

## STEM Teaching in Contemporary Education

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### Abstract

The education system serves as the primary producer of human capital, responsible for training competent personnel essential for the country's economic progress and rapid technological and economic development. Therefore, the educational standard aims to equip students with knowledge and skills necessary to capitalize on humanity's rapid progress, utilize modern achievements, and become active members of society. Moving beyond passive recipients of knowledge, students should transform into active learners capable of applying acquired knowledge for professional success and societal benefit. The paper explores the objectives of technical and science education, effectively implemented through STEM (Science, Technology, Engineering, and Mathematics), an interdisciplinary practical teaching approach. STEM education empowers children to engage in experiments, make mistakes, and draw conclusions based on personal experiences rather than solely relying on textbook information. This approach fosters active student participation and cultivates competencies such as creative and critical thinking, independent information processing, imagination, and interpretation skills. Moreover, STEM education plays a crucial role in shaping future professions that contribute to national development. While important projects have been implemented within the framework of the Millennium Program of the General Education School of Georgia to train STEM specialists, further efforts are needed. Effective school education and professional personnel training require a conducive school culture, qualified teachers, and abundant educational resources. To address this issue, our research utilized quantitative and qualitative methods, including questionnaire development, literature review, and analysis of international and local projects and training programs. These efforts aim to lay the groundwork for the preparation of STEM specialists. The paper seeks to answer key questions: Who should teach STEM, and how should STEM be taught? By ensuring the education of future generations capable of contributing to the country's economic development, political stability, and security, we aim to foster a prosperous and sustainable society.

**KEY WORDS:** *STEM education, future professions, interdisciplinary approach, innovative technology, contemporary challenges*

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### 1. Introduction

The education system functions as the cornerstone of societal development, serving as the principal engine for the cultivation and refinement of human capital. Within this framework, educational institutions play an important role in nurturing individuals with the fundamental knowledge, skills, and competencies to meet the demands of an ever-evolving global landscape. By equipping students with a solid educational foundation, the education system lays the groundwork for their subsequent contributions to various sectors of society, including the workforce, academia, and research and development.

One of the primary responsibilities of the education system is to train competent personnel who are indispensable for driving the nation's economic progress and facilitating rapid technological advancements. These competent individuals serve as the catalysts for innovation, entrepreneurship, and economic growth, thereby propelling the country forward on the path of prosperity and sustainable development.

Through rigorous academic curricula, hands-on learning experiences, and comprehensive skill-building initiatives, educational institutions endeavor to produce a skilled workforce capable of addressing contemporary challenges [11] and seizing emerging opportunities in the global marketplace.

The educational standard aspires to empower students with the requisite knowledge, competencies, and skills essential for navigating and thriving in an era characterized by rapid advancements and transformations across various domains of human endeavor. In recognizing the dynamic nature of contemporary society, educational institutions endeavor to equip learners with the tools and capacities necessary to adapt, innovate, and contribute meaningfully to the collective progress of humanity. Central to this endeavor is the cultivation of a diverse range of knowledge domains, spanning from the sciences and technology to the humanities and arts, thereby fostering a well-rounded and holistic educational experience. By imparting a broad spectrum of knowledge, educational institutions seek to provide students with a comprehensive understanding of the world around them and enable them to engage critically with complex issues and challenges facing society. Moreover, the educational standard emphasizes the acquisition of practical skills and competencies that enable students to harness modern achievements and technologies effectively. From digital literacy and information fluency to critical thinking and problem-solving skills, students are encouraged to develop a versatile skill set that empowers them to leverage the latest tools and resources for personal and collective advancement.

Transitioning from mere recipients of knowledge to active participants in the learning process is paramount in modern education. Rather than passively absorbing information [17] students are encouraged to engage actively with course material, apply critical thinking skills, and seek connections between concepts and real-world contexts [19]. This shift in educational philosophy acknowledges that learning is not merely about memorizing facts but rather about understanding concepts deeply and being able to apply them in diverse situations. Active learning strategies, such as collaborative projects, problem-based learning, and experiential learning activities, are instrumental in fostering student engagement and promoting deeper understanding [12]. Through hands-on experiences and interactive tasks, students have the opportunity to explore concepts in depth, experiment with different approaches, and gain practical skills that are applicable beyond the classroom.

Furthermore, the educational standard aims to instill in students a sense of civic responsibility nurturing their capacity to become active and engaged members of society. By fostering values such as collaboration, empathy, and social awareness, the educational system aims to prepare students to contribute positively to their communities and address societal challenges. In essence, the educational standard is designed to prepare students not only for academic and professional success but also for active participation in civic life. By equipping learners with the knowledge, skills, and values necessary to navigate an increasingly complex and interconnected world, the educational standard lays the foundation for a more inclusive, equitable, and prosperous society.

## **2. Basic Principles of STEM Education**

One of the basic principles of STEM education is the transformation of students into active learners capable of applying acquired knowledge for professional success and societal benefit, accordingly requiring a shift towards active, constructive learning pedagogies, professional skills development initiatives, and opportunities for civic engagement. By embracing these principles, educators can cultivate a generation of empowered and socially conscious individuals who are equipped to make a positive impact on the world. The paper delves into the fundamental goals of technical and science education and examines how these objectives are realized through the implementation of STEM (Science, Technology, Engineering, and Mathematics) education representing a holistic and interdisciplinary approach to teaching and learning that integrates concepts and principles from multiple disciplines to solve real-world problems [10].

At its core, the primary objective of technical and science education is to equip students with the knowledge, skills, and competencies necessary to succeed in an increasingly complex and technology-driven world. This includes cultivating a deep understanding of scientific principles, technological advancements, engineering design processes, and mathematical reasoning [13]. By developing proficiency in these areas, students are better prepared to navigate the challenges and opportunities of the modern workforce and contribute to innovation and progress in various fields [25]. STEM education serves as a conduit for achieving these objectives by providing students with engaging and hands-on learning experiences that bridge the gap between theory and practice. Through project-based activities, experiential learning opportunities, and collaborative problem-solving tasks, students are able to apply their knowledge and skills in authentic contexts and gain a deeper appreciation for the interconnectedness of STEM disciplines [3]. Moreover, STEM education emphasizes the development of critical thinking [4], creativity communication, and collaboration skills [29], which are essential for success in the 21st-century workforce. By encouraging inquiry-based learning and fostering a growth mindset, STEM education empowers students to think critically, explore innovative solutions to complex problems, and work effectively in teams.

The paper aims to shed light on the transformative potential of STEM education in achieving the objectives of technical and science education. By examining the principles, practices, and outcomes of STEM education, we can gain insights into how to prepare students for success in an increasingly interconnected and technology-driven world.

### **21.1. STEM education promoting lifelong competences**

STEM education empowers children by providing with opportunities to engage in hands-on experiments, allowing them to explore scientific concepts firsthand and develop a deeper understanding of the world around them [14]. Through experimentation, students have the freedom to explore, test hypotheses, and make discoveries, fostering curiosity and a sense of wonder about the natural world. Furthermore, STEM education encourages students to embrace failure as an essential part of the learning process. By allowing children to make mistakes and learn from them, STEM education cultivates resilience, perseverance, and problem-solving skills [27]. When students encounter challenges or setbacks during experiments, they are

encouraged to analyze their mistakes, revise their approach, and try again, reinforcing the idea that failure is not a deterrent but rather an opportunity for growth and learning.

Moreover, STEM education emphasizes the importance of drawing conclusions based on personal experiences and empirical evidence rather than relying solely on textbook information. Through STEM education, children learn to approach problems with curiosity, creativity, and an open mind, preparing them to tackle the complex challenges of the 21st century. By fostering a culture of experimentation, resilience, and critical thinking, STEM education equips students with the skills and mindset necessary to thrive in an ever-changing world. This approach to STEM education fosters active student participation by encouraging students to take an active role in their own learning process [25]. Instead of passively receiving information from teachers, students are actively engaged in hands-on activities, experiments, and projects that require them to think critically, solve problems, and collaborate with their peers [12]. Through active participation in STEM activities, students develop a range of competencies that are essential for success in the 21st century. One of the key competencies cultivated by STEM education is creative thinking. By engaging in open-ended tasks and projects, students are encouraged to think outside the box, explore alternative solutions, and come up with innovative ideas. Creative thinking skills enable students to approach problems from multiple perspectives, leading to more innovative and effective solutions.

In addition to creative thinking, STEM education also cultivates critical thinking skills [21]. Students learn to analyze information, evaluate evidence, and make reasoned judgments based on evidence. Critical thinking skills enable students to question assumptions, challenge existing ideas, and develop well-reasoned arguments. By honing their critical thinking skills, students become more discerning consumers of information and empowered to become independent thinkers and lifelong learners, better equipped to navigate the complexities of the modern world.

STEM education also promotes independent information processing skills. Through research projects and inquiry-based learning activities, students learn how to gather, evaluate, and synthesize information from multiple sources [16]. They develop the ability to think critically about the reliability and validity of information, discerning between fact and opinion, and making informed decisions based on evidence.

Furthermore, STEM education encourages the development of imagination and interpretation skills. Students are encouraged to explore their creativity, think imaginatively, and envision new possibilities [23]. They learn to interpret data, analyze patterns, and make connections between different concepts and disciplines. Imagination and interpretation skills enable students to see the world in new ways, fostering a sense of curiosity and wonder about the world around them.

STEM education promotes practicability, nurturing a mindset focused on real-world application rather than abstract theory. By emphasizing hands-on learning experiences and project-based activities, STEM education encourages learners to become creators and innovators, actively engaging in the design and development of solutions to complex problems [9]. This approach fosters a culture of experimentation and exploration, empowering individuals to apply their knowledge and skills in practical ways to address societal challenges and drive positive change. Ultimately, STEM education cultivates a generation of progressive doers who are equipped to make meaningful contributions to society through their ingenuity, creativity, and problem-solving abilities.

Thus, STEM education grows future professionals who are equipped with the interdisciplinary skills and knowledge needed to thrive in a rapidly evolving world [28]. By integrating science, technology, engineering, and mathematics disciplines, STEM education prepares individuals to tackle complex challenges and seize opportunities in diverse fields such as healthcare, engineering, computer science, environmental science, renewable energy, and environmental sustainability. Through collaborative projects and real-world applications, STEM learners develop critical thinking, communication, and teamwork skills essential for success in the global workforce. Moreover, STEM education fosters a spirit of innovation and entrepreneurship, empowering individuals to drive economic growth, fuel technological advancement, and shape the future of industries and societies worldwide.

## **21.2. STEM promoting future professions**

In today's rapidly evolving technological landscape, the demand for skilled STEM professionals is increasing across industries. STEM education ensures that students are well-prepared to meet this demand and excel in the careers of the future. For example, advancements in fields like artificial intelligence, robotics, and biotechnology require a workforce with strong STEM backgrounds to drive innovation and address complex challenges. STEM education fosters a culture of innovation and entrepreneurship, empowering students to develop new technologies, products, and solutions that address societal needs and drive economic growth. By encouraging students to think creatively, take risks, and pursue their ideas, STEM education nurtures the next generation of innovators and leaders who will shape the future of their industries and communities. Overall, STEM education is essential for building a skilled workforce, driving innovation, and fostering economic development in the 21st century [1]. By preparing students for careers in high-demand fields and empowering them to become innovators and problem solvers, STEM education lays the foundation for a prosperous and sustainable future.

## **3. Methodology**

To address the challenges and complexities surrounding STEM education and the preparation of STEM specialists, our research employed a comprehensive methodology that combined quantitative and qualitative approaches. Quantitative methods were utilized to gather numerical data and statistical insights, providing a quantitative understanding of various

aspects related to STEM education. These methods included the development and administration of questionnaires to gather data from stakeholders such as students, teachers, and policymakers.

Within a study, 20 public and private school principals, 80 teachers, and 200 pupils and BSU students were interviewed. In addition to quantitative methods, qualitative approaches were employed to gain deeper insights into the subjective experiences, perceptions, and motivations of individuals involved in STEM education. This involved conducting literature reviews to explore existing research, theoretical frameworks, and best practices in STEM education. The literature review process involved synthesizing findings from a diverse range of sources, including academic journals, books, reports, and policy documents, to inform our understanding of the current landscape of STEM education and identify gaps or areas for further exploration. Furthermore, qualitative analysis techniques were applied to analyze data collected from international and local projects and training programs in the field of STEM education. By examining program evaluations, and qualitative research findings, we sought to identify promising practices, innovative approaches, and challenges encountered in the implementation of STEM initiatives.

The qualitative analysis helped to contextualize our findings within the broader educational landscape and provided valuable insights into effective strategies for preparing STEM specialists. Overall, our research efforts aim to lay the groundwork for the preparation of STEM specialists by employing a rigorous and multidimensional research methodology. By integrating quantitative and qualitative methods, conducting thorough literature reviews, and analyzing real-world examples, we sought to generate actionable recommendations and evidence-based insights to inform policy, practice, and future research in the field of STEM education.

The paper seeks to answer key questions: Who should teach STEM, and how should STEM be taught? In addressing these questions, our paper delves into the multifaceted nature of STEM education and the diverse roles of educators in facilitating effective learning experiences for students. One key consideration is the qualification and expertise of teachers in the STEM disciplines. We explore the qualifications, training, and professional development opportunities necessary for the effective implementation of STEM teaching. This includes discussing the importance of content knowledge, pedagogical skills, and technological proficiency in preparing teachers to deliver high-quality STEM instruction.

#### 4. Research Findings

The research conducted with school principals provided the following insights. Regarding the first question on What is STEM education? The directors provided the following responses: "STEM refers to the integrated teaching of science, technology, engineering, and mathematics"; "STEM is the core of integrated learning"; "The integrated teaching of various subjects encompasses the following fields: natural science, technology, engineering, and mathematics"; "STEM education involves developing research skills and promoting project-based learning in students from an early age".

Who should teach STEM? According to the interviewed principals, 40% believe that STEM should be taught by mathematics teachers, 20% by physics teachers, and the remaining 40% considers it should be taught by other educators.

Does your school conduct STEM teaching? The majority of respondents, 18 principles, stated that STEM is not taught at school at all. Others admired that it is taught through project-based learning or partially, while integrating it into the teaching of various subjects.

Should technology, engineering, and programming be taught in contemporary schools? If so, how? The responses were as follows: "As desired"; "Yes, an appropriate space and a specialist should be allocated to ensure the inclusion of students interested in this direction in research projects".

What are some ways generating interest in STEM education and engaging students in STEM subjects? The principals provided the following responses: employing professional teachers, encouraging students through the implementation of projects tailored to their interests in science, technology, or related fields, and ensuring schools are equipped with appropriate infrastructure.

To the question - what is needed for Georgia to provide transition from a consumer of technology to a producer? We received the following responses from the directors: "The authorities should invest more money in education"; "Promoting interest in STEM education and student engagement in STEM subjects"; "It is necessary at the state level to begin opening appropriate enterprises and employment opportunities for the population, which will increase interest in this field".

When asked which is the most effective methodology for teaching STEM subjects in the modern educational space, the respondents named: Interesting activities, Project-based learning, Inquiry-based learning, Differentiated teaching, Experiments for STEM literacy development, Inquiry-based learning, among others.

In response to the question about the attitude of teachers/students towards STEM education, the principals noted: "Neutral"; "Positive"; "Teachers' attitudes toward STEM education may vary based on many factors, including culture, socioeconomic status, education, personal interests, and perceived desire for resources and knowledge. Consequently, students may also show less interest in this direction".

The directors' answer to the question: How do socioeconomic factors affect access to quality STEM education? "Socioeconomic factors have a 100% impact", "They directly affect", "Official-economic factors can significantly affect access to quality STEM education in several ways, primarily through financial resources, school funding inequality, and parents' involvement and education. If the school is provided with all the necessary resources, the quality will be high, but unfortunately, there is no proper infrastructure in the schools."

What challenges do educators face when implementing project-based learning in STEM subjects?" Teachers find it difficult to work with technologists"; "Technological resources and their correct use"; "It is important that teachers used various modern methods, project-based teaching, etc."; "Teachers do not have the necessary resources and space to implement projects, and it is necessary to integrate different subjects"; "They don't have the appropriate environment, laboratory or infrastructure."

The survey conducted with teachers provided the following responses to the question - What is STEM education? What does STEM mean? Some teachers mentioned: "STEM stands for Science, Technology, Engineering, and Mathematics"; "STEM is about joint teaching and integration of different subjects"; "It is a teaching method that combines subjects such as physics and mathematics"; "STEM focuses on learning science, technology, engineering, and mathematics so that students can relate what they have learned to everyday life and future plans. This enables them to see the practical significance and be able to apply these concepts".

To the question - Who should teach STEM? 60% of the surveyed teachers named the physics teacher, 20% named the math teacher, and 20% mentioned - others.

To the question - Is STEM taught in your school? 80% of the respondents answered "no", 5% stated that it is taught in the form of projects, and 15% mentioned that it is integrated into daily learning and used in the teaching process, as well as in the format of informal education within various activities.

To the question - What is needed in order for students to be interested in STEM education? Some of the respondents consider: technologies and innovative approaches, raising awareness, interest in demonstration lessons in laboratories, increasing the level of awareness in school communities.

What challenges do educators face in implementing project-based learning in STEM subjects? We received the following answers: one challenge is the competence to use technologies, as students may have difficulty understanding the essence of the project and working on it. Additionally, educators often face the challenge of insufficient resources.

Should STEM be taught in modern schools? Almost 98% of respondents confirmed the need to teach STEM.

How can STEM be integrated into education to improve learning outcomes? The teachers suggested the following option: by embedding it into projects, technology can be taught from elementary school. This approach will undoubtedly create a strong foundation for the future in all the mentioned areas, despite the challenges faced in its implementation. 10% of respondents stated that they do not know.

What is needed for Georgia to promote transition from being a consumer to a producer of technology? According to the interviewed teachers, it requires having adequate technology resources and teaching the meaning and essence of production from the primary level. Additionally, training teachers and providing relevant services from the primary level, along with appropriate technological and internet support for schools, are essential.

The results of a survey conducted among pupils and students. When asked, "What is STEM education?" 40% of the respondents answered, "I don't know." 15% mentioned "engineering and mathematics," another 15% described it as "a chance to deepen their knowledge of science and technology," and 30% stated that "STEM education is an innovative teaching method that considers the integrated teaching of science subjects, which in turn is focused on practical teaching."

The comments of some students regarding the mentioned question: "STEM is a set of academic disciplines whose teaching has a special role in the development of a child's technical skills"; "STEM provides a paradigm shift in early childhood education and seeks to sustain children's curiosity and genius into adulthood"; "STEM education is a branch of pedagogy that is adapted to the younger generation and helps to increase motivation in children. It is focused on practical teaching, which contributes to the development of the student; "STEM education involves combining 4 scientific subjects with modern approaches and all the subjects that a child needs"; "STEM education includes creativity, development in many aspects. A chance to deepen the knowledge of science and technology"; "It is a teaching method in which subjects are taught sequentially and not in isolation. It focuses on bridging the learning gap by placing children at the center of the experience, turning them into active learners and not passive listeners"; "STEM education is an innovative method of teaching that considers the integrated teaching of science subjects, which in turn is focused on practical learning"; "STEM offers a paradigm shift in early childhood education, aiming to sustain children's curiosity and ingenuity into adulthood."

To the question - What subjects does STEM include? 30% of the surveyed respondents state that they do not know; 15% mentioned Science, technology, engineering, and mathematics (STEM); 15% cited mathematics, physics, chemistry, engineering; 10% referred to biology, physics, chemistry; 15% mentioned information technologies, engineering, natural sciences, and mathematics; 5% specified mathematics, physics, chemistry; 10% indicated "STEM means technology, engineering, mathematics, and science (including social sciences: psychology, economics, sociology).

Does your school teach STEM? 35% of respondents stated – No; 25% mentioned "science subjects are taught separately, not integrated "; 20% responded yes, STEM is taught at my school. I think this is a new teaching method that should be in every school because it is very necessary in the 21st century; 20% indicated it is taught through projects conducted in different subjects.

Should technology, engineering, and programming be taught in a modern school? How should it be taught? We received the following responses: "Yes, it should be taught." This should be done using modern technologies and systems"; "These subjects must be taught by a competent teacher who knows the subject well"; "There should be a dedicated class for STEM because it involves practical teaching"; "Yes, studying technological subjects is necessary because our modern world demands it"; "The 21st century is the era of technology, where subjects like engineering, programming, and technology should be taught from an early age"; "Definitely, it should be taught by qualified teachers, and students should understand the purpose and significance of their studies"; "Complex subjects should not be taught at school. School is a place to establish

an elementary foundation"; "I believe that STEM should become an integral part of the school curriculum; it equips students with fundamental knowledge in the fields of science"; "Yes, it should be taught at least at a basic level"; "Yes, solely studying theories cannot motivate students as much as practical activities. Through practical application, students can understand and engage with the subject matter more profoundly"; "It should be taught practically, tailored to the students' interests, with the aim of fostering their development and discovering new possibilities within them"; "Of course, it should be taught. These professions are the professions of the future, so it is essential to master them from a young age"; "Yes, not with theoretical material but with practical work, because it's boring to learn only theory. It will be more interesting to learn STEM by doing."

As the research showed, most of the interviewees do not have information about STEM education as it is conducted just in 2 private schools in Batumi. Some of the respondents believe that STEM includes engineering, mathematics, programming, technology, and physics. Others believe that it involves integrating chemistry, biology, and mathematics. Students reveal the knowledge of STEM teaching foundations.

The analysis of the qualitative and quantitative research results showed us that STEM should become an integral part of the school curriculum, providing students with fundamental knowledge and preparing them for practical life in the future.

## 5. Recommendations for Educational Environment Promoting STEM Education

Research findings highlight the need to train teachers with appropriate STEM competence. While significant strides have been made through initiatives like the Millennium Program of the General Education School of Georgia to train STEM specialists [15], there remains a pressing need for further efforts to fully realize the potential of STEM education. Despite the progress achieved, challenges persist in ensuring equitable access to quality STEM education, fostering a supportive learning environment, and addressing gaps in teacher preparation and professional development.

To facilitate the effective teaching of STEM education, the article outlines activities and initiatives aimed at enhancing the effectiveness of STEM education programs:

1. Curriculum Development: Regular review and updating of STEM curricula to align with evolving industry needs and technological advancements.
2. Teacher Training and Support: Providing comprehensive training programs and ongoing support for STEM educators to ensure they have the necessary skills and resources to deliver high-quality instruction.
3. Student Engagement: Implementing innovative teaching methods and extracurricular activities to engage students and foster their interest in STEM fields from an early age.
4. Community Engagement: Collaborating with local communities, businesses, and organizations to create hands-on learning experiences and real-world applications of STEM concepts.
5. Technology Integration: Leveraging technology tools and resources to enhance teaching and learning experiences, including virtual labs, and interactive simulations.

By prioritizing these activities and initiatives, stakeholders can build a strong foundation for STEM education and prepare the next generation of innovators and problem solvers.

STEM students need to develop proficiency in a wide range of subjects to succeed in their academic pursuits and future careers. Some of the key subjects include:

1. Science: Understanding fundamental scientific principles, conducting experiments, and analyzing data across disciplines such as biology, chemistry, physics, and environmental science.
2. Technology: Mastering technological tools and platforms, coding languages, and software applications to solve problems, design solutions, and innovate in fields like computer science, engineering, and information technology.
3. Engineering: Applying mathematical and scientific principles to design, build, and test structures, machines, systems, and processes in areas such as civil engineering, mechanical engineering, electrical engineering, and aerospace engineering.
4. Mathematics: Developing strong mathematical reasoning, problem-solving, and analytical skills to tackle complex problems and models in fields like algebra, calculus, geometry, statistics, and data analysis.

To support STEM education in secondary and higher schools, a variety of programs and initiatives should be introduced, including:

1. Project-Based Learning (PBL): Implementing hands-on, inquiry-based projects that allow students to explore real-world problems, collaborate with peers, and apply STEM concepts in authentic contexts.
2. STEM Clubs and Competitions: Establishing extracurricular clubs and participating in competitions like robotics challenges, science fairs, and coding competitions to foster student interest and engagement in STEM fields.
3. Career Exploration Programs: Providing opportunities for students to interact with STEM professionals, visit workplaces, and participate in internships or job shadowing experiences to gain insight into potential career paths and industry expectations.
4. Maker Spaces and Innovation Labs: Creating dedicated spaces equipped with tools, materials, and technology for students to design, prototype, and test their ideas, fostering creativity, experimentation, and entrepreneurship.
5. Professional Development for Teachers: Providing ongoing training, workshops, and resources for educators to stay updated on the latest pedagogical approaches, technology tools, and content knowledge in STEM disciplines.

By implementing these programs and initiatives, educational institutions can create a dynamic learning environment that inspires curiosity, cultivates critical thinking, and prepares students for success in STEM fields and beyond. By building

upon the foundation established by existing STEM initiatives and committing to ongoing collaboration and investment, educational experts can work together to address the challenges and opportunities associated with STEM education.

### **5.1. STEM teachers equipped with diverse range of competences**

Central to the success of any educational endeavor are qualified and competent teachers who possess the knowledge, skills, and pedagogical expertise necessary to facilitate student learning effectively. STEM teachers play a vital role in preparing students for success in today's rapidly evolving world. To effectively teach STEM subjects and inspire students' interest in these fields, STEM teachers require a unique set of skills and competencies. Some key skills and competencies for STEM teachers include:

1. **Content Knowledge:** STEM teachers must have a strong foundation in the subject areas they teach, including deep knowledge of scientific principles, mathematical concepts, engineering principles, and technological applications. They should stay updated on advancements in their respective fields to provide students with accurate and relevant information.
2. **Interdisciplinary Thinking:** STEM education emphasizes the integration of concepts from multiple disciplines. STEM teachers should have the ability to make connections across different subject areas and demonstrate how concepts in science, technology, engineering, and mathematics are interconnected.
3. **Problem-Solving Skills:** STEM teachers should be skilled in problem-solving techniques and be able to guide students through the process of identifying, analyzing, and solving real-world problems using scientific inquiry and mathematical reasoning. They should encourage students to think critically and creatively to develop innovative solutions.
4. **Hands-On and Inquiry-Based Learning:** STEM education often involves hands-on, experiential learning experiences that allow students to explore STEM concepts through inquiry and experimentation. STEM teachers should design engaging and interactive lessons that encourage active participation and foster a spirit of curiosity and exploration.
5. **Technology Integration:** Technology plays a significant role in STEM education. STEM teachers should be proficient in using various digital tools, software applications, and multimedia resources to enhance instruction, conduct simulations and virtual experiments, and facilitate collaborative learning experiences.
6. **Innovative Thinking:** STEM teachers should cultivate a culture of innovation in the classroom by encouraging students to think creatively, explore new ideas, and approach problems from multiple perspectives. They should provide opportunities for students to brainstorm, experiment, and take risks in their learning process. By fostering an atmosphere of innovation, STEM teachers empower students to develop the confidence and resilience needed to tackle complex challenges and propose novel solutions.
7. **Communication Skills:** Effective communication is essential for STEM teachers to explain complex concepts, facilitate discussions, and provide feedback to students. They should be able to communicate clearly and effectively both verbally and in writing, adapting their communication style to meet the needs of diverse learners.
8. **Critical Thinking and Analytical Skills:** STEM teachers should foster students' critical thinking skills by challenging them to analyze data, evaluate evidence, and draw logical conclusions. They should encourage students to ask questions, explore multiple perspectives, and think critically about scientific phenomena and mathematical problems.
9. **Collaboration and Teamwork:** STEM education often involves collaborative projects and teamwork. STEM teachers should facilitate opportunities for students to work together in groups, communicate effectively, and collaborate on complex tasks and projects that require interdisciplinary approaches.
10. **Continuous Learning and Professional Development:** STEM fields are constantly evolving, and STEM teachers should engage in ongoing professional development to stay updated on current trends, research findings, and best practices in STEM education. They should be open to learning new instructional strategies, technologies, and pedagogical approaches to enhance their teaching effectiveness.

Overall, effective STEM teachers possess a diverse range of skills and competencies that enable them to engage, inspire, and empower students to become critical thinkers, problem solvers, and innovators in STEM disciplines. By nurturing students' interest and proficiency in STEM subjects, STEM teachers play a crucial role in preparing the next generation of scientists, engineers, technologists, and mathematicians to address global challenges and drive positive change in the world.

### **5.2. Educational resources creating enriching environment**

The availability of abundant educational resources is essential for creating engaging and enriching learning environments. These resources may include textbooks, laboratory equipment, digital learning tools, multimedia resources, and access to educational technology. In addition to the mentioned resources, effective STEM teaching also requires access to a variety of supplementary materials and support systems that facilitate hands-on learning, collaboration, and real-world application of concepts. Here are some other resources that are crucial for effective STEM teaching:

**STEM Kits and Materials:** Teachers need access to specialized STEM kits and materials that allow students to engage in hands-on experimentation and exploration. These kits may include robotics kits, engineering design materials, 3D printers, circuitry components, and renewable energy kits. Having access to such materials enables students to apply theoretical concepts in practical, tangible ways, fostering deeper understanding and retention of STEM principles.

**STEM Curriculum Resources:** Well-designed STEM curriculum resources provide teachers with a structured framework for delivering engaging and rigorous instruction across STEM disciplines. These resources may include lesson

plans, project ideas, assessment tools, and alignment to academic standards. A comprehensive STEM curriculum ensures that teachers have a roadmap for covering essential content while also fostering inquiry-based learning and critical thinking skills.

By ensuring access to a diverse range of educational resources educators can create dynamic and impactful STEM learning environments that inspire curiosity and creativity in students.

### 5.3. STEM education foundation of future professions

Education plays significant role in shaping the socio-economic landscape of nations by equipping individuals with the knowledge, skills, and competencies needed to thrive in a rapidly changing world. A well-educated workforce is essential for driving innovation, fostering entrepreneurship, and fueling economic growth [5]. By investing in STEM education, we empower individuals to harness the power of science, technology, engineering, and mathematics to address complex challenges and seize opportunities for advancement. STEM education plays an important role in preparing innovative individuals for a wide range of professions across various sectors [2], [8], [22]. Professions that are directly linked to STEM education:

**Software Developer:** STEM education provides the foundation for mastering programming languages, software development methodologies, and computational thinking skills required for designing, developing, and maintaining software applications, systems, and platforms.

**Engineer (Civil, Mechanical, Electrical, Aerospace, etc.):** STEM education equips individuals with the knowledge of mathematics, physics, and engineering principles necessary for designing, building, and testing infrastructure, machinery, electrical systems, aircraft, spacecraft, and more.

**Biomedical Scientist or Researcher:** STEM education offers the scientific background needed to conduct research, analyze data, and develop solutions in fields such as biology, biochemistry, pharmacology, and biomedical engineering to address medical challenges, develop new treatments, and improve healthcare outcomes.

**Data Scientist/Analyst:** STEM education provides the analytical and statistical skills required to interpret and analyze large datasets, derive insights, and make data-driven decisions across various industries, including finance, healthcare, marketing, and technology.

**Physicist or Astronomer:** STEM education lays the groundwork for understanding the fundamental principles of physics and astronomy, enabling individuals to explore the nature of the universe, conduct research, and contribute to advancements in fields such as astrophysics, cosmology, and particle physics.

**Chemical Engineer or Chemist:** STEM education fosters an understanding of chemistry, chemical engineering principles, and laboratory techniques essential for developing new materials, pharmaceuticals, chemicals, and processes to address environmental, industrial, and societal challenges.

**Environmental Scientist or Engineer:** STEM education provides the knowledge and skills necessary to study the environment, assess environmental impacts, and develop sustainable solutions to mitigate pollution, conserve natural resources, and address climate change.

**Mathematician or Statistician:** STEM education cultivates proficiency in mathematical reasoning, problem-solving, and statistical analysis, enabling individuals to pursue careers in academia, research, finance, insurance, and data science.

**Robotics Engineer or Technician:** STEM education offers the technical expertise needed to design, build, program, and operate robotic systems used in manufacturing, healthcare, agriculture, exploration, and other industries.

**STEM Educator or Curriculum Developer:** STEM education prepares individuals to teach and inspire the next generation of scientists, engineers, and innovators by developing engaging curriculum, hands-on activities, and inquiry-based learning experiences that foster curiosity, critical thinking, and problem-solving skills.

These professions represent just a fraction of the diverse career opportunities available to individuals with a background in STEM education. From technology and healthcare to energy and sustainability, STEM disciplines play a crucial role in driving innovation, economic development, and global progress.

### 5.4. STEM education – investment in future stability

Education serves as a catalyst for stability and social cohesion by promoting civic engagement. It plays a crucial role in promoting peace and security within a country and among the nations [6]. By investing in education, we invest in the future stability and security of our societies, paving the way for a more harmonious and peaceful world. As the national security depends on the strength of the nation's economy. The vibrancy of that economy depends on the advancements in science and engineering. Similarly, the ability of the nation's military to prevail during the conflicts in different missions depends heavily on continued advances in the technology base. A workforce with robust STEM capabilities is critical to sustaining a nation's technological advancement and innovation, which are essential for maintaining a competitive edge in the global landscape [20]. STEM education can significantly contribute to the safety and security of a nation [18] in several ways:

**Technological Innovation:** STEM fields drive technological innovation, leading to the development of advanced security systems, surveillance technologies, and defense mechanisms. Innovations in areas such as cybersecurity, biometrics, and data analytics enhance the ability of security agencies to detect and prevent threats to national security.

**Critical Infrastructure Protection:** STEM professionals, including engineers and computer scientists, play a vital role in designing and safeguarding critical infrastructure such as transportation networks, energy grids, and communication



systems. By implementing robust security measures and utilizing advanced technologies, they help protect these essential assets from cyber-attacks, natural disasters, and other risks.

**Defense and Military Technology:** STEM expertise is essential for the development and deployment of defense and military technologies [7] including weapons systems, aircraft, and unmanned aerial vehicles (UAVs). Research and innovation in defense-related STEM fields enhance national defense capabilities and strengthen deterrence against potential threats.

**Emergency Preparedness and Response:** STEM education equips individuals with the knowledge and skills needed to respond effectively to emergencies and natural disasters. Professionals in fields such as engineering, environmental science, and emergency management develop contingency plans, design resilient infrastructure, and coordinate disaster response efforts to mitigate the impact of emergencies on public safety and security.

**Cybersecurity and Information Assurance:** In an increasingly digital world, cybersecurity is paramount for protecting sensitive information, critical infrastructure, and national interests. STEM professionals specialized in cybersecurity develop advanced encryption methods, intrusion detection systems, and threat intelligence solutions to safeguard digital assets and prevent cyber-attacks from hostile actors.

**Health Security and Biodefense:** STEM expertise is essential for addressing public health threats and bioterrorism risks. Scientists and researchers in fields such as microbiology, epidemiology, and bioinformatics work to identify and mitigate infectious diseases, develop vaccines and medical countermeasures, and strengthen healthcare systems to respond to biological threats effectively.

Thus, by nurturing STEM talent and investing in STEM education and research, nations can enhance their capabilities to address emerging security challenges, protect their citizens, and promote stability and resilience in an increasingly complex and interconnected world.

## 6. Conclusion

Overall, the education system serves as a catalyst for societal progress and development, playing a crucial role in shaping the future trajectory of nations. Through its multifaceted endeavors, the education system nurtures human capital, fosters innovation and creativity, and fosters a culture of lifelong learning and continuous improvement, thereby laying the foundation for a prosperous and sustainable future. The paper provides insights and guidance on the effective teaching of STEM subjects by addressing the complex interplay of educator qualifications, instructional approaches, and learning environments. By prioritizing education and investing in STEM teaching methodologies, we can empower individuals to become active agents of change and contribute to the prosperity, stability, and sustainability of society. By equipping future generations with the knowledge, skills, and values needed to address global challenges and seize opportunities, we can build a brighter future for all.

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