions to the examined problems; It is necessary to determine a state education policy for STEM education, to carry out awareness activities, to design a curriculum that focuses on the skills and process suitable for STEM education, to train teachers who will implement this program in education faculties, to increase the competencies of current teachers and to create the necessary physical, social and

managerial infrastructure for STEM education. has been revealed.In the "Integration of STEM Education into Curriculum: Workshop Report" prepared as a result of the "Workshop on the Integration of STEM Education into the Curriculum" hosted by Istanbul Aydın University in 2018, the problems raised by teachers, experts and academics regarding the integration of STEM education into the curriculum were identified and the problems were divided into 11 themes. has been collected. Suggestions for solutions to the examined problems; It is necessary to determine a state education policy for STEM education, to carry out awareness activities, to design a curriculum that focuses on the skills and process suitable for STEM education, to train teachers who will implement this program in education faculties, to increase the competencies of current teachers and to create the necessary physical, social and managerial infrastructure for STEM education.

Table 2

Reports Laying the Foundations for the Implementation and Dissemination of the STEM Approach in Turkey

Date	Report Name	Institution Name	Emphasis on STEM Education in the Report
2004	Vision 2023 Strategy Document	TUBİTAK	As a vision in the field of education; developing the creativity and imagination of the individual; by observing and evaluating individual differences, each individual can develop himself at the highest level in line with his characteristics; freed from the constraints of time and space, it has created its own unique learning technologies and has the power to renew itself with its flexibility of change; It has been determined to have a learning and people-oriented education system.
2010	Science Technology Human Resources Strategy Document	TUBİTAK	Some strategies have been determined, such as adding project-oriented Science and Technology education to the curriculum in primary and secondary education, increasing the interest in scientific activities, making projects and adding popular science subjects to the curriculum of the education faculty, and disseminating R&D project competitions between primary and secondary school students.
2013	Tenth Development Plan	Ministry of Development	The main purpose of the education system; It is stated that it is the training of productive and happy individuals who have developed thinking, perception and problem-solving skills, have self-confidence and sense of responsibility, entrepreneurship and innovation, are prone to the use and production of science and technology, equipped with the basic knowledge and skills required by the information society.
2014	Demand and Expectations Research for STEM-Educated Workforce	TUSIAD	It has been stated that it is of great importance to make necessary reforms in the curriculum, education methods and teacher training in order to raise individuals who think creatively, innovatively, analytically and critically, and have high problem-solving skills in the education system, and it is necessary to aim to increase STEM skills at all levels of the education system.
2014	Scientix Project	MEB	The project encourages and supports Europe-wide collaboration between STEM (science, technology, engineering and mathematics) teachers, education researchers, policy makers and other STEM education professionals. The project aims to disseminate the use of technology and good practices in science education in Europe with the teacher communities created.

Table 2. *Continue*
Reports Laying the Foundations for the Implementation and Dissemination of the STEM Approach in Turkey

Date	Report Name	Institution Name	Emphasis on STEM Education in the Report
2015	2015-2019 Strategic Plan	MEB	It is stated in the plan that it is aimed to raise individuals who are entrepreneurial, innovative, creative, open to communication and learning, self-confident and responsible by gaining the knowledge, skills, attitudes and behaviors required by the age.
2015	STEM Education Turkey Report	IAU	In the report, the need for STEM education in Turkey has been revealed and suggestions have been made by determining the road map for its implementation.
2016	STEM Education Report	MEB	The situation regarding STEM education in our country has been revealed, and a STEM Education Action Plan has been presented in order to integrate STEM education into the education system in Turkey.
2017	Towards 2023 STEM Requirements in Turkey Report	PwC & TUSIAD	The critical role of STEM fields was mentioned, and it was emphasized that the steps required for the development of STEM education and STEM workforce should be addressed at the national policy level and supported by the public, action plans should be implemented with the cooperation of the public, education and business world, and progress should be followed closely.
2018	2023 Education Vision	MEB	It is planned to establish STEM workshops within the scope of "Design-Skill Workshops" in all schools for the development of children's interests, talents and temperaments.
2018	Integration of STEM Education into the Curriculum: Workshop Report	IAU	Problems raised regarding the integration of STEM education into the curriculum have been identified and solutions have been proposed for the problems examined.

Situation of STEM Approach in Curriculums in Türkiye

Compared to PISA 2015, Türkiye significantly increased its performance in all three areas (reading skills, mathematical literacy, science literacy) in PISA 2018 (MEB, 2019). Despite this increase, it does not rank high enough. It is possible to say that it is important for Türkiye to reach the desired level in the international PISA exams by adopting the STEM approach and integrating it into the curriculum.

Integraing STEM intocurricula at all levels from pre-school to university is of great importance for the spread of STEM. STEM-integrated curricula will enable students to use different disciplines together to solve problems encountered in daily life, enabling meaningful learning to take place (Aydeniz, 2017; Beane, 1995; Czerniak, Weber, Gonzalez&Kuenzi, 1999; Cerniak, et al., 1999; Yıldırım & Altun, 2015).

From this point of view, as it can be understood from what is explained below, studies have started and are continuing with the integration of the STEM approach into the curricula at all education levels in Türkiye.

Situation of STEM Approach in Preschool Curriculum:

The current program as a pre-school education program in Türkiye is the 2013 Pre-School Education Program prepared in 2013. Although there is no direct emphasis on STEM education in this program, the achievements and indicators belonging to all development areas, primarily the acquisitions and indicators related to cognitive development, can be easily associated with STEM education. It has been revealed that the achievements in the Education Program are related, include basic ideas and concepts related to STEM education, and have most of the features of STEM education (AtaDemircan, Şenyurt, & Çetin, 2017). In this respect, the program is suitable for STEM education.

It is also known that MEB, private education institutions and universities and NGOs carry out educational activities, fairs, competitions, curriculum development and implementation activities regarding the STEM approach in pre-school education in Türkiye (Polat and Bardak, 2019).

Some universities in Türkiye (such as METU, YTU, Bahçeşehir) organize trainings for preschool teachers such as STEM Workshop, STEM Trainer's Education Program, Early Childhood STEM Education, and it is aimed to raise awareness in preschool teachers and to have knowledge about practices.

Situation of STEM Approach in Primary/MiddleSchoolCurriculum:

The regulations regarding the integration of the STEM approach in the curricula in Türkiye are particularly striking in the science curriculum.

Although not under the name of STEM approach in the Science and Technology Curriculum prepared in Türkiye in 2005, the existence of issues such as "Science-Technology-Society-Environment Relationship", "Technological Design Cycle and Entrepreneurship" can be considered as a start for the implementation of the STEM approach.

In the "STEM Education Report" prepared by MEB in 2016, the necessity of STEM education was emphasized in the curriculum, and this emphasis was included in the report as follows: The examination system should be shaped accordingly, and students' high-level skills such as questioning, research, product development and invention should be highlighted. Science laboratories in schools should be reorganized and provided in accordance with STEM education." (MEB, 2016). In the classrooms, STEM applications were included as the last unit, under the name of "Applied Science", accompanied by the achievements that correspond to the steps of the engineering design process.

With the update made in the Science Curriculum in 2018, it was shown that the STEM approach was adopted by giving the "Science, Engineering and Entrepreneurship Practices" as covering all the units, although the name "STEM" was not clearly stated. In addition, the explanation regarding the application of the STEM approach in the program is as follows: "Within the scope of Science, Engineering and Entrepreneurship Applications in the program, first of all, students are expected to define a daily need or problem related to the topics covered in the units. It is desired that the problem is aimed at improving the tools, objects or systems used or encountered in daily life. In addition, the problems should be handled within the scope of material, time and cost criteria. In solving the problem, students compare alternative solutions and choose the appropriate one within the scope of the criteria. By planning for the chosen solution, they are expected to present and present the product at the next stage. The design and production process of the product is carried out in the school environment. Students are expected to make experiments during the product development phase, record the qualitative and quantitative data they have obtained as a result of these trials, and evaluate them with their ability to read or create graphs. They are asked to create strategies and use promotional tools to market the product in order to develop entrepreneurial skills. For example, students can prepare newspaper, internet, television advertisements or shoot short films for promotional purposes." (MEB 2018).

Situation of STEM Approach in Secondary School Curriculum:

Although STEM approach is not mentioned at all in the education programs of STEM courses (Physics, Chemistry, Biology, Mathematics and Computer Science), it has been determined that the applications of the STEM approach are either not included in the purchases or they are given little or no place (Karabolat, Atıcı & Tafl) , 2021; curriculum.meb.gov.tr).

Status in the University/Faculty of Education Curriculum:

The support and contributions of universities in Türkiye towards the implementation of the STEM approach have been increasing in recent years. IWithin the scope of this context, universities conduct various activities such as arranging trainers' trainings via application and research centers, integrating compulsory or optional STEM courses into their curricula, organizing symposiums, congresses, and workshops, as well as undertaking diverse scientific studies and projects (MEB, 2016). The links provided below offer noteworthy instances of these activities:

- 4th International STEM Education Conference: https://www.stempd.net/
- Hacettepe STEM & Maker Lab: https://hstem.hacettepe.edu.tr
- BİLTEMMCenter for Science Technology Engineering and Mathematics Education: https://biltemm.metu.edu.tr/tr
- Muğla Sıtkı Koçman UniversityScience Education Research & Application Centerhttps://mubem.mu.edu.tr/tr

Especially education faculties have an important place because they train teachers who will apply the STEM approach, and the teachers who are responsible for applying the STEM education approach provide academic support through in-service training. It is absolutely necessary to include courses in the curricula of education faculties that will enable teacher candidates to be trained to have STEM-related field knowledge, field education knowledge, and STEM application competencies.

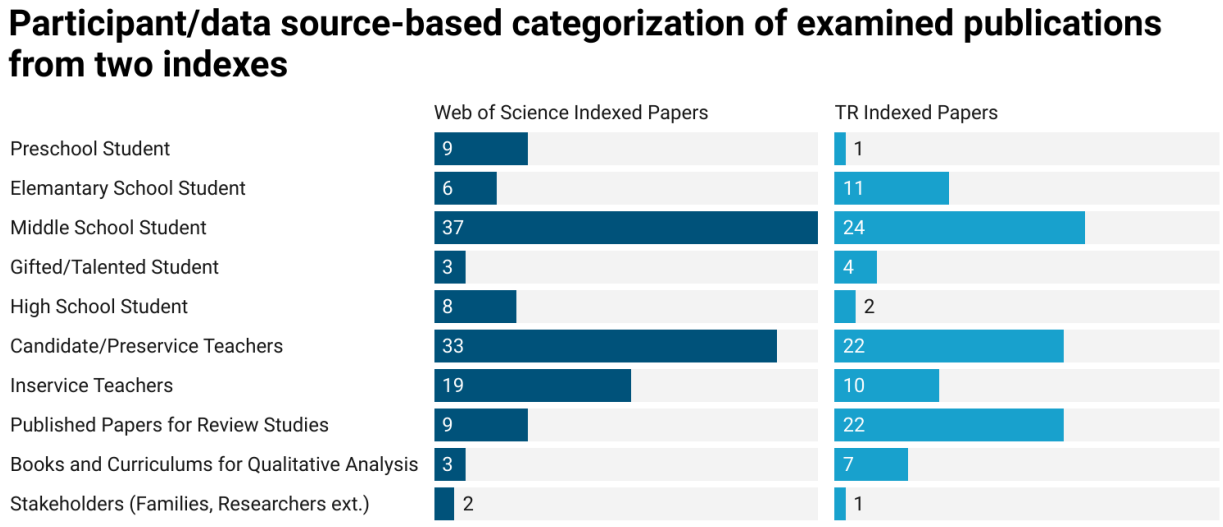
In Türkiye, education faculties undergraduate curricula were updated in 2018, and when the course names and course contents in teacher training undergraduate programs related to STEM fields are examined (Science Education, Elementary Mathematics Teaching, Computer and Instructional Technologies Teaching, Physics Teaching, Chemistry Teaching, Biology Teaching, It is seen that there are no courses related to direct STEM education in the programs (Türk, 2019; yok.gov.tr). However, it has been determined that in the curricula of Science and Primary School Mathematics Teaching departments, there is a course for associating the department field with other fields (Interdisciplinary Science Teaching, Relation in Mathematics Teaching). However, it has been determined that these courses are theoretical courses for 2 or 3 hours.

It is known that no undergraduate or graduate education programs related to STEM have been opened in any education faculties in Türkiye (Çolakoğlu & Günay Gökben, 2017).

This situation reveals the necessity of opening courses that are directly related to STEM education and including applications in undergraduate programs of education faculties, as well as postgraduate education programs and designing curricula for these courses.

State-of-the Art Research Initiatives in the Web of Science (WoS) and TR-Indexed Papers

In this analysis, we examined 226 papers on STEM education that were indexed in WoS and TR. Our extraction criteria involved searching for articles that were conducted in Turkish universities, schools, and other institutions. We collected all the relevant papers related to STEM education trends in Türkiye from WoS and TR indexed sources to ensure that the data was comprehensive and inclusive. Other scopes were excluded. Next, we organized the collected papers by creating a spreadsheet or database that contained important details such as the title, purpose, methodologies, participants, and results of each paper. This step may have required data cleaning and formatting to ensure consistency. We also carried out necessary transformations to standardize the coding structure.To analyze the data, we identified patterns, trends, and relationships among the papers. This involved summarizing the key findings of each paper and categorizing them into relevant codes or categories. Figure 1 summarizes the sources of data and participants of the published papers analyzed in the country report.



Note. The International Standard Classification of Education (ISCED) system, recognized by the United Nations Educational, Scientific, and Cultural Organization (UNESCO), classifies education as preschool, elementary, middle, and high school students, which are used to categorize different school levels in studies. It is important to consider that a study may involve multiple groups of participants.

Figure 1.
Sources of Data & Participants of Published Papers Analyzed in Country Report

Figure 2 depicts the analyzed papers and their respective methodologies that were indexed.

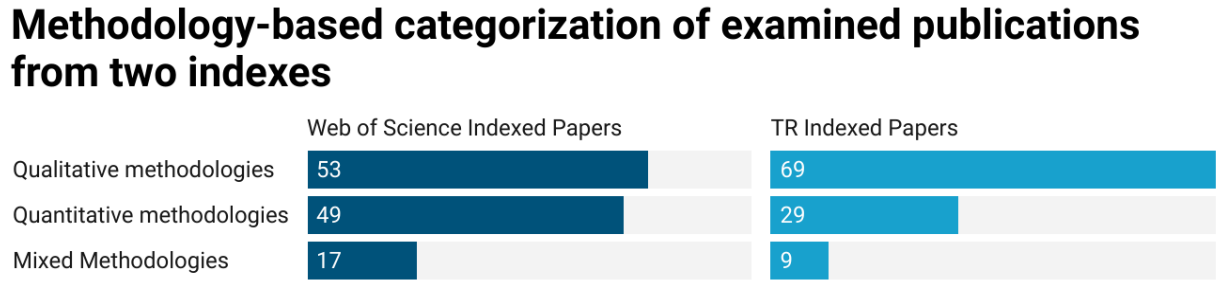


Figure 2.
Methodologies of Published Papers Analyzed in Country Report

The study involved various groups of participants, including students and teachers, and analyzed 226 articles indexed in WoS and TR that explored STEM education trends in Türkiye. The findings, presented through descriptive patterns for each participant group, offer insights into the different approaches to STEM education in the country.

Research Trends and Patterns Involving Student Participation:Sampling from Preschool, elementary, middle, and high schools

Studies with preschool students:

According to thestate-of-the-art studies, early exposure to **STEM activities** can help children develop an interest in science, technology, engineering, and math, which can inspire them to pursue careers in these fields in the future andhelp them develop a better understanding of engineering concepts(Akpinar & Akgunduz, 2022). Furthermore, **STEM activities** often involve problem-solving, which can help preschoolers develop critical thinking skills and learn how to approach challenges in a logical and systematic way(Bapoğlu Dümenci et al., 2021; Malcok & Ceylan, 2022). In addition, **STEM activities**can also encourage creativity and innovation, as children explore different solutions to problems and use their imagination to design and build things(Uret & Ceylan, 2021).Thus, studies emphasize the significance of incorporating **design thinking** in STEM education for preschoolers to stimulate the development of 21st century skills(Yalcin, 2022).

Studies also gives a better understanding about the perspectives and experiences of preschoolers. For example, studies have emphasized the importance of comprehending preschoolers' viewpoints and encounters regarding **engineering design-oriented STEM tasks** concerning theconcepts of science, like forces, floating/sinking(Ata-Akturk, 2023), as well as images of **engineers and engineering**(Ata-Akturk &

Demircan, 2022).In addition, educators and researchers have reported their observations from particular **STEM activities** in a more comprehensive manner, including but not limited to, egg-carrying without breakage(Ultay & Aktas, 2020), the realm of machinery(Abanoz & Yabas, 2022), and Makey-Makey programming and robotics activities(Tanik Onal & Saylan Kirmizigul, 2022).

Studies with elementary students:

Various studies have been conducted on elementary school students, resulting in different research outcomes. For instance, Akar andYadigaroğlu (2021), Bircan andCalisici (2022), Yetkin and Aküzüm (2022), and Pekmez et al. (2018) focused on **the impact of STEM activities** on students' attitudes towards STEM, related skills, and academic achievements. Moreover,Cetin et al., (2020)researched young children's preferences on STEM activities based on gender, whereas another group of studies examined **students' creativity, career choices, and perceptions of engineers and engineering,** such as Azgın and Şenler (2019), Çil and Özlen (2019), and Gülhan and Şahin (2018). Sisman et al. (2021)investigated the effectiveness of robotics training on **children's spatial ability** and attitude towards STEM, and various approaches were also examined, including **out-of-school STEM workshops**(Timur et al., 2020), STEM activities in free activity course (Yaşlık & Akçay, 2022), **biomimicry-based STEM activities** (Savran Gencer et al., 2020), **Ethno-STEM Approach**(Basaran & Erol, 2023), and **aesthetics in nature through STEM and STEAM education**(Reffiane et al., 2021), all of which were aimed at elementary school students.

Studies with middle school students:

Upon analyzing the state of the art of STEM studiesconducted with middle school students in TÜRKIYE, it becomes evident that various activities could incite STEM education in diverse manners. For example, STEMactivitiesin schools allow students to **develop a range of views and attitudes towards in science, technology, engineering, and math** (Akçapınar& Coşgun,2019; Ayaz et al., 2020; Aydın& Karslı, 2019; Ceylan& Karahan, 2021; Dönmez, 2020; Ertem Akbaş et al., 2019;Pişkin Tunç& Gündoğdu, 2022).By engaging in STEM activities, students can **develop a deeper interest and understanding of STEM fields** and can be inspired to pursue further studies in these areas(Dedeturk et al., 2021; Higde & Aktamis, 2022; Ozcan & Koca, 2019; Tozlu et al., 2019). These activities often involvedinquiry-based, project-based learning and problem-solving, which can help to build critical thinking and analytical skills(Bahşi & Açıkgül Fırat, 2020; Celik, 2022; Gülen& Yaman, 2018; Higde & Aktamis, 2022; Nağaç & Kalaycı, 2021).

Moreover,**Design-based STEM education studies**emphasizes the use of design processes to develop solutions to real-world problems. By engaging in design activities, students can **develop critical thinking and creativity skills, entrepreneurship and career choices and interest**(Delen & Sen, 2023; Gencer & Dogan, 2020; Kirkic & Uludag, 2021; Meral& Altun Yalçın,2022; Sarıgül& Çınar, 2021; Savran Gencer& Doğan2020;Yazici et al., 2022). The use of **technology and tools like 3D printers** can help to make the design and engineering process more engaging and accessible to students(Sen et al., 2020). Furthermore, **Engineering-oriented STEM activities** also allow students to explore concepts related to civil, mechanical, and electrical engineering(Aydogan & Cakiroglu, 2022; Johnston et al., 2019). By **engaging in engineering activities,**middle school students can develop skills in problem-solving, critical and computational thinking, and creativity(Ergun & Balcin, 2019; Ince & Koc, 2021). These skills are essential for interest in many STEM fields, including engineering, architecture, and construction(Balcin & Ergun, 2019; Ozkul & Ozden, 2020).

The studies on robotics, as well as coding and programing education provides hands-on learning opportunities for students to explore engineering and programming concepts(Akkaş et al., 2020;Cakir & Guven, 2019; Korkmaz et al., 2019). By engaging in STEM robotics activities, students can **develop skills in coding, mechanical engineering, and electronics, as well as perception, creativity and attitudes**(Adsay et al., 2020;Bolatlı& Korucu, 2018;Guven et al., 2022; Kutlu & Bakırcı, 2022; Ucgul & Altiok, 2022). These skills are essential for interest in many STEM career, including robotics, automation, and manufacturing.Furthermore, **game-based STEM design activities**with middle school students could help to promote interest in computer science and programming(Cakir et al., 2021). By engaging in game design, students could**develop skills in coding, storytelling, visual design and also deeper understanding on science topics**(Hacioglu & Donmez Usta, 2020). These skills are essential for many STEM fields, including game development, virtual reality, and graphic design.

STEM-based environmental activities can help to promote interest in environmental science and sustainability. By engaging in these activities, students can develop skills in biology, chemistry, and environmental engineering(Erkol et al., 2022; Öztürk&Özdemir, 2020; Uslu & Yaman, 2021). **Biomimicry activities** allow students to explore how natural systems can inspire engineering solutions to real-world problems(CanbazogluBilici et al., 2021; Gencer et al., 2020). Additionally, **out-of-School STEM Education Studies and Programs** provide opportunities for students to explore STEM fields outside of traditional classroom settings. These programs, like **robotic camps,**can offer hands-on, project-based activities that foster interest and engagement in STEM fields(Ucgul & Altiok, 2022). By offering exposure to **out-of-schoolSTEM programs,** these programs can help to promote interest in STEM-related careers, motivations and metacognitive awareness(Baran et al., 2019; Çevik & Abdioğlu,2018).

In addition, **studies onSTE(A)M education** emphasizes the integration of arts and design into STEM fields. By engaging in STEAM activities, students can develop creativity, critical thinking, and problem-solving skills(Bati et al., 2018; N. A. Cakir et al., 2021; Ozkan & Topsakal, 2021; Ozkan & Umdu Topsakal, 2021). This interdisciplinary approach can help to promote interest in STEM fields among students who may not have been interested in these subjects before.

Studies with high school students:

High school students have been the subject of numerous studies on STEM education. For instance, Donmez (2021)and Karamustafaoglu & Pektas (2022)conducted studies to investigate how **out-of-school STEM activities** can influence students' career choices and creative problem-solving skills. These studies often use **inquiry-based or project-based learning environments** to enhance academic achievement and career interests, particularly in **vocational high schools**(Cevik, 2018).

Moreover, other studies have focused on the **engineering design process**(Guvenilir & Olcay, 2019), utilizingstudents' **engineeringskills**(Yuceler et al., 2020), andinnovativetechnology-supportedapplications(Kumas, 2021) at thislevel. Through such studies, it has been demonstrated thathighschoolstudentsgenerallyhavemotivationandpositiveattitudestowards STEM education (Gok, 2021; Kızılay et al., 2019; Yerdelen-damar et al., 2021).

Research Trends and Patterns Involving Preservice Teacher Participation: Sampling from Education Faculties

Preservice teachers play a crucial role in shaping the future of STEM education. To ensure they are well-equipped to teach STEM subjects, studies have been carried out to explore the **effects of various STEM activities on their knowledge, skills, and attitudes**. Forinstance, studiesby Timur and Belek (2020),Yorulmaz and Okulu (2022), andUğraşandGenç(2018) havefocused on the impact of STEM activities on candidates' beliefs and STEM intention. Numerous studies have also been conducted to investigate prospective teachers' **perceptions and awareness of STEM education** (Acar et al., 2020; Akgün&Türel, 2021; Koyunlu Ünlü&Dere, 2019).Another study examined the development of computational thinking skills among preservice teachers(Gunbatar & Bakirci, 2019).Additionally, studiesbyÇakırandAltun (2021), andOzcakir Sumen and Calisici (2022)shed light on the relationship between STEM activities and academic achievement, problem-solving skills, and STEM awareness.Yildirim and Sidekli (2018), on the other hand, explored the link between STEM activities and self-efficacy and TPACK understanding. Kacan and Sahin, (2018) and Özçakır SümenandÇalışıcı, (2019)examined the development of creative thinking and project

development skills, while Alan et al., (2019) and Z. Cakir & Yalcin, (2022) studied the impact of STEM activities on lifelong learning and integrated teaching knowledge.Furthermore, studies have also looked into preservice teachers' **behavior towards technology and STEM education.**Gul and Ates (2022), for example, explored the factors that influence preservice teachers' acceptance of technology, while Aciksoz et al., (2020) investigated the relationship between STEM value-expectancy. Studies have focused on understanding **the views and attitudes of candidate teachers towards STEM education** (Hiğde et al., 2020; Yorulmaz& Okulu, 2022), as well as theirunderstandingabout STEM practices (Arslanhan& İnaltekin,2020; Aydın et al., 2021;Üre & Çoramık, 2020).For instance, Ciftci et al., (2022) examined preservice teachers' views on STEM education, while Kartal and Tasdemir, (2021) explored their attitudes towards STEM. Meanwhile, Buyukdede and Tanel (2019) investigated prospective teachers' opinions on the effectiveness of STEM activities.

STEM education has become increasingly important as the job market continues to shift towards careers in **engineering and other design-based fields**. To ensure that students are well-prepared for these careers, it is essential that pre-service teachers are equipped with the necessary skills to effectively teach STEM subjects. This has led to numerous studies that focus on the impact of differentteachingmethods on preserviceteachers' perceptions of STEM education. Forexample, Ergun andKiyici (2019)andÖzkızılcıkandBetül Cebesoy (2020), as well as Kuvac and Koc (2022), have examined the effect of **design-based applications** on students' perceptions of engineering education and engineering as a profession. Similarly, Guleryuz and Dilber, (2022)have investigated the impact of engaging students in **robotic coding and 3D visualization** on their academic success and interest in STEM careers.Other studies have focused on the effects of STEM-focused practical activities on various skills. (Sari, Celik, et al., 2022)have looked at the impact of **Arduino-based activities** on problem-solving and entrepreneurship skills, while Sari, Pektas, et al., (2022) have investigated the development of **algorithmic thinking skills** through physical computing activities with Arduino in STEM education.Finally, some studies have explored the use of media and technology to enhance STEM education, such as Ata and Cevik's (2020) research on the role of **computational thinking skills** in STEM awareness, and Ciftci and Topcu (2022) investigation of the impact of teaching self-efficacy beliefs in **computational thinking** in a STEM course. Alan et al. (2022) also have examined prospective science teachers' scientific processes while they use **Algodoo in their STEM practices**.These studies collectively demonstrate the value of STEM education and the importance of pre-service teachers being equipped with the necessary skills to effectively teach STEM subjects.

Several **qualitative studies** have been conducted to examine the development of pre-service teachers' knowledge and understanding of STEM education. One group of studies focused on investigating the STEM conceptions of pre-service teachers(Aydin-Gunbatar et al., 2021; Koyunlu Ünlü& Dere, 2018), their pedagogical content knowledge (Aydin-Gunbatar et al., 2020), STEM-focused lesson planning (Altan

& Ucuncuoglu, 2019; Bozan & Kaya-capoccı, 2022;Ürek&Çoramık,2020), andviews on roboticandSTEM-basedlearningenvironments(Delen & Uzun, 2018; Tekereket al., 2023; Yüksel,2022). Another set of studies aimed to gain a better understanding of the influence of a design-based elective STEM course on pre-service teachers' content knowledge, STEM conceptions, andengineeringviews(Aydin-Gunbatar et al., 2018), as well as the integration of engineeringinto STEM lessons(Gunbatar et al., 2022; Kınık Topalsan,2018;Tekerek&Tekerek, 2018).Additional studies explored the use of virtual reality technologies in STEM education through the perceptions of ICT pre-service teachers (Coban et al., 2020), and a redesigned online ICT course using TPACK for STEM pre-service teachers (Umutlu, 2022).Through these studies, we gain a better understanding of the effects of STEM activities on preservice teachers' knowledge, skills, attitudes, and behavior towards STEM education. This knowledge can help in the development of effective STEM teacher training programs and ultimately, enhance the quality of STEM education for future generations.

Research Trends and Patterns Involving Inservice Teacher Participation: Sampling from Teachers Working in the School Districts

There is a limited number of studies on STEM education carried out with in-service teachers compared to teacher candidates. However, some studies have been conducted to**understandtheperceptions, views, andawereness of in-service teachers**regarding STEM education (Acıksoz et al., 2020; Çınar& Terzi, 2021;Çolak& Buldur,2022;Karademir Coşkun et al., 2020; Özcan& Koştur, 2018).Workshops are commonly used as a professional development approach for in-service teachers in STEM education. Several studies have examined teachers' perceptions of STEM applications, includingAltunandApaydın(2022), Yucelyigit, (2021)andYildirim et al., (2022).

In addition, **specific training programs** have been developed for STEM education, such as STEM focused professional development (Bozan, & Anagün,2019), the mentorship model (Yabaş & Boyacı, 2022; Yabas & Bozoglu, 2022)and the STEM teacherinstitutestrainingmodel(Yildirim, 2020).Interdisciplinary activities are also used to integrate computational thinking into STEM activities. Ozdinc et al., (2022) presented an unplugged programming activity for this purpose. Moreover, Aykan andYildirim (2022)introducedtheLessonStudy Model into Distance STEM Education.Furthermore,parent involvement in early engineering education was investigated by Ata-Akturk & Demircan (2021), while MOOCs in STEM education were studied by Yildirim (2022).

Another group of studies focused on **understanding in-service teachers' STEM classroom practices**. Aydin (2020)examined prerequisites for elementary school teachers before practicing STEM

education, Demircan, (2022) determined preschool teachers' perspectivesregardingintegrative STEM practices, and Tezcan Şirin et al (2022) examined STEM activities in schoolsciencetextbooks. Similarly, Preschool teachers' and middle school science teachers preparation and views were investigated by AtaandArslan(2021) andYildirim (2021), whileAydogdu et al., (2020) examined the change in perceptions of science teachers about E-STEM. Mumcu et al. (2023)and Durak et al. (2022) investigated teachers' views on computational thinking through design-based or art-integrated practices.

State-of-the Art Research Initiatives in Master Thesis & Doctoral Dissertations

Initially, our team's focus was to examine the prevailing trends, challenges, and best practices in STEM education. To achieve this, we analyzed 230 Master's and PhD theses published within the last 5 years. Subsequently, we set the scope of our analysis to cover the last 5 years (2018-2023) and specifically targeted the theses published in Turkish Thesis Center (YÖK Tez) and carried out in Turkiye Universities. All of the selected theses had STEM education as their main topic.

We developed a search strategy that involved identifying relevant keywords and their synonyms for STEM education, such as Science, Technology, Engineering, Mathematics, STEM education, STEM teaching, STEM learning, STEM curriculum, STEM pedagogy, and STEM assessment. We only used official thesis databases (YÖK Thesis) to conduct the search and extracted pertinent information from the selected theses, such as research objectives, methods, findings, and participants. We then organized the collected data in a spreadsheet or database for convenient analysis.Our team performed a descriptive analysis of the collected data, including the frequency of STEM education topics, research methods used, and participants involved. Additionally, we conducted an analysis of the various topics addressed in the studies. The main findings of our analysis are presented in Figure 3.

The evaluation of STEM Education Master's and PhD Theses has concluded, comprising a total of 230 theses. These theses encompassed 10 preschool students, 25 elementary school students, 78 middle school students, 7 gifted/talented students, and 10 high school students. In addition, 39 prospective/preservice teachers and 35 active teachers took part in the study. Moreover, 13 published articles, 3 books, and curriculums were scrutinized for qualitative analysis. The analysis also involved 10 stakeholders, such as families and researchers. Individuals can access data files,and analysed the sis through the Open Science Framework website (https://osf.io/mcyv7/?view_only=2d17fc24b6974a20a945a49c6a21bf71).

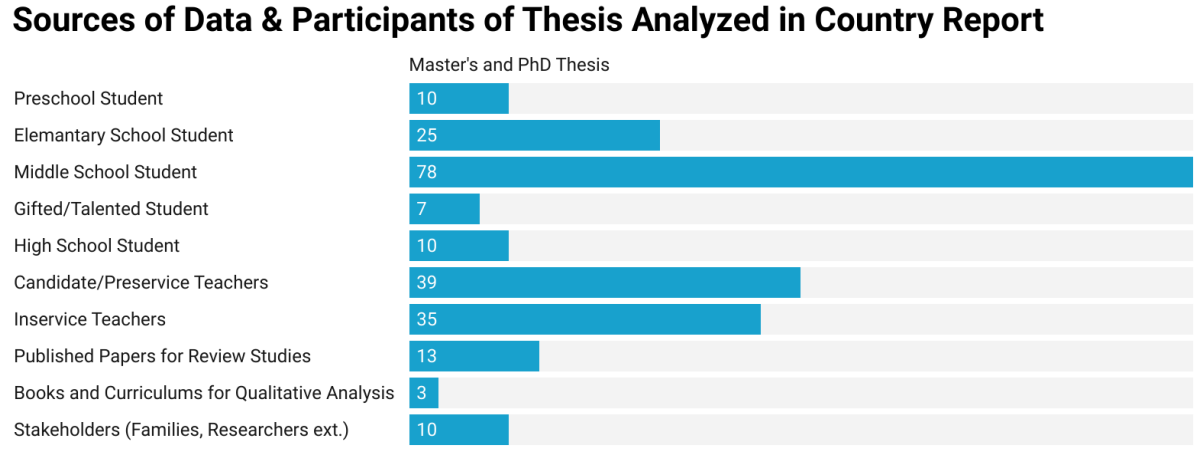


Figure 3.
Sources of Data & Participants of Thesis Analyzed in Country Report

The analyzed thesis emphasizes various developmental aspects in preschool children, as revealed by the frequency data presented in Figure 4. The table comprises eight distinct topics, each assigned a frequency score of either 1 or 5. The first topic, science process skills, refers to the capacity of preschool children to comprehend and apply scientific principles and methodologies. The second topic, age-appropriate developmental skills, pertains to the acquisition of skills typically observed in preschoolers, such as social skills, language development, and gross and fine motor skills. Creativity is the third topic, indicating the ability of preschoolers to express themselves through art and imaginative play. The remaining topics relate to different areas of academic development, such as academic self-esteem, critical thinking, problem-solving skills, and academic progress. These topics are critical for preschool children as they lay the groundwork for their future academic success and lifelong learning. Taken together, the frequency table suggests that the analyzed thesis focuses on a wide range of developmental domains in preschool children, including science, creativity, and academic skills.

Moreover, based on the frequency table provided, it appears that the analyzed thesis focuses on a range of topics related to the development and education of elementary school students. The table includes 12 different topics, each of which has a frequency ranging from 1 to 11, suggesting that the thesis covers a variety of themes with varying levels of importance.The most frequently occurring topic in the table is attitude towards STEM, with a frequency of 11.

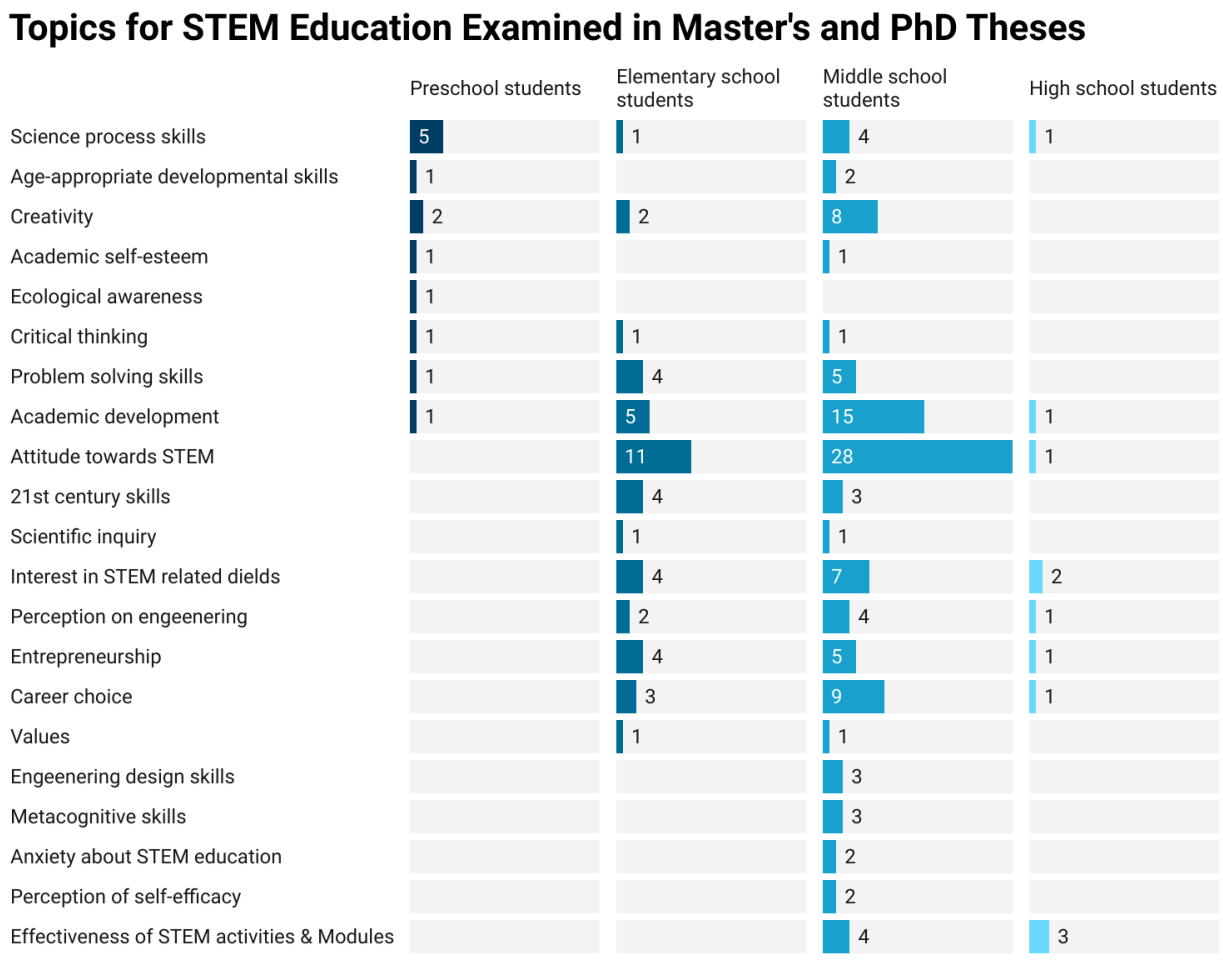


Figure 4.
Topics of Thesis Analyzed in Country Report

This suggests that thet hesis are primarily focused on exploring how students' attitudes towards science, technology, engineering, and math impact their academic and career aspirations. Understanding students' perceptions of STEM fields is crucial for educators, as it can inform curriculum development and teaching strategies.In addition to attitude towards STEM, the frequency table reveals several other important topics related to academic and personal development. Academic development has a frequency of 5, indicating that the thesis likely explores the academic skills and abilities of elementary school students. Problem solving skills, 21st century skills, interest in STEM related fields, and entrepreneurship all have frequencies of 4, suggesting that the thesis may delve into the ways in which these skills and interests can be fostered in elementary school students.Creativity and critical thinking, both with a frequency of 2, may be areas of focus for the thesis in terms of developing students' ability to approach problems in new and innovative ways. Perception on engineering, career choice, and values, all with frequencies of 1, suggest that the thesis are

explore these topics in less depth but still touch on their importance for elementary school students.Overall, the frequency table indicates that the analyzed thesis explores a wide range of topics related to the development and education of elementary school students, with a particular emphasis on STEM-related fields and skills. By examining the topics, strategies for cultivating students' academic and personal growth, as well as their interest and engagement in STEM fields.

Furthermore, Figure 4 provided covers a range of topics related to middle school students and their attitudes, skills, and perceptions towards STEM education. The table shows that the most frequently mentioned topic is "attitude towards STEM," which was mentioned 28 times. This suggests that researchers and educators are interested in understanding how middle school students perceive STEM subjects and how they feel about them.Other notable topics that were mentioned multiple times include "academic development" (15), "career choice" (9), "creativity" (8), and "interest in STEM-related fields" (7). These topics suggest that there is a focus on understanding how to engage middle school students in STEM subjects and how to encourage them to pursue careers in STEM-related fields.In addition, there are several topics that were only mentioned once or a few times, such as "academic self-esteem," "critical thinking," and "scientific inquiry." These topics highlight the importance of developing specific skills and attitudes that are necessary for success in STEM subjects.Overall, the frequency table provides a broad overview of the different topics that researchers and educators are interested in exploring related to middle school students and STEM education. These topics can help guide future research and program development aimed at improving STEM education and increasing student engagement and success in STEM subjects.

Inaddition,theFigure 4 presented includes several topics related to STEM education among high school students. One of the most prominent themes is the interest in STEM-related fields, which was ranked with a frequency of 2. This suggests that students in high school have a significant interest in pursuing careers or fields of study related to science, technology, engineering, and mathematics.Another topic that is relevant to STEM education is the effectiveness of STEM activities and modules, which was rated with a frequency of 3. Attitude towards STEM and perception of engineering were rated with a frequency of 1 each, suggesting that there is room for improvement in these areas. It is important toexplorethereasonswhystudentscouldhavenegativeattitudestowards STEM or engineering and develop strategies to address these issues.Academic development, entrepreneurship, and career choice were also rated with a frequency of 1 each. These topics are all important for students' success in the STEM fields, as they relate to developing the skills and knowledge needed to succeed in these areas.Overall, this frequency table provides valuable insights into the current state of STEM education among high school students.

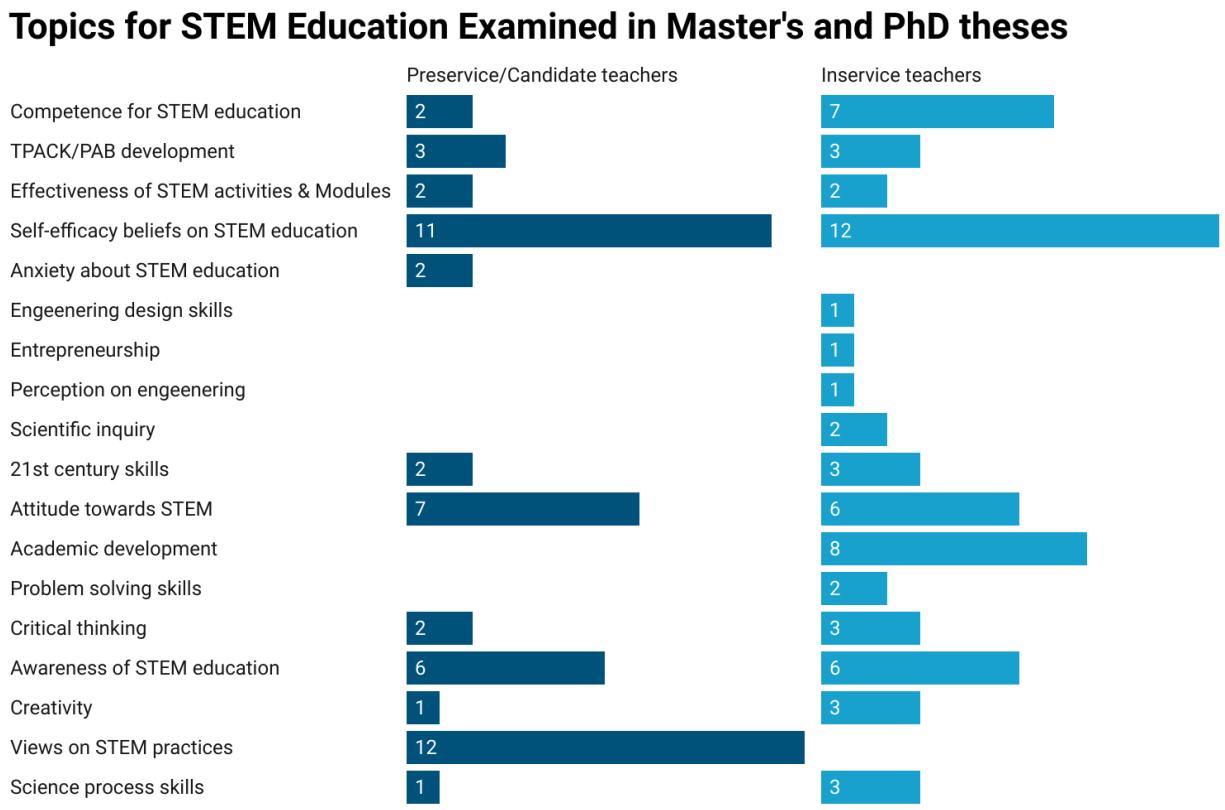


Figure 5
Topics of Thesis Analyzed in Country Report (Sampled from Preservice & Inservice Teachers)

Figure 5presentsthetopicsanalyzed in a thesis on Preservice/Candidateteachers. The tableindicatesthe number of time seach topic was mentioned in thethesis. Based on thetable, it appearsthatthethesisfocusedmore on thecandidates' viewsandawareness of STEM practices, as well as their self-efficacybeliefs on STEM education. Thesetopicsweremention ed 12 and 11 times, respectively. Thecandidates' attitudestowards STEM education and their competence for STEM education were also discussed in thethesis, with 7 and 2 mentions, respectively. Thelowfrequency of mentionsforcreativity, criticalthinking, 21st-century skills, anxietyabout STEM education, andeffectiveness of STEM activities & modules in dicatethat these topics were not the primary focus of thethesis.The findings suggest that the thesis primarily focused on exploring the candidates' views, awareness, and self-efficacybeliefs on STEM education. The thesis likely aimed tounders tand the candidates' perceptions of STEM educationan did entify ways to improve their preparation for teaching STEM subjects. Overall, the topics analyzed in the thesis reflect the importance of STEM education and the need to equip teachers with the necessary knowledge, skills, and attitudes to effectively teach STEM subjects. Theresults of the thesis could be used to inform teacher training programs and curriculum development to better prepare candidates for teaching STEM subjects.

Inaddition, Figure 5 provides a quick overview of the various topics analysed in the thesis related to inservice teachers. From the table, it is evident that self-efficacy beliefs on STEM education and academic development are the most frequently analysed topics, with 12 and 8 occurrences respectively.STEM education is a rapidly evolving field, and the topics covered in this thesis highlight the skills, competencies, and attitudes that are essential for inservice teachers to effectively teach STEM subjects to their students. The high frequency of topics related to STEM education, such as awareness of STEM education, attitude towards STEM, competence for STEM education, and TPACK/PAB development, highlights the importance of addressing these areas in inservice teacher training programs.The topics of creativity, critical thinking, 21st century skills, science process skills, and problem-solving skills are also frequently analysed in the thesis. These skills are essential for students to develop in order to succeed in STEM fields, and it is important for inservice teachers to possess these skills themselves to effectively teach them to their students.The low frequency of certain topics, such as perception on engineering, entrepreneurship, andengineeringdesignskills, couldindicatethatfurtherresearch is needed in these areas to fully understand their relevance to inservice teacher training programs.Overall, the topics analysed in this thesis highlight the importance of developing the skills, attitudes, and competencies necessary for inservice teachers to effectively teach STEM subjects to their students.

State-of-the-art STEM centers& STEM-related interactive exhibits and workshops in Science Centers and Museums

STEM centers play a crucial role in Türkiye STEM education initiatives by promoting, supporting, and providing resources for STEM education. STEM centers are typically established within universities, research institutions, or other organizations and work to enhance the quality of STEM education (Table 3).Some of the roles of STEM centers in Türkiye STEM education initiatives include:

1. Developingandimplementing STEM education: STEM centersdevelopandimplement STEM activitiesthatarealigned with national standards and provide opportunities for hands-on learning.
2. Training and professional development for teachers: STEM centers provide training and PD for teachers to improve their knowledge and skills in teaching STEM subjects.
3. Providing STEM resources: STEM centers provide a range of resources such as books, journals, software, and hardware for use by students and teachers.
4. Supporting research: STEM centers support research in STEM education to develop evidence-based approaches to teaching and learning.
5. Collaborating with industry: STEM centers collaborate with industry partners to provide opportunities for students to engage in real-world STEM experiences and learn about STEM careers.

Many critical and pioneering steps have been taken towards the establishment of STEM centers in Türkiye. For example, In June 2016, MEB emphasized the significance of establishing STEM centers in its report on STEM education. The report included a framework for the STEM education action plan, which highlighted the following objectives: setting up STEM education centers, conducting STEM research in collaboration withuniversities, training teachers in STEM education approaches, updating curricula to integrate STEM education, and creating teaching environments and materials for STEM education in schools.

Table 3

STEM centers established within universities, research institutions, or other organizations

Center	Funded by	Link
STEM Education and Coordination Center	Co-funded by EU and Türkiye	https://stemegitimmerkezi.com/
STEM School - Istanbul Aydın University	University funded	http://stemokulu.com/stem-okulu-hakkinda/
STEM and Science Center	Funded by Erasmus+ Ka2 Project	https://www.urfastem.gov.tr/
Diyarbakır STEM Center	Co-funded by Development agency and Ministry of Education	https://www.diyarbakirstemmerkezi.com/hakkimizda
Kahramanmaras Stem Center	Funded by Provincial Municipality	https://kahramanmaras.bel.tr/stem-merkezi
Bursa Innovation Center	Co-funded by Provincial Directorate of National Education and Development Agency	https://www.bursainovasyonmerkezi.com/ortaokul-ogrencileri-icin-stem-atolyesi/
Ülker AYDIN STEM Center	Funded by Provincial Municipality	https://tarsus.bel.tr/tr/stem-merkezi/
Turkish Stem Education Association	A researcher initiative	http://stemtr.org/
Istanbul STEM Learning Center Project	Funded by Development Agency	https://i-stemerkezi.com/?fbclid=PAAaZy4dRuRAi2cgxELKzfWelvg-Um8UMqL_PM0i3zJ0PPBVvNTASpa9g3tz0
STEM Lab	University funded	https://www.izu.edu.tr/akademik/fakulteler/egitim-fakultesi/laboratuvarlar/stem-laboratuvari
Hacettepe STEM & Maker Lab	University funded	https://hstem.hacettepe.edu.tr/
Muğla Sıtkı Koçman University Science Education Research & Application Center	University funded	https://mubem.mu.edu.tr/tr/mubem-projeler-1739
BİLTEMM | Center for Science Technology Engineering and Mathematics Education	University funded	https://biltemm.metu.edu.tr/tr

Morover, Istanbul Aydın University, a leading institution in the field of STEM education, has established a STEM center to provide top-notch laboratory facilities and exemplary education in STEM for teachers and students. The center aims to bring together individuals and organizations involved in STEM activities in Türkiye and provide support for all STEM initiatives in the country(Akgündüz et al., 2015).According to a report, universities are the ideal institutions to establish STEM centers, with Hacettepe University and Istanbul Aydın University already having done so.However, these efforts are not enough to fully integrate STEM education into formal education. To achieve this, education and engineering faculties should form STEM centers and collaborate with MEB's STEM center. These centers can offer research opportunities to integrate STEM education into the education system, provide up-to-date training, update the curriculum, offer professional development opportunities for teachers, facilitate project partnerships, and organize competitions for teachers and students. A coordinated structure is proposed in the diagram below.

STEM centers have been emphasized as necessary in academic studies and reports (Akgündüz et al., 2015; Uğraş, 2017; Türk, 2019; Uyar, Canpolat, Şan, 2021). Bahçeşehir University established the BAUSTEM STEM Center within their Teacher Professional Development Application and Research Center in 2016 to provide training to increase teachers' STEM application skills. The STEM: Leader Teacher Professional Development Program aims to maintain effective communication and interaction between teachers and academics (see https://inteach.org/hakkimizda/). The Middle East Technical University (METU) BİLTEMM Education Application and Research Center aims to advance education in science, technology, engineering, and mathematics through studies conducted by a group of researchers consisting of faculty members from different disciplines. Their objectives include providing educational opportunities to schools, teachers, and students in the relevant fields and training teacher candidates at theundergraduatelevel (see https://inteach.org/hakkimizda/). Hacettepe STEM & Maker Lab, established within the body of Hacettepe University in 2009, participates in projects within the scope of European Union Framework Programs to raise individuals not only at the national but also at theinternationallevel (see https://hstem.hacettepe.edu.tr/).Below is a table displaying the STEM centers and laboratories that

universitie shave established collectively (Table4).

Table 4
STEM Centers within universities in Turkey

University	Name of the Center	Year of Foundation
Hacettepe University	Hacettepe Science, Technology, Engineering and Mathematics Education and Applications Laboratory	2009
Yalova University	Science and Technology Application and Research Center	2011
Muğla Sıtkı Koçman University	Science Education Application and Research Center	2013
İstanbul Aydın University	Istanbul Aydın University STEM Laboratory	2015
Bahçeşehir University	Teacher Professional Development Application and Research Center – (BAUSTEM)	2016
Van Yüzüncü Yıl University	Science Technology Engineering and Mathematics Education Application and Research Center	2017
Yıldız Technical University	STEM Labrotary	2017
Aydın Adnan Menderes University	Science, Technology, Engineering and Mathematics Education Application and Research Center	2018
İstanbul Gedik University	Science, Technology, Engineering, Mathematics Application and Research Center	2018
Muş Alparslan University	STEM Education Application and Research Center	2019
İstanbul Zaim University	Faculty of Education STEM laboratory	2018
ODTU (Ortadoğu Technical University)	BİLTEMM Science, Technology, Engineering and Mathematics Education Application and Research Center	2017

Note. Source:Polat, Ö. & Bardak, M. (2019). STEM Approach in Early Childhood in Türkiye. International Journal of Social Science Research, 8(2), 18-41.

Integrating STEM (science, technology, engineering, andmathematics) practices into science centersand museums can be an effective way to engage visitors with hands-on, interactive exhibits that promote inquiry-based learning. Here are some ways to integrate STEM practices into science centers:

1. Offer interactive exhibits that promote inquiry-based learning: Science museums can create exhibits that encourage visitors to ask questions, make observations, and test hypotheses. For example, a

physics exhibit might feature hands-on experiments with pendulums or demonstrate the properties of sound waves using interactive displays.

2. Use technology to enhance exhibits: Science museums can use technology to enhance exhibits and provide visitors with new ways to interact with scientific concepts. Virtual reality, augmented reality, and interactive displays can help visitors visualize complex scientific concepts in new and exciting ways.

3. Offer STEM-related programs and workshops: Science museums can offer programs and workshops that provide visitors with opportunities to learn about STEM concepts through hands-on activities. For example, a robotics workshop might teach visitors how to build and program a robot.

4. Partner with local schools and universities: Science museums can partner with local schools and universities to provide educational programs that complement classroom learning. This can include field trips, science fairs, and science camps.

5. Encourage visitors to participate in citizen science projects: Science museums can encourage visitors to participate in citizen science projects, which allow them to contribute to real scientific research. For example, a museum might host a bird-watching event and ask visitors to record their observations for a research project.Table 5 showcases noteworthy science centers and museums that receive high visitation.

STEM Centers in Türkiye offer both STEM Basic Level and STEM Advanced Level Trainings, and they provide ongoing training for teachers. The activities at the center are coordinated with the STEM activities planned by teachers in schools, and the center monitors students' interest and attitude scales, as well as their academic achievements. Trained teachers are visited periodically, and a science festival is held annually to exhibit student and teacher products. Some STEM centers also provide guidance activities for teachers on integrating STEM into their curriculum, as well as repairing and supporting materials used in STEM education.

STEM education is available at all levels, from kindergarten to university students, and the centers are generally located in city centers with easy transportation access. Free education is provided to students, but due to high demand, some centers can only offer STEM education one day a week per student.STEM Centers offer a variety of services and resources to their visitors. The event implementation times are flexible and are determined by an appointment system in some centers, while others provide training between 16:00 and 22:00. The physical conditions of some centers are considered sufficient to meet the needs of their visitors.The STEM classes available in these centers cater to a wide range of ages and educational levels, from kindergarten to vocational high school. The classes cover various concepts such as industrial robotics, coding, and scientific inquiry. The centers also provide individual workshops and intelligence games workshops.In addition, the centers offer several STEM workshops for kindergarten, primary, secondary,and high schools. Some centers are equipped with fischer technical building sets, Lego and Arduino robot sets,

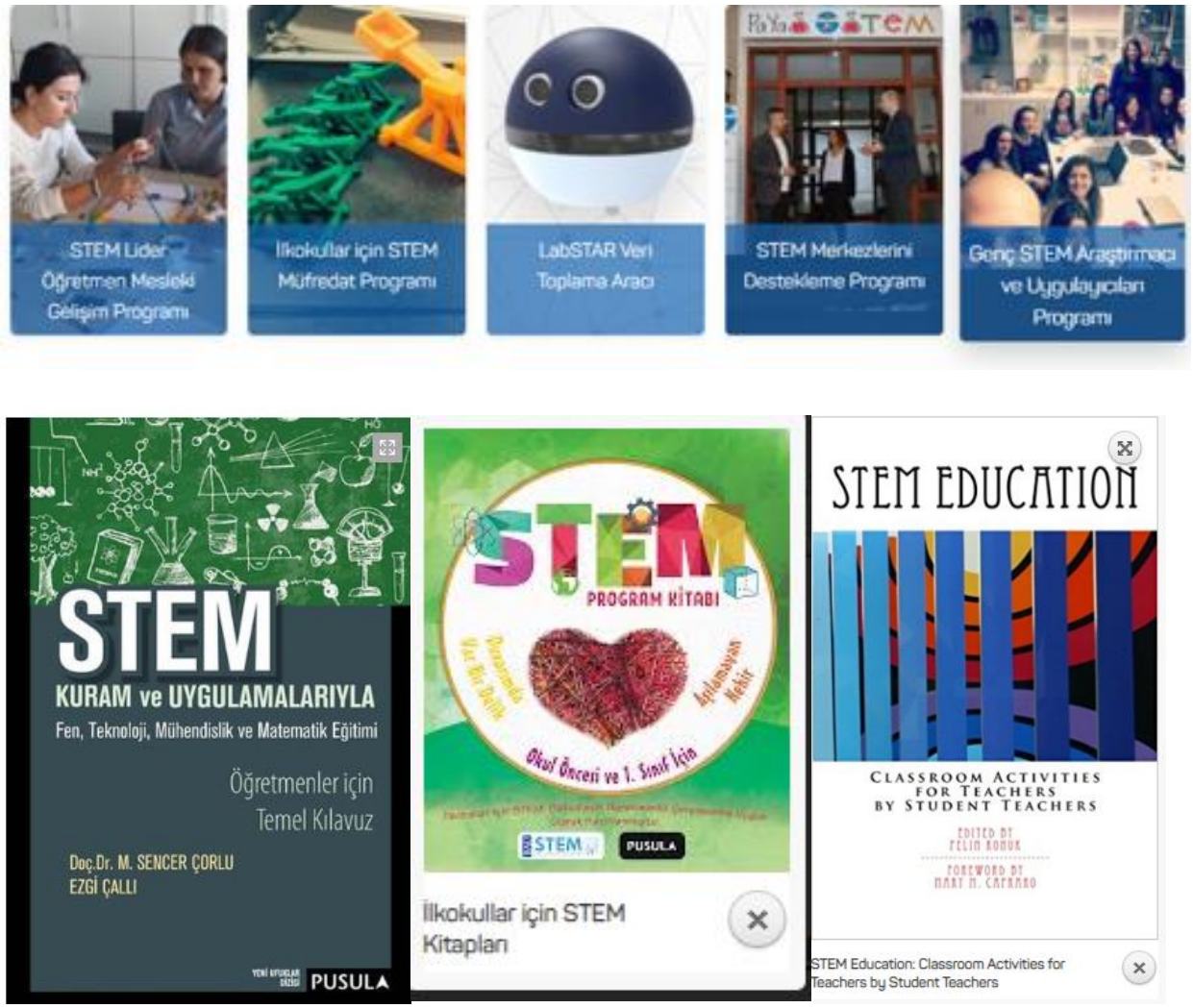
science laboratory materials, three-dimensional printers, and computers(Bircan, Köksal & Cımbız, 2019; Uyar, Canpolat & Şan, 2021; Karaduman & İnanç, 2023). Publicand Private Universities provide various resources and training programs for teachers, undergraduate students, primary and secondary school students. Istanbul Aydın University is one of the institutions that has established STEM centers and laboratories to contribute to STEM education.The STEM Laboratory at Istanbul Aydın University offers a STEM teacher training program, both face-to-face and online education programs, as well as integrated STEM education for students. Additionally, the university also provides support to institutions that are interested in establishing their own STEM labs.Additionally, Istanbul Aydın University's STEM center also focuses on environmental STEM education and provides STEM education to vocational and technical high schools.

Table 5.

Noteworthy Science Centers and Museums That Receive High Visitation

Center	Funded by	Info	Link
Bursa Science and Technology Center: BTM	Bursa Metropolitan Municipality's vision project	The goal of the Bursa Science and Technology Center is to promote sustainable development, foster a society based on science, and train future scientists, with the aim of accelerating Turkey's progress in the field of science and technology and serving as a model for the entire country.	http://www.bursabilimmerkezi.org/
Konya Science Center	Konya Metropolitan Municipality	The Konya Science Center, established by the Konya Metropolitan Municipality and supported by TÜBİTAK, is Turkey's first science center. Its goal is to cultivate a passion for science in people aged 7 to 70 and encourage interest in science throughout all levels of society.	https://www.konyabilimmerkezi.com/
Kayseri Science Center	Kayseri Metropolitan Municipality and TUBITAK	The goal is to merge theory and practice for young individuals to work, create, succeed, and adapt to current demands.	https://www.kayseribilimmerkezi.com/
Space Camp Turkey	Private funded Science Museum	Space Camp Turkey, a space and center, is focused on motivating young people to pursue careers in science, mathematics and technology. In programs related to STEAM (Science-Technology-Engineering-Art-Mathematics) learning approaches; increasing their interest in creative sciences through applied training; Suggestions for establishing dialogue, questioning and critical thinking are aimed to be guiding. A dynamic and fun journey used by space-related operations, both for children and adults; training in communication, teamwork and management. Providing scientific education, Space Camp Turkey, headquartered in Huntsville Alabama, has the American Space Sciences Exhibition Commission License and is a member of the Turkish Camps Association.	https://www.spacecampturkey.com
Eskişehir Science and Experiment Center	Eskişehir Metropolitan Municipality	The Eskişehir Science Experiment Center is created with the aim of educating our upcoming generation. It provides an opportunity for children who are interested in science, eager to learn by experimenting and observing, to utilize various experimental tools and gain new knowledge. Both young and old who share a common curiosity are welcome to visit the center.	http://www.eskisehirbilimdeneymerkezi.com/default.aspx
Istanbul Technical University (ITU) Science Center	Istanbul Technical University	The ITU Science Center aims to provide students of all ages with hands-on experiences in science, technology, and nature's fundamental laws. Its goal is to promote scientific culture in society, making science and technology accessible and popular, and inspiring people of all ages to engage in these fields.	https://www.bilimmerkezi.itu.edu.tr/hakkinda/itu-bilim-merkezi/
Kocaeli Science Center	Kocaeli Metropolitan Municipality-TUBITAK	The Kocaeli Science Center, a collaboration between Kocaeli Metropolitan Municipality and TUBITAK, intends to unite science and technology with people of various ages and levels of understanding, while promoting the significance of these fields in society.	http://www.kocaelibilimmerkezi.com/

Moreover, BİLTEMM: The Science, Technology, Engineering and Mathematics Education Application and Research Center, as located in Middle East Technical University, offers various programs and projects to support STEM education. These initiatives include teacher training workshops, STEM days, as well as national and international projects and studies. The center also conducts interdisciplinary practices and innovation development workshops, such as the Edusteam Project, to promote STEAM studies.Bahçeşehir University's BAUSTEM center offers a range of programs and resources to support STEM education. These include a Young STEM researcher and practitioner program, designed to provide support to STEM centers, as well as several STEM education programs. The center has also published educational books on STEM Theory and Practices, which provide a basic guide for teachers, as well as guides specifically tailored for primary schools (See Figure 6).



Note. Images are taken from BAUSTEM offical website

Figure 6. STEM Initiatives and Books Published by BAUSTEM

The Payas Stem Center is a remarkable educational facility located in the Payas district of Hatay province in Türkiye. This center is housed in a two-story building spanning an area of 700 m2 and is notable for being established outside of metropolitan cities. Among its offerings are classes in Robotic Coding, Mathematical Modeling, Scientific Inquiry, World of Words, and Mind Games sections. Students who attend classes at the Payas Stem Education Center benefit from engaging workshops that utilize a variety of educational tools, including Sensors, Electronic Circuits, 3D Printers, Lego Minstorms EV3s, and Mind Games.

In conclusion, the evaluation of academic research, reports, and studies conducted in STEM centers reveals a diverse range of applications, projects, and workshops aimed at promoting STEM education in Türkiye, alongside supportive initiatives for newly established centers. Moreover, valuable educational resources, including books and brochures, are being developed to aid teachers and students in the pursuit of academic excellence. These efforts serve as a testament to the importance of STEM education and the commitment of Turkish institutions to nurturing a thriving culture of scientific inquiry and technological innovation.

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

EXECUTIVE SUMMARY

Report WP2 is a comprehensive study that explores STEAM (Science, Technology, Engineering, Arts, and Mathematics) education in Slovenia, with a particular focus on incorporating sustainable practices and the green transition. The introduction highlights Green STEAM, which seamlessly integrates environmental awareness throughout all levels of learning.

The subsequent section delves into the Slovenian education system, outlining its unique characteristics. This system encompasses primary, secondary, and tertiary education, along with adult education opportunities.

The heart of the report is in the chapter, where a detailed examination of green STEAM education's current state in Slovenia takes place. While green transition and sustainability are partially present in various educational stages, their strongest integration is found in tertiary education and research institutions. Despite this, there's a noticeable lack of systematic inclusion of green technologies and sustainability across educational frameworks. Encouragingly, multiple initiatives are underway at different education levels to address this gap on a national scale.

The final chapter presents a blueprint for a STEAM education and training monitoring framework. This framework enables a comparison between Slovenian students and global educational approaches. An important finding emerges from this assessment: Slovenian educational methods and test results surpass the average.

Crucially, a significant conclusion arises from this analysis. Educational approaches and test outcomes go beyond the norm, indicating the system's adeptness in assimilating novel skills relevant to contemporary environmental issues. This readiness spans the entire spectrum of education, from early years to adulthood, demonstrating the education system's responsiveness to urgent ecological concerns.

INTRODUCTION

Green STEAM, which stands for Science, Technology, Engineering, Arts, and Mathematics with a focus on environmental consciousness, eco-friendly technologies, and sustainable practices, holds immense importance for the future society. It plays a crucial role in promoting sustainability, preserving the

environment, and mitigating climate change. The integration of environmental awareness into STEAM education fosters Sustainable Innovation, Climate Change Mitigation, Environmental Awareness, Cross-disciplinary Collaboration, Green Career Opportunities, Resilient Communities, and Global Impact.

Through green STEAM education, individuals should be equipped with the knowledge, skills, and mindset necessary to tackle environmental challenges and create a sustainable and resilient world. By encouraging the application of arts, technology, and scientific principles in an environmentally conscious manner, we inspire the next generation to become environmentally responsible innovators. This, in turn, leads to a brighter future for everyone, with a focus on harmonious coexistence with nature and a commitment to global sustainability.

SLOVENIAN EDUCATION SYSTEM

The education system in Slovenia comprises three main sections: primary, secondary, and tertiary education, with additional provisions for adult and special needs education.[1] For detailed schematics see the APPENDIX – *Education system in Slovenia*

1. Primary education encompasses a variety of institutions such as public and private kindergartens, basic schools, those with adapted education programs, music schools, and educational institutions catering to children with special educational needs. This stage covers early childhood education and care, basic education, and music education.
2. Secondary education is delivered through upper secondary schools and secondary schools, each offering distinct pathways. Students can choose between general or vocational technical education and secondary professional or technical education.
3. Tertiary education is available through both public and private institutions and includes higher post-secondary vocational education and higher education. Higher vocational colleges offer short-cycle higher vocational education, while faculties, academies, and independent higher education institutions provide higher education options.

Additionally, Slovenia also emphasizes adult education and Special needs education, which are organized by private entities or non-profit organizations, providing opportunities for individuals seeking further development or requiring specialized support. By structuring the education system in this manner, Slovenia aims to provide a comprehensive and diverse learning experience for its citizens, catering to various interests, abilities, and needs. The focus on both general and specialized education paths equips students with

the necessary skills and knowledge for future success, while adult education and special needs education initiatives contribute to a more inclusive and accessible learning environment for all members of society.

STATE-OF-THE-ART – (GREEN) STEAM EDUCATION IN SLOVENIA

STEAM education in Slovenia has been gaining significant attention and recognition in recent years and it represents an interdisciplinary approach to learning that encourages creativity, critical thinking, problem-solving, and collaboration among students. In Slovenia, the implementation of STEAM education has been driven by the recognition of the importance of equipping students with skills that are essential in the 21st century workforce. The government, educational institutions, and various non-governmental organizations have been actively promoting STEAM initiatives to foster innovation and prepare the next generation for a technology-driven and rapidly changing world.

One of the primary goals of STEAM education in Slovenia is to bridge the gap between traditional academic subjects and real-world applications. By integrating science, technology, engineering, arts, and mathematics, students are encouraged to approach problems in a holistic manner, allowing them to better understand complex issues and develop comprehensive solutions.

Slovenia has been investing in the professional development of teachers to ensure they have the necessary skills and knowledge to effectively implement STEAM methodologies in their classrooms. Workshops, training programs, and networking opportunities have been organized to support educators in incorporating STEAM principles into their teaching practices. Moreover, the Slovenian government has collaborated with private sector companies and research institutions to provide students with access to cutting-edge technology and real-world experiences. These partnerships have resulted in various mentorship programs, internships, and school-industry collaborations, giving students the chance to work on actual projects and learn from professionals in different fields. Furthermore, initiatives promoting diversity and inclusion in STEAM education have also gained traction in Slovenia. Efforts are being made to encourage more girls and underrepresented groups to pursue STEAM-related fields and careers, aiming to create a more diverse and inclusive workforce in the future.

STEAM education in Slovenia is on a positive trajectory, as it continues to empower students with the skills, knowledge, and mindset needed to thrive in a technology-driven society. With a focus on hands-on learning, interdisciplinary approaches, and industry partnerships,

Slovenia is positioning itself to foster a new generation of innovative thinkers and problem solvers, making significant contributions to both local and global challenges.

PRE-SCHOOL EDUCATION (Primary) (age 1 to 6)

The curriculum for kindergartens has remained relatively unchanged since its establishment in 1999.[2] Primarily focused on the fundamentals of art and mathematics, it employs a playful approach to early learning. However, a transformative shift is evident in 2022, marked by the release of revised guidelines for kindergarten curriculum renewal.[3] Notably, these revisions place a significant emphasis on sustainability as a cornerstone. This update underscores the critical role of instilling sustainable development values, particularly fostering a sense of responsibility towards oneself, fellow human beings, other living entities, and the surrounding environment within the realm of childhood education. As part of a larger initiative funded by the Mechanisms for Recovery and Resilience (NOO - Mehanizma za okrevanje in odpornost),[4] the rejuvenation of educational programs coincides with the revitalization of key foundational documents, encompassing the curriculum for kindergartens, lesson plans, and knowledge catalogs. This comprehensive endeavor operates under the imperative of accomplishing its goals by the deadline of December 31, 2025.

BASIC EDUCATION (Primary& Lower secondary) (age 6 – 15)

Primary and lower secondary education in Slovenia follows a unified nine-year structure within a single basic school system, catering to students aged 6 to 15 years. This educational framework is offered by both public and private schools, with private basic schools accounting for a minority share of students (less than 1%). Additionally, educational institutions catering to students with special educational needs and adult education organizations are also part of the educational landscape. Basic school program is composed of Compulsory and Extended programs (Figure 1)[5]. For detailed program see APPENDIX for *Basic Education school program*.

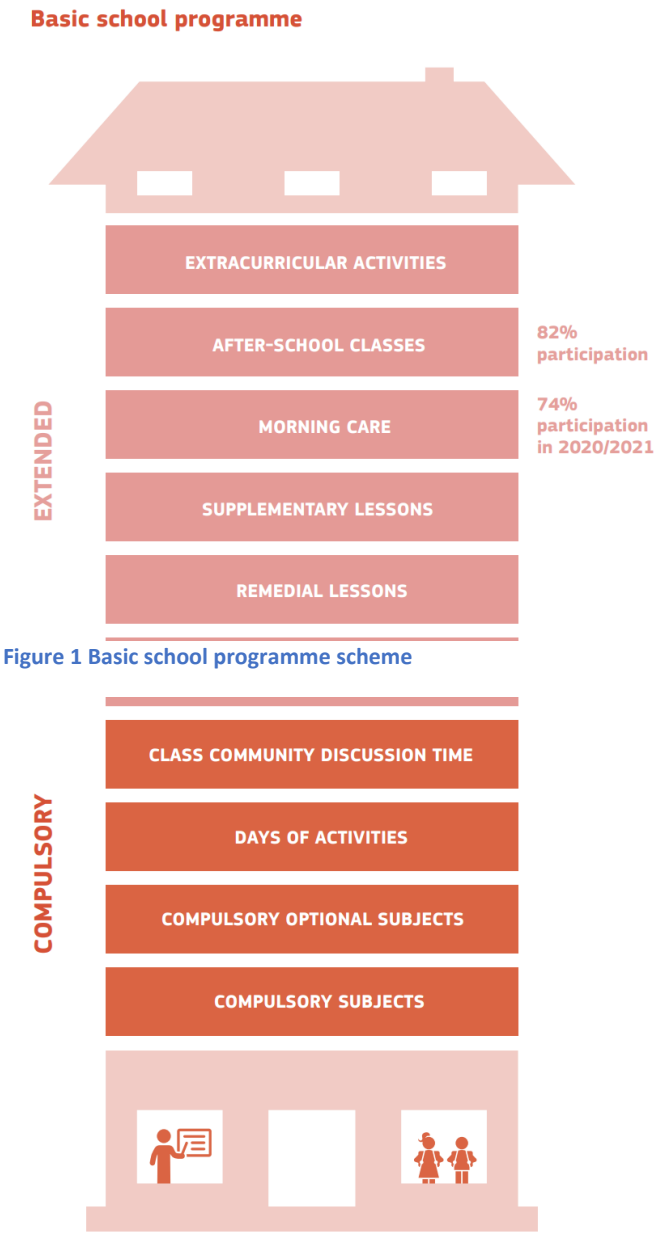

Figure 1 Basic school programme scheme

Aligned with the stipulations of the Constitution of the Republic of Slovenia, basic school education is not only mandatory but also financially supported by the state.

First educational cycle (age 6 – 9)

Within the First Educational Cycle, a quartet of compulsory courses emerges, aptly classified as STEAM subjects, encapsulating Mathematics, Fine Art, Music, and the Fundamentals of the Environment (*slo.* "Spoznavanje okolja"). Notably, the curriculum of the Fundamentals of the Environment course extends its purview to encompass green technologies as well.The course of environmental topics serves as a catalyst for fostering education and training aimed at sustainable development. This course comprehensively embraces interconnected facets of the environment, economy, and society. The curriculum of this course is rooted in foundational concepts that not only enhance understanding within disciplines such as natural sciences and technology, but also extend into the realms of society. This integration takes place within the second educational cycle. Furthermore, it spans across subjects involving natural sciences, technology, and social sciences in the subsequent educational phase, solidifying its multi-dimensional impact.

Second educational cycle (age 9 – 12)

The spectrum of subjects constituting the realm of STEAM education undergoes expansion within the second cycle, now encompassing an array of disciplines: Mathematics, Fine Art, Music, Natural Science (*slo.* "Naravoloslovje"), Natural Science and Technology (*slo.* "Naravoslovje in Tehnika"), and Engineering and Technology (*slo.* "Tehnika in Tehnologija"). Notably, all subjects pertaining to the domain of natural

sciences, engineering, and technology incorporate references to green technologies within their curricula. This integration creates a vertical interconnectedness between them and Fundamentals of the Environment (*slo.* "Spoznavanje okolja") from First educational cycle. In the realm of technical courses, students delve into the fundamental framework of technology, which is delineated by four interconnected domains:

- Technical Resources: This domain encapsulates an array of vital components including processing tools, machinery, energy converters, transmission systems, movements, and mechanisms for handling information.
- Technological Processes: Within this realm, students explore the various facets of technological manipulation such as shaping, transformation, cutting, joining, surface treatment, and related operations.
- Organizational Dynamics: This domain encompasses the dynamic interplay of problem analysis and product development, serving as the driving force behind efficient work methodologies.
- Economic Considerations: Here, the evaluation of products and work takes center stage, shedding light on the economic dimension of technological endeavors.

Together, these domains collectively enrich the learning journey and create a holistic educational experience. Notably, within this landscape, energy converters assume a pivotal role. They delve into Energy and Storage technologies, offering a doorway to the realm of alternative green technologies. This comprehensive approach equips students not only with knowledge but also the awareness of the transformative potential of sustainable energy solutions.

On the other hand, within the realm of natural sciences, students embark on a journey of learning and cultivating a profound comprehension of fundamental natural science concepts and principles. These foundational elements serve as the bedrock for comprehending the intricate tapestry of phenomena in the natural world. Moreover, students delve into the intricate interplay between living and non-living aspects of nature, unraveling the complex relationships that exist between the structure, properties, and functions of these dynamic systems. Throughout their exploration of science, students gain insights into the profound significance that natural sciences hold for the advancement of humanity. This process not only cultivates knowledge but also nurtures attitudes and perspectives toward themselves, their environment, and the broader natural world. It instills an acute awareness of the imperative of responsible behavior, underpinning the care of personal safety and the well-being of others. Through this holistic approach, students are empowered to forge a symbiotic relationship with nature, fostering a sense of stewardship and underscoring the vitality of conscientious actions for the collective welfare. All of this knowledge serves as a crucial foundation for the development of modern green technologies.

Concluding the second educational cycle, students' proficiency in core subjects—Slovene language, Mathematics, and English—is assessed through the National Knowledge Test (NPZ). This assessment is obligatory for all students.

Third educational cycle (age 12 – 15)

The distinctive feature of the third educational cycle is that only subject-specialist teachers (*slo.* Predmetni pouk) are responsible for instruction. This unique arrangement fosters more comprehensive and in-depth exploration across all fields, including the STEAM courses. Additionally, students are mandated to opt for a minimum of two hours' worth of elective courses annually.

In this advanced phase, the canvas of subjects aligned with the STEAM framework widens further, encompassing Physics, Chemistry, and Biology. Alongside these, students enjoy the freedom to select two elective courses from an extensive assortment of options. Essentially, these electives are divided into two sets: one covering Social Sciences and Humanities, and the other focusing on Natural Science and Technical domains. Among these courses are Mathematical Workshops, Nutritional Practices, Material Processing, Chemistry and Physics Experiments, Engineering and Computational Principles, as well as Geometry and Technical Drawing (involving 3D printing and modeling). Notably, several of these offerings establish either direct or indirect ties to green technologies.

An additional significant aspect of basic education comprises mandatory activity days (Figure 1), encompassing excursions, nature outings, and technical sessions. During these periods, students are provided with chances to explore research laboratories, institutions, museums, and more. Much like the second educational cycle, students in the third cycle undergo assessment via the National knowledge test (NPZ). This evaluation covers proficiency in Slovene language, Mathematics, and a third subject determined by the Government. This mandatory assessment applies to all students.

UPPER SECONDARY EDUCATION (Secondary) (age 15 – 19)

After completing their mandatory primary education, students, typically at around the age of 15, can opt to continue their academic path at the upper secondary level, selecting a school and program that aligns with their preferences. This phase typically spans from two to five years for completion.

Moreover, attaining an upper secondary education qualification remains attainable during adulthood through regular programs that incorporate specialized organizational adjustments tailored for adult learners. However, the enrollment of candidates may be constrained if the number surpasses the school's capacity.

The framework of upper secondary education operates within a centralized structure. Consequently, determinations concerning school establishment, funding, and educational programs are formulated at the national level. While schools and educators uphold autonomy in executing mandated programs, they also wield independence in matters pertaining to human resource selection and management.

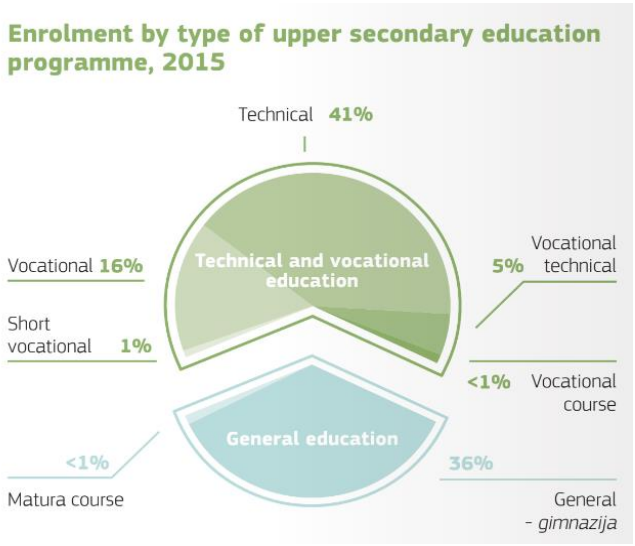

Figure 2 Enrolment by type of upper secondary education programme, 2015

Upper secondary education is organized into two streams: general education and technical and vocational education. Among the students, approximately one-third opt for general education, while the remaining two-thirds opt for technical and vocational education (as shown in Figure 2).[6] The duration of general programs spans four years, while technical and vocational education can vary in length, spanning 2, 3, or 4 years. The latter is further categorized into different tracks, including Technical Programs (4 years), Short Vocational Programs (2 years), Vocational Programs (3 years), and Vocational Technical Programs (2 years).

General Education (Matura)

The primary benefit of General high school education (*slo.* "Gimnazija") lies in its comprehensive knowledge spectrum. This knowledge equips students with the prerequisites for pursuing further education at universities, both in Slovenia and across the globe. Completion of a gymnasium program, along with achieving a general Matura, is a prerequisite for those aspiring to pursue higher education at universities and certain colleges.

The curriculum for general education comprises a blend of compulsory and elective courses. Within the realm of STEAM, pivotal subjects are incorporated as compulsory components, including Fine Art, Biology, Physics, Geography, Informatics, Chemistry, and Mathematics. Similarly, an array of elective courses is available, presenting students with more advanced or in-depth iterations of Biology, Physics, Geography, Informatics, Chemistry, and Mathematics.

The current study program briefly touches upon green technologies in different sections, lacking in-depth exploration. Addressing this, a specialist working group has drafted foundational principles for revamping curricula in elementary and high schools.[7] Their key observation is that the 21st century demands education to reflect significant societal changes that influence society's essence. This era emphasizes resolving environmental and societal issues such as digitization's impact, resource implications of consumer choices, and environmental preservation. Thus, fostering sustainable development awareness and digital competence in the youth becomes pivotal.

Moreover, a transformative shift is underway wherein machines transcend their traditional confines of physical labor and increasingly contribute to human cognitive capacities. This reevaluation of their function necessitates a comprehensive comprehension of machine dynamics, akin to the established scientific disciplines. As a result, the curriculum's evolution endeavors to foster environmental consciousness, digital adeptness, and a nuanced comprehension of machine intricacies, aligning seamlessly with the transformative landscape of the 21st century. These insights underscore the imperative of incorporating Green STEAM into the education system.

Technical and Vocational Education

Technical and vocational education presents a specialized array of STEAM courses that delve deeply into distinct technical and natural fields. This facet of education provides a concentrated focus on diverse areas, offering students a comprehensive understanding of various technical and scientific disciplines. In addition to the conventional subjects like Mathematics, Music, Fine Art, Biology, Chemistry, Physics, and Informatics, this avenue introduces a range of specialized courses closely aligned with the realms of Green STEAM.

These specialized courses encompass a multitude of disciplines that are intrinsically connected to the domains of sustainability and environmental consciousness. Notable examples include Biotechnology, Electrical Engineering, Materials Science, Mechanics, Computer Science, Electronic Systems, Construction, Agriculture, Woodworking, Microbiology, Spatial Modeling, Computer Systems and Networks, Mechanical Engineering, Laboratory Exercises, Astronomy, Selected Chapters in Biotechnology, Creative Entrepreneurship, Research Papers and Other Products, Project Work Incorporating Research Methodologies, Environmental Studies, and Education for Solidarity. The list, though extensive, merely scratches the surface of the comprehensive offerings.

Despite this expansive selection, the core challenge remains that the current curricula lack a holistic perspective when it comes to comprehending green technologies. The intricate interplay between various STEAM components and their application to sustainability-focused fields such as renewable energy, resource management, and ecological preservation often gets fragmented. This deficiency underscores the need for a unified approach that bridges the gaps, providing students with a profound grasp of green technologies within a broader educational context.

HIGHER AND SHORT-CYCLE HIGHER VOCATIONAL EDUCATION (Tertiary)

Following the Bologna reform, Slovenia's tertiary education structure comprises three cycles: the 1st cycle - Bachelor's (3 years), the 2nd cycle - Master's (2 years), and the 3rd cycle - Doctoral. The country is home to four distinguished universities: the University of Ljubljana, the University of Maribor, the University of Primorska, and the University of Nova Gorica.

These universities are united by a shared mission centered around fostering interdisciplinary exploration, innovation, and creativity. They are dedicated to empowering students as critical thinkers and active contributors to society, emphasizing the essential connection between science, art, and societal progress. Through adaptable and dynamic educational methodologies, these institutions strive to equip graduates with the capabilities necessary to confront the intricate challenges of the contemporary world, including the realm of green technologies (Figure 3)[8].

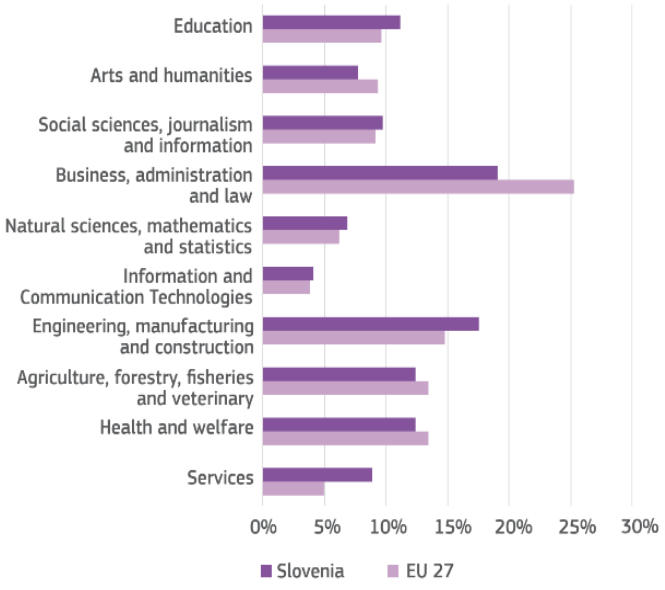

Figure 3 Distribution of tertiary education graduates by broad field of education, 2020

Green technologies are well represented within various study programs as well as within the research groups at the universities.

All four universities establish robust connections with public research institutes (Jozef Stefan Institute, National Institute of Chemistry, National Institute of Biology, The Geological Survey of Slovenia, Slovenian Forestry Institute, Institute for Hydraulic Research, The Institute of Metals and Technology, Agricultural Institute of Slovenia, Educational Research

Institute, Urban Planning Institute of the Republic of Slovenia, Slovenian National Building and Civil Engineering Institute, etc.) and select private entities, as well as house formidable research and development units within the corporate realm. The synergy between a rich scientific heritage and a contemporary research and development structure drives substantial engagement in the fields of green technologies and sustainability. Despite Slovenia's relatively modest population of around 2 million, the nation's scientific community comprises over 11,000 dedicated researchers who contribute significantly, resulting in 1.346 international scientific co-publications per 100,000 individuals.

Slovenia's deep appreciation for science and education is evident in the remarkable count of new doctoral graduates per 100,000 residents, an impressive figure of 355. This unwavering commitment to scholarly pursuits is deeply ingrained in the country's culture, underscoring the pivotal role that science and research play in shaping Slovenia's society. This shared dedication signifies that the critical mass needed to embrace and implement innovative green technologies is substantial enough to drive transformative changes across various sectors as well as down the education vertical.

Green Education and Research at University of Ljubljana

Slovenia, notably the University of Ljubljana, proudly stands as a distinguished member of the EU STEM Coalition. This coalition functions as a pan-European network devoted to advancing STEM (Science, Technology, Engineering, Mathematics) education across the continent. Its overarching mission is to craft and implement STEM education policies and strategies that not only drive economic growth but also create widespread opportunities and enhance overall well-being. Collaborating closely with policymakers, educational institutions, and industry stakeholders, the coalition is committed to championing innovative approaches to educational delivery. Furthermore, it actively seeks out and disseminates evidence-based solutions to address the pressing issue of skill mismatches within the STEM fields. By tackling challenges ranging from the shortage of skilled STEM professionals to fostering robust partnerships between educational bodies, corporations, and governments, the coalition offers an unparalleled platform. At the core of its activities lies the provision of a unique forum and knowledge hub, serving as a repository for data-driven analyses, sharing of best practices, and direct support. Through this multifaceted approach, the coalition not only envisions a future with an abundance of STEM talent but also catalyzes collaboration that extends beyond traditional boundaries, ensuring the continued advancement of STEM education and its myriad benefits.[9]

The University of Ljubljana is the oldest and largest higher education and scientific research institution in Slovenia. The university was founded in 1919. It has approximately 38,000 undergraduate and postgraduate students and employs approximately 6,000 higher education teachers, researchers, assistants and administrative staff in 23 faculties and three arts academies.[10] The University of Ljubljana stands out for its exceptional programs in both social and natural sciences, as well as technical studies. These programs are meticulously designed in accordance with the principles set forth in the Bologna Declaration. The institution remains at the forefront of advancements in arts, sciences, and technology, both within the country and on the global stage. Recognizing the pressing need for STEM expertise in Slovenia, the University of Ljubljana is actively engaged in a diverse array of outreach initiatives, aimed at fostering a robust pipeline of STEM talent. These initiatives encompass:

- Collaborative efforts through Quadhelix partnerships, bringing together educational institutions, industries, non-profit organizations, and government bodies.
- Engaging STEM activities within MakerLabs and FabLabs, empowering hands-on exploration and creativity.
- Orchestrating summer and winter schools, along with CAMPs, tailored for students in elementary and secondary education.
- Playing a key role in formulating a comprehensive national STEM strategy in conjunction with other stakeholders.
- Offering specialized training sessions for students, parents, and educators alike.
- Promoting awareness about promising STEM careers and showcasing inspirational role models.
- Undertaking research ventures focused on pressing issues such as Sustainable Innovation, Climate Change Mitigation, Environmental Awareness, Cross-disciplinary Collaboration, Green Career Opportunities, Resilient Communities, and Global Impact.

While these efforts hold immense significance, it's crucial to recognize that they currently don't fully come together as a well-integrated and organized approach to effectively address the complex challenges of Green STEAM. Nevertheless, a shining model of commitment to green challenges is evident at the University of Ljubljana. Here, a comprehensive approach to tackling a range of green challenges is built upon three main pillars:

a) Enriched or dedicated Study Programs:

b) Cutting-edge Research Endeavors:

c) Impactful Project Ventures:

Study Programs

The University of Ljubljana is forging ahead by infusing sustainability-oriented content and principles across its diverse array of study programs. Students are being equipped not only with foundational knowledge but also with a profound understanding of the interconnectedness between their chosen fields and the pressing environmental concerns. Through thoughtfully curated coursework, students are empowered to become proactive agents of change, steering industries towards greener horizons.

University of Ljubljana and its Faculties are fostering several study programs that are devoted to Delivering the European Green Deal with the aim to transform the economy and societies.[11] This comprehensive initiative aims to drive transformative changes in both economies and societies. Across all three academic cycles, a majority of the existing study programs now offer a selection of courses that center around the principles of the green transition. Refer to Table 1 for an overview of these efforts.

Table 1 University of Ljubljana member Faculties that offer courses related to Sustainability.

Faculty:	Study program:	Study cycle	Courses:
Faculty of Chemistry and Chemical Technology	Chemical sciences	3.	• Selected topics in environmental engineering • Selected topics in materials for new energy sources
	Chemistry	2.	6 different courses related to Materials for Energy Storage and Conversion. Detailed curriculum [12]
Faculty of Mechanical Engineering	Mechanical Engineering	3.	3 different fields related to Green Transition: • Machine Design and Mechanics Engineering Science, • Energetical, Process and Environmental Engineering Sciences,

			• Production Engineering Sciences, Cybernetics and Mechatronic
Faculty of Electrical Engineering	Electrical Engineering	3.	• Photovoltaics • Energy Conversions and Environment • Intelligent buildings • Intelligent mobile transport systems
	Advanced Power Systems	2.	Several courses see reference [13]
Biotechnical Faculty, Faculty of Arts, Faculty of Chemistry and Chemical Technology, Faculty of Civil and Geodetic Engineering, Faculty of Law, Faculty of Maritime Studies and Transport, Faculty of Mathematics and Physics, Faculty of Mechanical Engineering, Faculty of Medicine, Faculty of Natural Sciences and Engineering, Faculty of Social Sciences, School of Economics and Business, Veterinary Faculty	Interdisciplinary doctoral programme in Environmental protection	3.	Several courses see reference [14]
Faculty of Education	Teacher Education and Educational Sciences	3.	• Semantic Technology and the Virtual Learning Environment
Biotechnical Faculty	Forestry and Renewable Forest Resources	1.	• Forest Entrepreneurship • Landscape ecology • Forest harvesting

			• Forest Ecology and Tending • Introduction to Ecology • Production of Forest Reproductive Material
	• Economics of Natural Resources • Ecology and Biodiversity • Forestry and Forest Ecosystem Management • Biotehnology	2.	Several courses see reference [15]
Biotechnical Faculty, Faculty of Computer and Information Science, Faculty of Electrical Engineering, Faculty of Health Sciences, Faculty of Mechanical Engineering	Biosciences	3.	Several courses see reference [16]
Faculty of Computer and Information Science	Computer and Information Science	3.	• Selected Topics in Artificial Intelligence 1 • Selected Topics in Artificial Intelligence 1
Faculty of Natural Sciences and Engineering	Getechnology	2.	• Geothermal energy • Waste treatment • Energy politics • Clean technologies • Geothermal research and underground fluid modelling
	Matrials and Metallurgy	2.	• Industrial ecology and energetics

	Geology	2.	• Environmental mineralogy • Protection and managenemt og groundwater resources
Faculty of Civil and Geodetic Engineering, Faculty of Natural Sciences and Engineering	Built Environment	3.	• Applied Environmental Geochemistry • Assessment of • Water Management Impact on River Basin • Protection of Water Environment • Climate adapted buildings

Research Endeavors

UL boasts a formidable team of over 3,500 researchers whose collective efforts have garnered remarkable recognition. According to data gleaned from the Thomson-Reuters Web of Knowledge database, faculty members and researchers at the University of Ljubljana consistently contribute to nearly half of all globally renowned scientific publications emerging from the Republic of Slovenia.

In recent years, UL has ascended to exceptional heights. It proudly resides within the top 3% of the world's most accomplished universities according to The Times Higher Education ranking. Additionally, in the esteemed Shanghai Ranking, UL secures a place among the top 500 research universities worldwide. Its influence extends beyond rankings, evidenced by its strong presence in terms of international resonance, as reflected by citations of its scientific publications. A remarkable showcase of its pinnacle research accomplishments is presented annually during the University Week.

This institution provides a thriving research milieu alongside modern cutting-edge equipment,[17] both to its resident researchers and those visiting. Such an environment is conducive to the pursuit of groundbreaking research breakthroughs and fostering innovation.

The University's commitment to pioneering research is manifesting prominently in its initiatives focused on green initiatives too. By fostering an environment conducive to innovative exploration, researchers are delving into the depths of complex challenges, unraveling intricate relationships between the environment and technology. These investigations are yielding insights that have the potential to catalyze transformative breakthroughs, reshaping industries and practices for a more sustainable future.

Project Ventures

Recognizing that practical implementation is an indispensable component of sustainable progress, the University of Ljubljana is not merely confining itself to theoretical pursuits. Instead, it's engaging in hands-on project endeavors that bridge the gap between conceptualization and real-world application. Collaborative projects, spanning disciplines, are channeling the collective wisdom of academia towards tangible solutions. These projects don't just remain confined to campus but have the potential to radiate positive change throughout local and global communities. Report on EU tenders and applications for EU projects in 2021 and the current status of EU projects at University of Ljubljana is very telling of many ongoing research activities related to sustainability.[18]

Probably the biggest project and the most relevant at University of Ljubljana is project ULTRA – reform of the university curriculum for a sustainable society (duration of the project: from 01.07.2022 until 31.12.2025, project value: 25.620.588,00 EUR). The investment is strategically designed to propel forward the implementation of pivotal pilot projects that focus on revamping the curricula across 29 Faculties and their professional study programs.

This comprehensive endeavor by University of Ljubljana spans a dynamic landscape, establishing inter- and multidisciplinary pilot projects that synergistically bring together multiple stakeholders in each initiative. This collaborative approach empowers University of Ljubljana to holistically confront the intricate challenges posed by the green and digital transition across a diverse spectrum of academic domains. Moreover, it positions University of Ljubljana to effectively address the societal and economic intricacies connected to the pervasive green and digital transformation reshaping our world.

A total of 11 pilot projects will be executed within the framework of this initiative, each honing in on distinct facets of this transformative journey:

1. Natural Resources and Food
2. Digital and Green Renovation of study programs
3. Innovative Learning Environments
4. Sustainable Space
5. Environmental and Digital Literacy
6. Environmental Technologies
7. The Digital Future: Navigating the trajectory of our digital landscape and its impact
8. Lifelong Learning and Micro-credentials

9. Educational Ecosystem for Digital Competences
10. Strengthening Learning and Teaching for Sustainability
11. Sustainable and Digital University of Ljubljana: Pioneering sustainable and digital practices within the university itself.

This strategic venture signifies UL's resolute commitment to not only enhancing education but also to actively contributing to the advancement of a greener, digitally informed society. Through these pilot projects, the University of Ljubljana is setting the course for a comprehensive transformation that reverberates beyond academia, nurturing sustainable progress on various fronts.

In a world where the Green STEAM challenges are growing in complexity and urgency, the University of Ljubljana's multi-pronged approach is an embodiment of a concerted effort to surmount these challenges. However, it's essential to acknowledge that this journey is ongoing, and the University remains dedicated to continually refining and expanding its initiatives. As strides are made within each of these pillars, the vision of a harmonious coexistence between human advancement and ecological equilibrium becomes increasingly attainable.

Adult education and life-long learning

In the rapidly evolving world of green technologies, the idea of lifelong learning carries significant weight. As this field progresses swiftly, people of all ages and from diverse backgrounds are acknowledging the need to continuously update their knowledge and skills. Lifelong learning acts as a bridge that spans generations, making sure that everyone can tap into the latest insights, methods, and advancements in green technologies.

The Slovenian Institute for Adult Education stands out as a prominent institution in the field of andragogy, with a keen awareness of the importance of green practices and sustainability. They're actively involved in several ongoing projects geared toward equipping the adult generation with the emerging technologies and tools that will shape our future. These projects encompass both national and international endeavors. Two especially notable initiatives are "Education for Sustainable Development, [19]" which was introduced in 2007 and is still evolving, and "Lifelong Learning of Adults for Sustainable Development and Digital Breakthrough.[20]"

These projects embody Green STEAM education, epitomizing the dynamic interplay between environmental consciousness and personal growth. In a world where sustainable practices are increasingly vital, adults are enthusiastically seizing the chance to expand their knowledge. Whether it's comprehending renewable energy systems, mastering sustainable design principles, or navigating the intricacies of eco-friendly manufacturing, adult learners are immersing themselves in a wide range of topics that directly contribute to a more sustainable future.

What sets adult learners apart is their practical life experience, enriching the learning environment. This fusion of hands-on knowledge with formal education enhances the conversation, nurturing a holistic grasp of how green technologies can seamlessly integrate into various sectors, even within their homes. Ultimately, this approach embodies our shared dedication to nurturing a generation of environmentally conscious individuals, armed with the know-how and tools to drive positive change. This commitment extends beyond personal lives, influencing the global stage as well. The journey of lifelong learning in green technologies becomes a conduit for shaping a brighter, more sustainable future for all.

EDUCATION AND TRAINING MONITOR IN STEAM

Assessing the quality of education and gauging innovative methodologies within the educational sphere is an intricate and often underappreciated endeavor. Yet, within this complex landscape, there exist studies that offer statistical perspectives on ongoing efforts in the realm of STEAM education in Slovenia. The capacity to effectively measure innovation stands as a crucial cornerstone for devising educational enhancement strategies.

In the field of quantifying inventive approaches, an analysis conducted in 2014 yielded enlightening findings. This examination revealed that among 29 countries included in the study, Slovenia secured the 9th position in terms of overall innovation in education (as depicted in Figure 4). This positioning offers a quantitative glimpse into Slovenia's progressive strides in integrating innovation within its educational framework.[21]

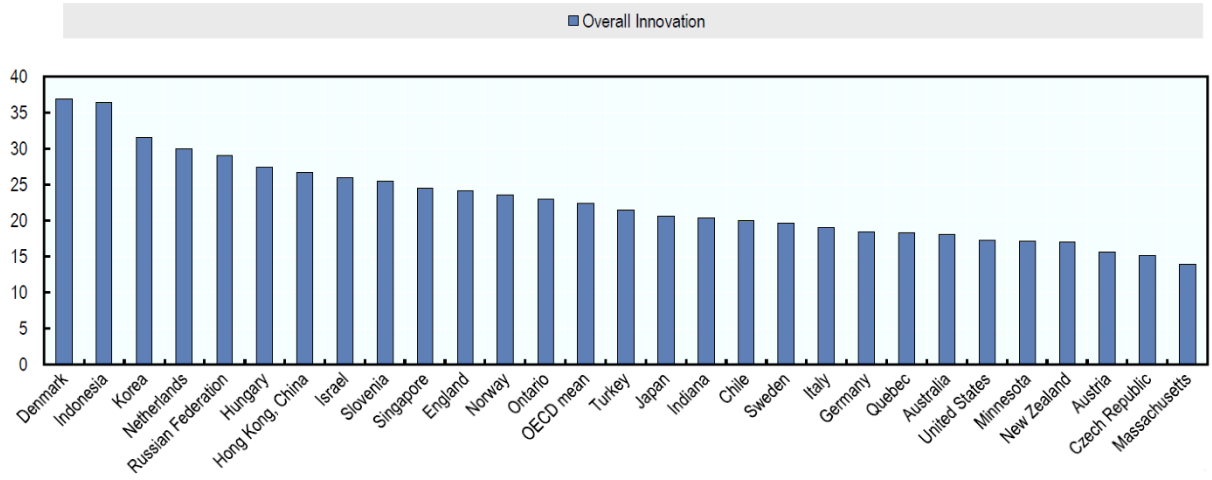

Figure 4 Overall composite innovation index, 2000-2011

Expanding on the Education and Training Monitor 2020 report,[22] as well as insights gleaned from the OECD's Programme for International Student Assessment, it's evident that Slovenia has secured a remarkably high standing in terms of student performance in STEAM subjects. Delving into specifics, it's notable that Slovenian students have demonstrated exceptional prowess, particularly excelling in the domains of Science and Mathematics (Figure 5). These students have consistently outperformed their EU counterparts in these crucial disciplines, showcasing a depth of understanding and skill that surpasses the regional average. Furthermore, the proficiency of Slovenian students in Science has even surpassed the EU's predefined target, signifying an outstanding level of attainment and proficiency. This accomplishment underscores not only the dedication of educators and institutions but also the commitment of the nation to fostering a well-rounded and advanced educational landscape.

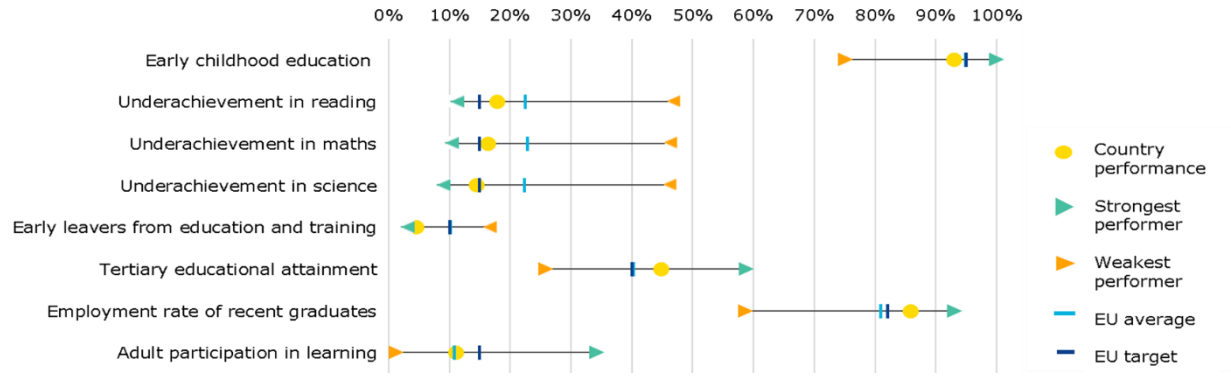

Figure 5 Position in relation to strongest and weakest performers. Slovenia position is labeled with yellow dot.

Amid these commendable achievements, it's important to acknowledge that this success is a result of concerted efforts across various sectors. Effective teaching methodologies, robust curriculum design, and the emphasis on hands-on learning experiences have all played pivotal roles in elevating the educational standards in Slovenia.

Beyond the numbers, this achievement resonates on a broader scale. It reflects the potential of a nation to equip its youth with the skills and knowledge that will shape the trajectory of future National and EU directions toward sustainable society. As the global landscape becomes increasingly reliant on STEAM disciplines, Slovenia's commitment to excellence in these subjects positions its students to become future leaders, innovators, and contributors to green fields that drive societal progress.

However, the path ahead is still unfolding, and this impressive accomplishment provides a sturdy groundwork for an unceasing journey of enhancement. As educational systems continually evolve and the requisites of the contemporary world undergo transformation, the unwavering pursuit of excellence remains a guiding principle. This unwavering commitment to nurturing critical thinking, problem-solving, and creative capacities within students ensures that Slovenia stands ready to uphold its notable standing in the domain of Green STEAM education. This positioning, in turn, contributes significantly to a future characterized by heightened technological advancements and enriched insights in pivotal areas such as Sustainable Innovation, Climate Change Mitigation, Environmental Awareness, Resilient Communities, and Global Impact.

CONCLUSIONS

STEAM education in Slovenia is undeniably charting a positive trajectory, bolstered by a resolute commitment to equipping students with the essential skills, comprehensive knowledge, and adaptable mindset crucial for excelling in a technology-driven society. At the heart of this educational evolution lies a robust emphasis on experiential learning, interweaving disciplines in a manner that ignites holistic understanding. By nurturing an environment where hands-on exploration flourishes, Slovenia is cultivating a fertile ground for students to grasp complex concepts through tangible engagement.

Intriguingly, the educational landscape in Slovenia thrives on interdisciplinary approaches, transcending the conventional boundaries of courses. This methodology not only mirrors the real-world dynamics but also cultivates in students the prowess to connect ideas across seemingly disparate domains. As a result, learners are equipped to tackle multifaceted challenges by approaching them from myriad angles, fostering an innovative mindset that holds tremendous potential.

Moreover, Slovenia's strategic partnerships with industries amplify the real-world applicability of education. By bridging academia and industry, students gain access to practical insights, cutting-edge developments, and the opportunity to work on projects that mirror actual professional scenarios. This symbiotic relationship enhances the quality of education while also preparing students to make meaningful contributions as they transition into the workforce.

In essence, Slovenia's dynamic approach to STEAM education is a strategic investment that doesn't merely create proficient graduates; it shapes proactive problem solvers and forward-thinking innovators. This transformative education isn't confined to national borders—it reverberates globally. The solutions incubated within Slovenian classrooms hold the potential to address not only local challenges but also the broader spectrum of global issues, from environmental sustainability and resource management to health advancements and technological breakthroughs. In this way, Slovenia is carving a path towards systematically introducing sustainability and green transition in education that extends far beyond the classroom, shaping a future where knowledge and ingenuity act as driving forces for progress.

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

STEM education in Greece

The rapid changes in scientific, social and political culture point to reorientations of the curricula as well as the development of new career opportunities, mainly related with Sciences, Technology, Engineering, and Mathematics (STEM). The current view for STEM education, the so called integrated STEM education, gets above the notion of high quality education in the STEM fields.

Integrated STEM education concerns the incorporation of real - authentic world problems in the teaching process. This approach involves Engineering (E) not as a separate discipline, but as a way of thinking and solving problems by taking into account the restrictions of the real world. Integrated STEM education aims at the development of cognitive skills as well as the development of the 21st century competences (critical thinking, creativity, collaboration, communication). Integrated STEM approaches are transdisciplinary and interdisciplinary and follow student-centered constructivist instructional models, such as inquiry-based and project-based learning. Recently, STEM involves other fields such as culture and is called STEMAC.

One dimension of STEM education is to solve environmental problems (Widya et al., 2019). This is towards the direction of the so-called recently “Green STEM” education, “the intersection between STEM and Environmental Education” (Garcia-Piqueras, & Ruiz-Gallardo, (2021). Yean and Abdul Rahim note that “Sustainable Development and sustainability, lies at the heart of Green STEM” (2021). Green or Greening STEM education, concerns the desing and development of environmentally-centred programs that add value to students lives and well-being, and contribute to the school community (social world). As mentioned above, a third synonymous term that is used to describe Greening or Green STEM education is Education for Sustainable Development.

Lately, various organisations are interested in Green STEM education. The National Environmental Education Foundation (NEEF) in USA, claims that by “incorporating elements of placed-based learning, three-dimensional learning, project-based learning, and community-based learning, the Greening STEM approach increases students' academic achievement, strengthens their ties to their community, and encourages a deeper appreciation for the environment” (https://www.neefusa.org/what-we-do/k-12-education/greening-stem-hub/greening-stem-approach).

In the same line, the National Oceanic and Atmospheric Administration (NOAA, USA) supports that through Green STEM education, students respond to “challenges in the natural environment” (https://www.noaa.gov/education/stories/environmental-education-shows-what-it-means-to-do-green-stem).

In the following sections, we provide information about STEM education in Greece and recommendations for certain actions.

The state of STEM education in Greece

STEM education in elementary and secondary education

STEM education in Greece is met at all levels of education, starting from preschool to tertiary education. In elementary and secondary education, STEM education is involved into a subject called "skills' workshops", taught in preschool, elementary, and secondary education. Following this approach, STEM education focusses on the development of scientific attitudes and values through educational activities in terms of constructivist learning approaches. Specifically, the "skills' workshops" called "skills development laboratories", "create and innovate – creative thinking and initiative" describe four thematic units, coming from the Global Sustainable Development Indicators (environment, well-being, security, civil society, modern technology and entrepreneurship) (http://iep.edu.gr/el/psifiako-apothetirio/skill-labs/1008-stem-steam).

The "skills' workshops" subject, proposes targeted STEM skills development, which are grouped in cycle as follows:

C) Technology, engineering, and science skills

C1. Technology skills (Skills for creating and sharing digital creations, Skills for analyzing and producing content in printed and electronic media, Skills for interdisciplinary and cross-curricular use of new technology).

C2. Media Management Skills (Information Literacy, Digital Literacy, Technology Literacy, Media Literacy, Internet Safety).

C3. Robotics (Modeling and simulation skills, Scientific/computational thinking).

STEM education in higher education

In tertiary education, STEM education appears as undergraduate and postgraduate courses, master's programs, doctoral topics, as well as further training seminars (e-learning seminars). Since Universities design their own curricula, STEM courses appear in various Departments. The "STEM education" course, is an example at undergraduate level in the Department of Primary Education, University of Ioannina (https://ptde.uoi.gr/wp-content/uploads/dee808e.pdf).

Regarding master's programs, table 1 presents three programs offered by Greek Universities.

Table 1. Three Master programs related to STEM education.

Program name	URL
"STEM education and Educational Robotics Systems", University of Athens	https://stemroboticspostgrad.webnode.gr/
"Educational Applications with STEM Epistemology", University of Thessaly	http://stem.cs.uth.gr/
"Robotics, STEAM and New Technologies in Education", International University	https://steam.dipae.edu.gr/

Recommendations

To improve the state of STEM education in Greece, its scope and impacts on science teacher education trends, policies, practices and challenges, the following implementation actions are recommended:

- Teachers professional development programs through synchronous and asynchronous (e.g., moocs) workshops.
- Guidelines design for educational approaches to STE(A)M and Green STEM education.
- Development of a prototype Green STEM educational scenario and a series of senarios.
- Develoment of a series of digital educational resources and learning objects tosupport Green STEM eduvcational scenarios.
- Development of a website that hosts digital learing objects, digital educational resources and senarios.

Common priorities for innovations and changes

Establishing STEM centers

STEM centers that advance research and practice in STEM education may be developed by secondary, tertiary educational level structures as well as other orginizations.

National structures called “Science Laboratory Centers” (EKFE) exist in every region in Greece, directed by the secondary education directorates. EKFE design and develop science experiments for both secondary and elementary education. They are addressed to both teachers’ professional development and students’ learning. These structures may incorporate STEM activities and act as STEM centers.

STEM centers may be also created by Universities in the context of STEM courses or programs.

A third case are the private “STEM education” organizations, which involve STEM activities for school children.

The above three cases may include Green STEM activities to promote Sustainable Development and sustainability. They may organize workgroups and workshops, stakeholders and experts, and act as open schooling Green STEM actions.

Reforming STEM education curriculum

We focus on rethinking and structuring STEM education programs that promote teacher self-efficacy toward integrated STEM as an approach to teaching and learning and empowering students through procedural, conceptual, and applicable problem-solving skills. New methids need to be developed and tested to accelerate changes in teaching practices in order to design, apply and monitor progress STEM education, which could start from early years of schooling. A set of STEM strategy indicators could be developed and used in STEM and Geen STEM education. A well designed STEM framework would meet new demands of STEM education and attract more students to STEM careers.

Several standard educational scenarios specialized in "Green STEM" and an empirical study on the effectiveness on the proposed educational scenarios would provide practice and important outcomes for future work. The designed activities and the use of real and digital educational resources in supporting teachers in their efforts would challenge students meaningfully.

Analysis of the applicability of the common priorities

Analyzing the applicability of the common priorities in STEM education in Greece, a context aligned with the key areas for Greece is provided.

There seems to be a gap in STEM education in Greece regarding resources that could be applied in authentic educational settings, namely STEM activities. Considering the recommended indicators, STEM education reform could reach long-term human capacity for community development based on science literacy, inclusion and evidence-based practices.

Our strategy of linking carefully designed interdisciplinary educational scenarios provides a framework for cooperation and co-creation among STEM-related research, education, and other relevant stakeholders. This priority is important for Greece as it leads to research, innovation, enterprise and employability. Regarding research, a STEM strategy in Greece would place the institutions as STEM leaders and strengthen their engagement with stakeholders. Sharing and synthesizing research contributes to findings evaluation that identify successful STEM interventions and inform school practice.

Through these processes students could improve their attitudes toward STEM and increase their intentions to STEM career orientation. Acquiring awareness of the range of STEM careers that are available for students with high STEM skills and knowledge, they could take advantage of new job opportunities and contribute to country' s economic growth, technological advancement, social and cultural support. A well-structured plan for cooperation can attract public and private funding for research and development projects. This funding can support advanced research initiatives, technological development, and interdisciplinary connections within research and educational settings.

Conclusion

The proposed professional development of teachers, the creation of a series of real-life and digital educational resources, as well as the formation of STEM centers, facilitate the integration and assessment of STEM education into curricula. A well designed STEM strategy based on interdisciplinary connections enables priorisation on investment and curriculum planning for Greece.

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