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Research article

Enhancing student motivation and achievement in science classrooms through STEM education

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Abstract: This qualitative study investigated how science teachers integrate science, technology, engineering, and mathematics (STEM) into their lessons, focusing on the benefits, challenges, and implementation strategies. Data were collected through semi-structured interviews with 26 science teachers in public schools in Irbid Governorate, Jordan, during the 2023–2024 academic year. The findings revealed that while teachers generally have a positive attitude toward STEM education, they encountered significant challenges related to inadequate physical resources and time constraints. Additionally, STEM education was shown to promote student engagement in research activities. The study employed a thematic analysis approach to identify, analyze, and report patterns within the data, providing a detailed account of the themes that emerged from the teachers' experiences. The study underscores the importance of addressing these challenges to facilitate the effective integration of STEM into science education.

Keywords: STEM education, science teachers, qualitative research, implementation challenges, student engagement

1. Introduction

STEM, an acronym formed by combining the initials of Science, Technology, Engineering, and Mathematics, holds significant importance in all aspects of life. The fields of STEM require individuals to possess knowledge and skills aligned with these disciplines. Consequently, it is essential to adopt educational approaches that enable future generations to actively participate in STEM-related fields. One such approach gaining prominence in recent years is STEM education. STEM education encompasses integrated teaching practices that align with the real-world work of professionals in STEM disciplines. By combining these disciplines, STEM education offers a comprehensive framework for explaining various situations encountered in everyday life and solving complex problems. Moreover, it focuses on developing critical skills that are highly valued in today's world, such as problem solving, self-improvement, and systematic thinking. In order to meet the demands of the 21st century, education systems should strive to provide students with a range of skills, including problem solving, creativity, research-questioning, critical thinking, entrepreneurship, and communication. STEM education facilitates the learning and application of these essential skills. Research has shown that STEM education has a positive impact on students' ability to solve problems, foster innovation, think critically, become technologically literate, and engage in discovery [1–3].

The STEM approach has gained significant attention and popularity worldwide in recent years. It is recognized as a global trend in developing educational resources and curricula for science students. STEM education equips learners with critical and analytical thinking skills, fostering innovation and preparing them to become professionals in STEM fields. Educators need to receive training in STEM-based teaching approaches to effectively implement STEM education. The increased interest in STEM education is driven by educational, economic, and retention factors. STEM education provides advanced opportunities for students, promotes economic development, and retains talented individuals within STEM fields. Studies conducted by Aldahmash, Alamri, and Aljallal [4] and Choi and Hong [5] support the notion that STEM education enhances students' problem-solving abilities, encourages innovation, develops critical thinking skills, and empowers them to become proficient in utilizing technology. By integrating STEM disciplines, students gain a broader perspective, are better equipped to address real-world challenges, and contribute to scientific and technological advancements [6].

STEM education provides students with an opportunity to develop a comprehensive understanding of the world, moving beyond fragmented knowledge. In traditional education, subjects are often taught in isolation, resulting in a fragmented understanding of concepts. However, STEM education encourages an integrated approach, where students learn to make connections across different subject areas. AlAli, Alsoud, and Athamneh highlight that STEM education allows students to make sense of the world holistically, rather than viewing it in isolated fragments. Real-world problems rarely have simple solutions that rely on knowledge from a single subject area. Therefore, schools need to embrace the reality of integrated problem-solving by incorporating STEM education [1]. Alghamdi emphasizes the importance of integrated STEM education, which acknowledges that real-world problems require interdisciplinary approaches. By integrating science, technology, engineering, and mathematics, students can develop a deeper understanding of complex issues and apply their knowledge in practical, meaningful ways. One of the benefits of well-designed STEM experiences is that they can engage a broader range of students [7]. English suggests that integrated STEM education provides learning experiences that cater to diverse student interests and backgrounds. By connecting STEM disciplines and incorporating real-world applications, students are more likely to find relevance and engagement in their learning [8]. However, many teachers struggle to make connections across STEM disciplines, leading to isolated and disjointed instruction [9].

Kelley and Knowles highlight the challenge of disconnected science and math learning, where students fail to see the crosscutting concepts and real-world applications. This lack of integration can result in disengagement and a limited understanding of how STEM concepts relate to the world around them. To address these challenges, the integration of engineering design activities in STEM education can be highly beneficial [10]. AlAli, Alsoud, Athamneh suggest that engineering design activities enable students to develop valuable 21st century skills, such as effective communication, technological proficiency, innovation, and synthesis of information [1]. By engaging in hands-on projects and problem-solving activities, students learn to apply STEM knowledge in practical contexts and develop essential skills that are highly valued in the modern world [11].

The STEM approach encompasses four areas: science, technology, engineering, and mathematics. In today's world, children are exposed to technology from a very early age. Therefore, it is essential to provide them with structured and controlled education about the advantages and disadvantages of technology. This education helps children develop a balanced understanding of technology's role in their lives and equips them to make informed decisions about its use [12]. Engineering education is a fundamental component of STEM education as it promotes in-depth learning and the development of scientific process skills. Introducing engineering concepts to children at an early age has a profound impact on their overall growth. From an early age, children naturally engage in engineering activities, using their innate curiosity and creativity to design and build objects by manipulating materials. This process fosters the development of problem-solving skills and nurtures their creative thinking abilities [13,14].

In STEM education, it is emphasized that the problems encountered by students in real life are not confined to a single discipline. Real-world issues require an integrated approach that draws on knowledge and skills from multiple STEM disciplines. Asghar et al. argue that the teaching of STEM disciplines in an integrated manner is well-suited to addressing real-life situations. By integrating science, technology, engineering, and mathematics, students gain a comprehensive understanding of complex problems and develop the ability to apply interdisciplinary solutions. By adopting a STEM approach, students are exposed to a holistic educational experience that encompasses a range of disciplines and reflects real-world scenarios. The integration of STEM disciplines allows students to see the connections between different subjects and apply their knowledge to solve authentic problems [15]. This approach encourages critical thinking, creativity, and collaboration, which are essential skills for success in the 21st century.

STEM education is focused on providing high-quality education in science, mathematics, and engineering fields. Researchers such as AlAli et al.; AlAli, Alsoud, and Athamneh; Al-Jalal; and Çakici et al. [1,16–18] have highlighted several key benefits of STEM education:

Interdisciplinary Work: STEM education encourages an interdisciplinary approach to learning. It brings together concepts from science, technology, engineering, and mathematics, allowing students to see the connections and relationships between these disciplines. By integrating knowledge from various fields, students develop a more holistic understanding of the subjects they study.

Critical and Advanced Thinking Skills: STEM education promotes the development of critical thinking and advanced thinking skills in children. Through hands-on activities, problem-solving tasks, and project-based learning, students are encouraged to analyze, evaluate, and apply their knowledge to real-world situations. This cultivates their ability to think critically, solve complex problems, and think creatively.

Preparation for the Business World: STEM education aims to prepare individuals who are well-equipped for the demands of the business world. By fostering skills such as collaboration, communication, and innovation, STEM education develops the qualities that employers seek in the workforce. It equips students with the knowledge and skills necessary to succeed in STEM-related careers and contribute to technological advancements.

Connection with Everyday Life: STEM education emphasizes the connection of knowledge with everyday life. It helps students understand how scientific principles, mathematical concepts, and engineering practices are relevant and applicable in their daily lives. This connection enhances students' motivation and engagement in STEM subjects by demonstrating their practical significance.

Industry-School Cooperation: STEM education promotes collaboration and partnership between schools and industries. By establishing meaningful connections between educational institutions and the business sector, students have opportunities to engage in real-world problem-solving, internships, mentorship programs, and industry visits. This collaboration enriches students' learning experiences and provides them with exposure to professional environments.

Knowledge and Skills in the Engineering Design Process: STEM education focuses on developing children's knowledge and skills in the engineering design process. Through hands-on projects and activities, students learn to identify problems, generate solutions, design prototypes, test and evaluate their designs, and iterate based on feedback. This process develops their engineering mindset, problem-solving abilities, and creativity.

Economic and Technological Development: STEM education plays a crucial role in a country's economic and technological development. By producing a skilled and knowledgeable workforce in science, mathematics, and engineering, STEM education contributes to innovation, research and development, and the growth of industries. It prepares individuals to meet the demands of a rapidly evolving technological landscape and drives economic progress.

STEM education provides students with an opportunity to engage in deep learning and contributes to their academic success. According to Yildirim and Selvi, STEM education allows students to delve into subjects in a comprehensive and rigorous manner, leading to improved academic performance. Students' scientific process skills play a crucial role in problem-solving and overall development [19]. Robinson et al. highlight the connection between scientific process skills and problem-solving abilities. By engaging in STEM education, students develop skills such as observation, experimentation, analysis, and critical thinking, which are vital for effective problem-solving [20].

STEM education aims to prepare individuals to thrive in the 21st century economy. Schiavelli emphasizes that STEM education equips students with the knowledge and skills necessary to contribute to and benefit from a technologically advanced society. The interdisciplinary nature of STEM education allows students to gain a broad understanding of various fields, fostering adaptability and versatility in the workforce. To develop STEM skills, children need certain foundational skills and experiences [21]. Gropen et al. identify key skills that support STEM learning, including organizing information, setting strategies, maintaining focus during the learning process, and evaluating and planning. These skills form the basis for effective STEM engagement and learning [22].

STEM practices have a positive impact on children's confidence and attitude toward school.

Sahin et al. report that engaging in STEM activities boosts students' sense of courage and self-efficacy, which can contribute to their overall academic engagement and success. Additionally, STEM activities facilitate the retention of learned information by providing hands-on, experiential learning opportunities. Furthermore, STEM activities promote collaboration and group cohesion among students [23]. The use of materials and hands-on experiments encourage teamwork and cooperation, as reported by Sahin et al. Working together on STEM projects allows students to develop interpersonal skills, communication abilities, and the habit of acting collaboratively. However, it is noted that teachers may lack sufficient knowledge of engineering during their work. Akaygun and Aslan-Tutak highlight the importance of teachers' pedagogical content knowledge in delivering effective STEM education. It is crucial for teachers to receive proper training and support to enhance their understanding of engineering concepts and practices, enabling them to effectively facilitate STEM learning experiences for their students [24].

In light of this, the main goal of this research is to explore the perspectives of science educators on STEM education. To achieve this objective, we aim to address the following inquiries:

- How do science teachers incorporate STEM education into their teaching practices?
- What benefits and drawbacks do science teachers associate with the adoption of STEM education?
- What challenges arise during the implementation of STEM education in science classrooms?
- What strategies do science teachers employ to overcome the challenges of implementing STEM education?

2. Theoretical framework

The theoretical framework for understanding the integration of STEM education in science classrooms draws from various educational theories and concepts.

1. Self-Determination Theory (SDT): Self-determination theory posits that individuals are intrinsically motivated to engage in activities that satisfy their basic psychological needs for autonomy, competence, and relatedness. In the context of STEM education, autonomy is fostered through student-led inquiry and problem-solving tasks, while competence is nurtured through challenging yet attainable STEM projects. Relatedness is promoted through collaborative learning experiences, where students work together to solve problems and achieve common goals.

2. Constructivism: Constructivist theory emphasizes that learners actively construct their own knowledge and understanding through hands-on experiences and interactions with their environment. In STEM classrooms, constructivist approaches involve inquiry-based learning, where students explore scientific concepts through experimentation and discovery. By engaging in authentic, real-world problem-solving tasks, students develop a deeper understanding of STEM concepts and principles.

3. Social Cognitive Theory (SCT): Social cognitive theory highlights the role of observational learning, self-efficacy beliefs, and social reinforcement in shaping behavior. In STEM education, exposure to successful role models, such as scientists and engineers, can inspire students and enhance their self-efficacy beliefs in STEM fields. Additionally, providing opportunities for peer collaboration and constructive feedback can further bolster students' confidence and motivation to

engage in STEM activities [25].

4. Task Value Theory: Task value theory suggests that students' motivation to engage in academic tasks is influenced by their perceptions of the task's value and utility. In STEM classrooms, emphasizing the relevance of STEM concepts to students' everyday lives, future careers, and societal challenges can enhance their intrinsic motivation to learn and succeed in STEM subjects.

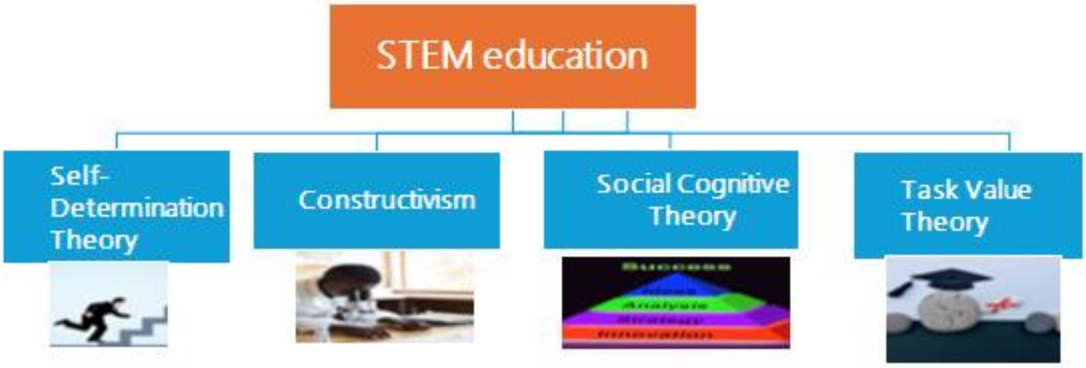

Figure 1. Integration of STEM into science and mathematics classes.

3. Methodology

This study utilized a thematic analysis approach to analyze qualitative data collected from science teachers regarding the integration of science, technology, engineering, and mathematics (STEM) in their lessons. The thematic analysis method is well-suited for identifying, analyzing, and reporting patterns within qualitative data, providing a detailed account of the themes that emerge from the teachers' experiences and perspectives. This approach allows for a nuanced exploration of trends in thought and opinions, offering a deeper understanding of the research problem.

Participants

The research focused on science education in public schools within the Irbid Governorate, Jordan, during the first semester of the 2023/2024 academic year. The geographical scope included schools across the six Directorates of Education in Irbid Governorate. Participants were selected using an available sample method, based on accessibility and willingness to participate, resulting in a sample size of 26 science teachers.

Study instrument

The study employed a semi-structured interview approach, which allowed for flexibility in questioning while maintaining a consistent set of topics. This method enabled participants to provide detailed and individualized responses, offering valuable insights into their perspectives on STEM education [26]. The interview questions were developed by the researchers, who have expertise in teacher supervision, and were designed to align with the study's specific objectives and research questions.

The formulation of the interview questions was informed by a comprehensive review of educational literature and previous studies on STEM education. Key references included works by Jamaluddin et al., AlAli and Al-Barakat, Kubat, Toma and Greca, Ntemngwa and Oliver, Gardner, Heba, Ercan et al., and Honey et al. [27–35]. These sources provided insights, theories, and findings that enriched the design of the interview instrument.

The instrument consisted of the following four questions:

1. How do science teachers incorporate STEM education into their teaching practices?
2. What benefits and drawbacks do science teachers associate with the adoption of STEM education?
3. What challenges arise during the implementation of STEM education in science classrooms?
4. What strategies do science teachers employ to overcome the challenges of implementing STEM education?

Validity and Reliability

To ensure the validity of the interview instrument:

- Formulating Questions: Seven initial questions were developed to gather relevant data on science educators' perspectives on STEM education, considering the researchers' expertise in science education, measurement and evaluation, and supervision.
- Review by Specialists: The questions were reviewed by specialists in science education, measurement and evaluation, and supervision to assess clarity, relevance, and appropriateness.
- Elimination and Modification: Based on specialist feedback, three questions were identified as problematic or redundant and were eliminated. Two questions were modified for clarity and precision.
- Finalized Interview Instrument: The final version comprised four questions deemed most relevant and effective in eliciting valuable insights.
- The instrument's reliability was established through two repeated interviews with seven science teachers not part of the study sample, conducted two weeks apart. Independent analyses by the researchers and a colleague revealed complete consistency, affirming the reliability of the data analysis process.

Data Collection

The study adhered to qualitative research methodology principles outlined by Cresswell, AlAli and Wardat, and Patton [36–38] to uphold high credibility in data collection. These principles included:

- Transparent communication of the study's objectives to potential interviewees.
- Emphasizing the confidentiality of the collected data.
- Obtaining informed consent before interviews.
- Considering participants' circumstances in determining the interview time and location.
- Establishing a friendly and respectful relationship to foster a comfortable interview environment.
- Participant identities were kept confidential by replacing names with assigned numbers. Interview questions were sometimes rephrased to ensure response accuracy. Participants

reviewed and modified transcripts after transcription, enhancing the stability and credibility of the data obtained.

4. Findings and discussion

After analyzing the responses of the participants to the first question, "How do you use STEM education in the science course?", several main categories of responses were identified.

First, the researchers conducted a detailed analysis of the participants' responses to gain insights into how STEM education was being utilized in the science course. This involved a careful examination of the responses to identify recurring themes and patterns in the participants' approaches to incorporating STEM education.

Second, several main categories of responses emerged from the analysis, shedding light on the different ways in which participants reported using STEM education in the science course. The first category, identified by 42% of the participants, was the integration of STEM education into various classroom activities. This finding suggests that a significant portion of the participants actively incorporated STEM principles and practices into their regular teaching practices. It is likely that they recognized the value of hands-on experiences, problem-solving, and critical thinking in enhancing student engagement and understanding of science concepts.

The second category, highlighted by 27% of the participants, focused on the use of STEM education in creating or utilizing models as part of their instructional approach. Models can serve as powerful tools for visualizing and comprehending complex scientific concepts, providing students with tangible representations to aid their understanding. By utilizing models, educators can foster a more interactive and immersive learning experience, enabling students to explore scientific phenomena in a practical and engaging manner.

The third category, expressed by 19% of the participants, revealed a sense of uncertainty or lack of knowledge regarding the effective use of STEM education in the science course. This finding underscores the need for targeted professional development and support to empower educators in implementing STEM education more confidently. It suggests that a considerable number of participants may benefit from training programs, resources, and mentorship opportunities that can enhance their understanding of STEM principles, pedagogical strategies, and inquiry-based teaching methods.

The fourth and final category, mentioned by 8% of the participants, involved assigning STEM-related tasks as homework. This approach aimed to extend STEM learning beyond the confines of the classroom, providing students with opportunities to independently explore and apply STEM concepts. Assigning STEM-related tasks as homework can reinforce learning, encourage self-directed inquiry, and promote the development of problem-solving skills outside of the structured classroom environment.

When considering the distribution of responses across these categories, it is notable that 42% of the participants emphasized the use of STEM education in classroom activities, indicating its significance in their instructional practices. This finding suggests that many educators recognize the value of hands-on experiences and interactive learning in promoting student engagement and understanding. The emphasis on making models by 27% of the participants further reinforces the importance of visual and tangible representations in facilitating student comprehension of complex scientific concepts.

On the other hand, it is concerning that 19% of the participants expressed a lack of knowledge or uncertainty about effectively incorporating STEM education into the science course. This highlights the need for professional development initiatives that can provide educators with the necessary knowledge, skills, and pedagogical approaches to integrate STEM effectively. Addressing this gap through targeted training and support can enable educators to confidently implement STEM education and maximize its impact on student learning outcomes.

Finally, 8% of the participants mentioning the assignment of STEM-related tasks as homework indicates a potential avenue for extending STEM learning beyond the boundaries of the classroom. By assigning such tasks, educators can encourage the development of independent exploration, critical thinking, and problem-solving skills. Homework assignments in STEM can provide students with opportunities to apply their knowledge in real-world contexts and promote self-directed learning.

The researchers conducted a thorough analysis of the participants' responses to the second question regarding the advantages and disadvantages of using STEM education in the science class. The aim was to identify common themes and patterns in their responses.

Advantages: The analysis resulted in the identification of several main categories for the advantages of using STEM education in the science class. These categories included:

a. Direction to Search: 46% of the participants emphasized that one of the advantages of STEM education is that it provides a direction for students to search and explore scientific concepts more effectively.

b. Permanence: 23% of the participants highlighted the advantage of STEM education in fostering a deeper understanding of scientific concepts and promoting long-term retention of knowledge.

c. Individual Learning: 19% of the participants emphasized that STEM education supports individualized learning experiences, catering to the unique needs and interests of each student.

d. Professional Development Guidance: 12% of the participants highlighted the advantage of STEM education in providing guidance and opportunities for professional development for educators.

Disadvantages: The analysis also revealed several main categories for the disadvantages of using STEM education in the science class. These categories included:

a. Time Management: 35% of the participants emphasized that one of the disadvantages of using STEM education is the challenge of managing time effectively within the constraints of the curriculum.
b. Lack of Knowledge: 19% of the participants expressed a lack of understanding or awareness of the potential disadvantages associated with STEM education.
c. Teacher Exhaustion: 19% of the participants highlighted the potential for increased teacher exhaustion due to the demands of implementing STEM education.
d. Sustainability Challenges: 15% of the participants emphasized the difficulty in sustaining the implementation of STEM education over time.
e. Teacher-Student Communication Disruption: 12% of the participants identified the potential disruption to teacher-student communication as a disadvantage of using STEM education in the science class.

The analysis of the data revealed several main categories for the advantages and disadvantages of using STEM education in the science class. Regarding the advantages, participants highlighted that STEM education provides a clear direction for students to search and explore scientific concepts effectively, helping them develop inquiry skills. This enables students to engage in independent exploration and critical thinking. Additionally, STEM education was found to foster a deeper understanding of scientific concepts and promote long-term retention of knowledge. Hands-on activities and experiential learning experiences contribute to a more profound comprehension of scientific principles. Furthermore, STEM education supports individualized learning experiences, catering to the unique needs and interests of each student. This personalized approach allows students to engage with the material in a way that is meaningful and relevant to them. Moreover, STEM education offers guidance and opportunities for professional development for educators, helping them enhance their teaching skills and stay updated with current practices.

On the other hand, the analysis also revealed several categories for the disadvantages of using STEM education in the science class. Time management was identified as a significant challenge, as incorporating hands-on STEM activities may require additional time, making it difficult to cover the curriculum adequately within the given timeframe. Additionally, a notable percentage of participants expressed a lack of understanding or awareness of the potential disadvantages associated with STEM education, indicating a need for increased knowledge and awareness among educators. The demands of implementing STEM education, such as preparing and organizing hands-on activities, were recognized as a potential cause of increased teacher exhaustion. Sustainability challenges were also identified, highlighting the difficulty of maintaining the necessary resources, infrastructure, and support for STEM education over time. Lastly, the potential disruption to teacher-student communication during STEM activities was acknowledged as a disadvantage, as the interactive and collaborative nature of these activities might pose challenges in maintaining effective communication.

The researchers carefully analyzed the participants' responses to the question regarding the difficulties faced when implementing STEM education in the science course. The aim was to identify recurring themes and patterns in their responses. After closely examining the participants' responses, the study identified several main categories of difficulties encountered when using STEM education in the science course. One significant difficulty highlighted by 31% of the participants was dealing with crowded classes. In these instances, limited individualized attention and challenges in facilitating hands-on activities were prominent. The constraints of overcrowded classrooms, including limited resources and space, further hindered the effective implementation of STEM education. As a result, providing personalized guidance and support to each student became a challenge, compromising the overall effectiveness of STEM learning experiences.

Another difficulty mentioned by 15% of the participants was the abundance of content in the curriculum. Integrating STEM education into an already packed curriculum poses challenges in allocating sufficient time for in-depth exploration of STEM concepts and engaging in hands-on activities. The pressure to cover a wide range of topics within a limited timeframe restricts opportunities for students to fully engage in meaningful and experiential learning experiences offered by STEM education. Approximately 23% of the participants highlighted the difficulties faced by students in grasping and applying STEM concepts. STEM education often involves complex and abstract scientific principles, which can be challenging for some students. The application of critical thinking, problem-solving skills, and teamwork may also be demanding for students who lack prior experience or familiarity with these approaches. Additional support and guidance are necessary to address the individual needs of students and ensure their success in STEM education. The study also revealed that 12% of the participants identified physical conditions as a significant obstacle to effective STEM implementation. Insufficient laboratory equipment, materials, or technology hindered hands-on experimentation and practical application of STEM concepts. Inadequate classroom space or facilities further limits the scope and quality of STEM activities, impacting the overall learning experience for students. Furthermore, 12% of the participants emphasized the lack of sufficient knowledge and understanding among teachers regarding STEM education. Effective implementation of STEM requires educators to possess a solid understanding of STEM principles, pedagogical strategies, and inquiry-based teaching methods. Without proper training and professional development opportunities, teachers may struggle to incorporate STEM education effectively into their science instruction, resulting in less impactful learning experiences for students. Lastly, a smaller percentage (8%) of participants admitted their own lack of knowledge regarding the difficulties associated with using STEM education in the science course. This finding suggests that some educators may be unaware of the specific challenges that can arise when implementing STEM education. Addressing this lack of knowledge through training, sharing best practices, and professional development opportunities can help educators better navigate and overcome the difficulties associated with STEM integration.

5. Conclusions

This study highlights the importance of incorporating key features such as production, creative thinking, problem-solving, easy access to information, collaboration, and critical thinking at the beginning of a science course. The STEM (science, technology, engineering, and mathematics) approach offers an interdisciplinary perspective that helps students acquire creativity, critical thinking, high-level thinking skills, and problem-solving abilities. In the 21st century, there is an increased demand for scientific thinking, interdisciplinary approaches, and creative thinking [1,24].

Research findings suggest that science teachers generally have a positive attitude toward using STEM education. However, they face challenges when it comes to effectively integrating STEM education into their teaching practices. Despite this, teachers in the study group acknowledge both the advantages and disadvantages of STEM education, indicating a willingness to overcome the challenges associated with it. This positive view of science teachers toward using STEM education in the learning-teaching process is consistent with previous studies [7,39,40].

When science teachers incorporate STEM education into their teaching, they tend to use it more in class activities and encourage students to create models. However, it is concerning that some teachers lack knowledge about what STEM education is and how it should be applied. This knowledge gap poses a significant challenge for the future of science education. STEM education is known to have a profound influence on individuals, fostering an innovative mindset that values inquiry and curiosity [29,40]. To address this issue, it is crucial to review and update the in-service training provided to science teachers, ensuring the effective implementation of STEM education.

In the context of the learning-teaching process, science teachers' views on STEM education indicate that these activities promote research among students and lead to more lasting learning experiences. Previous studies have shown that using STEM education benefits students by enhancing their understanding of scientific processes and positively impacting their affective and psychomotor development [4,41,42].

However, challenges related to time management have been identified as a significant disadvantage of implementing STEM education in the learning-teaching process. Teachers often struggle with time management when using STEM activities, indicating that their training may not be effective in designing STEM-based learning environments. Eroglu & Bektas have highlighted time management as one of the most important problems associated with the use of STEM education [39].

Addressing the challenges faced by science teachers using STEM education is crucial. It is evident that science teachers often work in crowded classrooms, which poses additional obstacles. Teachers have reported difficulties related to physical conditions, student challenges, and problems arising from teachers' lack of knowledge. Similar findings have been reported in the literature, with teachers facing challenges in time management and course management when implementing STEM activities [18,40]. Kubat also found that participants in their study experienced time insufficiency and overemphasis [29].

What sets this study apart from previous research is its focus on the practical challenges faced by science teachers in a specific geographical context (Irbid Governorate, Jordan) and during a defined timeframe (the 2023–2024 academic year). Unlike broader studies, our research provides a detailed exploration of the unique obstacles and opportunities within this region. This localized focus allows for more targeted recommendations and highlights the need for context-specific strategies in implementing STEM education effectively.

6. Recommendations for future studies

Based on our findings, we make the following recommendations for future research:

1. Diverse Sample and Longer Duration: Future studies should consider a more diverse sample and a longer duration to capture a broader range of experiences and insights. This would provide a more comprehensive understanding of the challenges and benefits of STEM education.
2. Detailed Examination of Training Programs: Future studies should investigate the effectiveness of different in-service training programs for STEM education. Comparing various training models could identify the best practices for preparing teachers to implement STEM effectively.
3. Focus on Specific STEM Activities: Future research could examine the impact of specific STEM activities or projects on student learning outcomes. This would help in understanding which aspects of STEM education are the most beneficial.
4. Longitudinal Studies: Future work can conduct longitudinal studies to track the long-term impact of STEM education on students' academic performance and career choices. This would provide valuable insights into the sustained benefits of STEM learning.

Author contributions

Rommel AlAli: Methodology, Validation, Investigation, Data curation, Writing – review & editing, Supervision; Yousef Wardat: Conceptualization, Software, Resources, Writing – original draft, Visualization; All authors: Formal analysis. All authors have read and approved the final version of the manuscript for publication.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

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Conflict of interest

The authors declare that there are no conflicts of interest in this paper.

Ethics declaration

The authors state that the study was approved by the institutional review committee of King Faisal University. Informed consent was obtained from all individual participants included in the study.

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