Future Science Teachers' STEM Experiences: Challenges and Implications for STEM Teacher Preparation

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Abstract

STEM (Science, Technology, Engineering, and Mathematics) education is an interdisciplinary approach aimed at enhancing students' understanding of these disciplines and fostering critical thinking and problem-solving skills. This study investigated the experiences and perceptions of 20 third-year pre-service science teachers (PSSTs) participating in STEM practices at a Turkish public university. The study addressed three key questions: (1) What are the opinions of STEM teacher candidates? (2) What benefits and challenges did they encounter during STEM practices? (3) How do they perceive STEM education and its implications for students and teachers? A qualitative case study method was employed to gather in-depth insights from PSSTs. The sample was selected using criterion sampling to ensure relevance to the study's focus. Over a four-week period, PSSTs engaged in STEM activities designed to align with the science education curriculum. Data collection involved a "Views on STEM Education Questionnaire" developed by the researcher and reviewed by two experts in STEM education. Content analysis was used to analyze the collected data, ensuring reliability through inter-coder agreement assessment. The results indicated that STEM education encompasses not only the four core disciplines but also interdisciplinary interactions. Participants recognized its positive impact on cognitive and psychomotor skills, creative thinking, problem-solving abilities, and its real-world relevance. However, limitations in time, resources, and pedagogical technological content knowledge were noted as potential challenges. Effective STEM instructors were described as possessing strong communication skills, creativity, innovation, and a passion for research. The findings of this study contribute to a deeper understanding of STEM teacher candidates' perspectives, shedding light on the importance of interdisciplinary approaches and the qualities required for successful STEM educators.

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Introduction

STEM represents a multidisciplinary educational approach that combines science, technology and mathematics disciplines with the engineering channel (Buber & Unal Coban, 2023). STEM education is interdisciplinary with the aims of (1) building students' understanding of each discipline by building on their prior knowledge, (2) deepening their understanding of STEM disciplines by enabling students to study socially relevant STEM topics, and (3) making STEM disciplines and careers more accessible and interesting to students. It is an approach with natural connections (Chai, 2019; Wang et al., 2011). This approach basically has two goals that it plans to achieve in education (Thomasian, 2011). The first is to strengthen the innovative workforce of countries by increasing the number of individuals who will pursue careers in science, technology, engineering and mathematics after high school. The second is to increase the proficiency of all students in STEM subjects so that they can gain the skills to use STEM concepts and apply creative solutions in their daily lives. When these goals are achieved, individuals will be able to think critically by using their knowledge in these disciplines while defining a problem and to create their own algorithms in the process of solving the problem (Unal Coban & Buber, 2021).

Diana et al. (2021) conducted survey research on the difficulties faced by teachers in studies in the literature in the last five years to make STEM applications more effective and reported the difficulties encountered in the implementation process, adhering to seven main articles. The findings of the study show that mathematics teachers have difficulties in presenting abstract mathematics concepts to students in the context of real life, that science teachers do not have an adequate understanding of what the STEM approach is, that they have problems in establishing a meaningful and relevant connection between two or more disciplines, time limitations and sufficient in different disciplines. It has been shown that they have problems in executing STEM applications due to their lack of knowledge. Tang and Williams (2018) stated that this uncertainty stems from the fact that science, technology, engineering, and mathematics disciplines do not contain compulsory connections with each other in terms of content or pedagogy. The papers collectively highlight several challenges and implications for STEM teacher preparation. Dailey and his collogues (2015) discusses a STEM teacher preparation program that received positive feedback from candidates, indicating their satisfaction and motivation to continue in the program. Ramli and Talib (2017) explores teachers' readiness to implement STEM education and identifies factors such as lack of confidence, teaching materials, and laboratory facilities as barriers. Kolikant and his colleagues (2020) emphasizes the need for STEM teachers to adapt to the changing educational landscape, incorporating digital technology and keeping up with curriculum reforms. Sungur-Gul and Tasar (2023) focuses on the design, implementation, and evaluation of a STEM education course for pre-service science teachers, providing insights into effective strategies for preparing future STEM educators. Overall, these papers highlight the importance of addressing challenges such as readiness, resources, and pedagogical adaptation in STEM teacher preparation programs.

Although STEM disciplines are at the different epistemological fields, they are becoming closely linked in science and engineering applications. It has been suggested that complex real-life problems should be included in STEM activities as a way to overcome this challenge in STEM education and transform STEM into more than the sum of its constituent disciplines (Pitt, 2009; Williams, 2017). STEM instructors’ pedagogical skills, readiness, attitudes and use of sources support successful implementation of effective STEM lessons. In addition to these characteristics, instructors' perceptions of STEM have emerged as an important element that has spurred improvements in teaching techniques and improved student learning results (Czajka & McConnell, 2016). Teachers need to have an adequate understanding of the subject they are teaching to properly present the curriculum to students, and it is critical to be aware of teachers' opinions and ideas that have molded their techniques and strategies for implementing STEM instruction (Madani, 2020). Identifying how STEM teachers perceived STEM concepts, pedagogies, and curricula to make such implementations is critical because their perceptions influence both teachers' guidance to students and students' understanding of STEM content and concepts (Margot & Kettler, 2019).

Teachers play an important role in developing effective STEM policy. El-Deghaidy and Mansour (2015) investigated science teachers' opinions of STEM education and identified the necessity for teachers to establish a clear grasp of the pedagogical material that would enhance the implementation of STEM education in the classroom. As a result, knowing teachers' views is equally vital for creating effective interventions to assist instructors match themselves and their ideas appropriately to the varied conditions and contexts.

In this background, the researcher designed STEM practices including teaching and learning methods and 3rd year pre-service science teachers (PSSTs) experienced these practices in the science laboratory application course. Reflective teacher educators and researchers (Cochran Smith 2003) seek to examine the efficacy of the teacher education course and draw implications for their own teaching and the instruction of other educators with similar interests. To that end, the purpose of this study was to describe how STEM teacher candidates experienced STEM practices in an integrated way and their opinions about the STEM practices. Three research questions guided the study: (1) What are the opinions of STEM teacher candidates? (2) What were the benefits that they faced in experienced STEM practices? (3) What were challenges that they faced in experienced STEM practices?

Method

Research Design

A case study, one of the qualitative research approaches, was used to perform the study. Case studies focus on a specific individual, community, event, or scenario. As a result, the goal of case studies is not to generalize the findings, but rather to disclose the attitudes or actions of a sample in response to an incident (Ersoy, 2016).

Research Sample

The study group comprised of 20 third year PSSTs studying at a Turkish public university. The study's sample was determined using a criterion sampling method, which is one of the deliberate sampling methods. The goal of purposeful sampling is to gather the most accurate information about an individual, occurrence, or circumstance that is directly relevant to the study's subject (Maxwell, 1996).

Procedure and Research Instrument

In the current study, STEM activities were developed for PSSTs to successfully use the STEM practices in the classroom. These activities were sought to offer appropriate strategies for students' developmental stages and explain how these methods may be implemented in STEM education. The researcher developed the example activities based on the science education curriculum. STEM activities were carried out for four weeks and practices took place for 2 hour per week.

Data related to PSSTs' opinions regarding what STEM education is, its advantages, limitations for students and teachers, which skills and competencies are crucial for STEM teachers, and how to enhance and spread STEM practices were collected in this study. The PSSTs' opinions on their STEM experiences and STEM education were collected via "Views on STEM Education Questionnaire". The questions in the instrument were developed by the researcher. The opinions of the 2 experts studying in STEM education were consulted and necessary corrections were made on the instrument. After the STEM education practices, the opinions of PSSTs were collected via the instrument.

Data Analysis

Content analysis was used to examine the data. Content analysis is a method for describing qualitative data using a systematic methodology (Schreier, 2014). In content analysis, reliability is assessed by examining the consistency of the researchers' descriptions. The analysis was based on the researcher's and an expert in STEM education's individual descriptions. The researchers' individual coding was compared based on the "agreement" and "disagreement" between the points of view. The agreement percentage method, "reliability = agreement / (agreement + disagreement) x 100" (Miles & Huberman, 1994), was used to estimate the reliability of the content analysis completed in the current study. The study's agreement percentage was determined to be 0.73. Because the obtained value was greater than 70%, it was determined that the content analysis was reliable (Yıldırım & Şimşek, 2003).

Results

The findings of the study revealed that STEM education is more than four disciplines because it includes all four disciplines and interdisciplinary interactions, that it develops students' cognitive and psychomotor skills, develops creative thinking and problem-solving skills, and is innovative and related to daily life. However, it is also among the statements that time and material limitations and inadequacy of pedagogical technological content knowledge will negatively affect the guidance of the process. It was also stated that the teachers who will carry out STEM applications should have strong communication skills, they should be creative, open to innovation teachers who love to do research. Table 1 presents the frequency and percentage values of the responses of teacher candidates.

Table 1. PSSTs' opinions regarding their STEM experiences

Categories	**Codes**	**Frequency**	**%**	**Categories**	**Codes**	**Frequency**	**%**
General aspects of STEM Education	-Integration of four disciplines	30	31	Characteristics of Effective Learning Environments in STEM Education	-With sufficient resources	16	40
	-Creating interdisciplinary connections	23	24		-With technology	2	5
	-Design development process	12	13		-Supporting group work	4	10
	-Learning approach	2	2		-Innovative	2	5
	-Applications for understanding the systems and tools	3	3		-Thought-provoking	3	7,5
	-Transfers from theory to practice	2	2		-Critical thinking	2	5
	-Comprehensive	4	4		-Encouraging reasoning	1	2,5
	-Technology integration	5	5		-Laboratory	5	12,5
	-Transformation of knowledge into products	3	3		-Open-minded	4	10
	-Student-centered approach	4	4		-Empowering	1	2,5
	-Active learning	8	9		Total	40	100
	Total	96	100	Desirable Qualities for	-Possess 21st-century skills	2	3

Challenges and Limitations -Teacher -Student	*Teacher*			STEM Teachers	-Be technologically/ digitally literate	5	7,5
	-Difficulty with time management	16	32		-Be creative	6	9
	-Challenges in classroom management	5	10		-Have diverse domain knowledge	13	19,5
	-Insufficient materials	6	12		-Be pedagogically competent	11	16,5
	-Students' lack of cognitive readiness	1	2		-Innovative	5	7,5
	-Incompatibility with the curriculum	2	4		-Critical	3	4,5
	-Negative impact of excessive guidance on outcomes	1	2		-Have strong communication skills	4	6
	-Lack of psychomotor skills	3	6		-Act as guides	1	1,5
	-Difficulty in selecting age-appropriate activities	1	2		-Be scientifically literate	1	1,5
	-Implementation challenges in crowded classrooms	1	2		-Have research and inquiry skills	11	16,5
	-Inadequate safety precautions	1	2		-Be patient	2	3
	-Parental pressure	1	2		-Facilitate interdisciplinary connections	1	1,5
					-Be dedicated	1	1,5
					-Have high motivation	1	1,5
		8	16			67	100

		1	2		Total		
	Student	2	4				
	-Difficulty in mechanical tasks	2	4				
	-Challenges due to lack of domain knowledge	1	2				
	-Difficulty in understanding	3	6	Strategies for Effective STEM Teaching	-Connect learning with real-life experiences	2	25
	-Difficulty in error correction	50	100		-Facilitate interdisciplinary connections	2	25
	-Group work challenging students				-Make efforts	1	12,5
	-Causing student attention distractions				-Establish connections between theory and practice	2	25
	Total				-Anticipate needs	1	12,5
Benefits and Outcomes -Teacher -Student	*Teachers*				Total	8	100
	-Develops 21st-century skills	3	1,5				
	-Addressing conceptual misconceptions	5	2,5				
	-Relating to daily life	18	9				
	-Facilitation of effective learning	13	6,5				

	Students						
	-Ensures retention	26	13				
	-Develops different perspectives	3	1,5				
	-Develops creativity	4	2				
	-Develops psychomotor skills	17	8,5				
	-Develops domain knowledge	7	3,5				
	-Develops scientific reasoning	3	1,5				
	-Develops research and inquiry skills	7	3,5				
	-Multidimensional thinking	8	4				
	-Problem-solving	11	5,5				
	-Critical thinking	6	3				
	-Collaborative work	6	3				
	-Enlightening	3	1,5				
	-Science literacy	4	2				
	-Rapid learning	9	4,5				

	-Motivation -Innovative thinking -Curiosity -Provision of lifelong learning -Modeling -Effective on job choices Total	26 2 2 3 2 2 200	13 1 1 1,5 1 1 100				

When Table 1 is examined, it is observed that the responses of teacher candidates are categorized under 5 categories: General aspects of STEM Education, Challenges and Limitations for Teachers and Students, Benefits and Outcomes for Teachers and Students, Characteristics of Effective Learning Environments in STEM Education, Desirable Qualities for STEM Teachers and Strategies for Effective STEM Teaching. PSSTs predominantly define STEM Education as the integration of four disciplines (31%) and creating interdisciplinary connections (24%), emphasizing that this process is a design and development process (13%). When the negative experiences of teachers and students in STEM practices are examined, it is expressed that there are challenges in time management for teachers (32%), and for students, there are difficulties in completing mechanical tasks that require psychomotor skills (16%). The benefits of STEM activities for teachers are teaching abstract concepts by relating them to daily life (9%) and providing effective learning (6.5%), while for students, the benefits are improving psychomotor skills (8.5%) and problem-solving skills (5.5%). The characteristic features of effective learning environments in STEM education are frequently expressed as having adequate resources (40%) and laboratory (12.5%) environments. It is stated that prospective teachers who will conduct STEM activities should have sufficient subject knowledge (19.5%), pedagogical competence (16.5%), and research-inquiry skills (16.5%). The strategies for the effective use of STEM activities are expressed as relating what is learned to real-life experiences (25%), sharing interdisciplinary connections (25%), and establishing connections between theory and practice (25%).

Discussion, Conclusion and Recommendations

The papers collectively suggest that STEM education encompasses not only the four core disciplines (science, technology, engineering, and mathematics) but also interdisciplinary interactions (Nowikowski 2017; Yıldız et. al. 2019). Participants in the studies recognized the positive impact of STEM education on cognitive and psychomotor skills, creative thinking, and problem-solving abilities, as well as its real-world relevance (Hebebci 2022; Kaleci & Korkmaz 2018; Nowikowski 2017). Bal and Bedir (2021) highlighted that teachers perceive STEM education as essential in today’s age and emphasized its benefits in terms of student success, self-confidence, and learning. Bozkurt and his collogues (2019) investigated the reflective evaluations of prospective teachers and identified concerns related to material supply, preparation, implementation, and student cooperation in STEM activities. Goodnough (2014) discussed the effectiveness of professional development in STEM education, highlighting the need for diverse and collaborative learning opportunities for teachers. However, limitations in time, resources, and pedagogical technological content knowledge were identified as potential challenges (Nowikowski, 2017). Effective STEM instructors were described as possessing strong communication skills, creativity, innovation, and a passion for research (Nowikowski, 2017). These findings contribute to a deeper understanding of STEM teacher candidates' perspectives and highlight the importance of interdisciplinary approaches and the qualities required for successful STEM educators (Nowikowski, 2017).

Conclusion

In conclusion, the analysis of the data presented in Table 1 provides valuable insights into the perceptions and perspectives of teacher candidates regarding STEM education. The responses have been systematically categorized into five main themes: General Aspects of STEM Education, Challenges and Limitations faced by Teachers and Students, Benefits and Outcomes for Teachers and Students, Characteristics of Effective Learning Environments in STEM Education, and Desirable Qualities for STEM Teachers, along with Strategies for Effective STEM Teaching. The study revealed that STEM education extends beyond the boundaries of individual disciplines, fostering interdisciplinary interactions and benefiting students' cognitive and psychomotor skills, creative thinking, and problem-solving abilities. However, it also identified challenges related to time constraints, resource limitations, and the need for improved pedagogical technological content knowledge among educators. Effective STEM instructors were described as possessing strong communication skills, creativity, innovation, and a passion for research. In essence, this analysis underscores the multi-faceted nature of STEM education and the complex interplay of factors that shape it. Understanding these themes and insights is crucial for educators and policymakers striving to enhance STEM education and prepare future STEM teachers effectively. This paper presents some recommendations for enhancing STEM education based on these findings.

Recommendation

To effectively advance STEM education, a comprehensive approach is imperative. Primary among these considerations is the promotion of interdisciplinary integration, characterized by the facilitation of collaboration among educators spanning disciplinary boundaries and the development of curricula that authentically reflect the inherent interconnectivity of STEM disciplines. This approach fosters a learning environment conducive to holistic comprehension and a profound appreciation of STEM concepts. Furthermore, it is essential to prioritize professional development for STEM educators, with a focus on the continuous enhancement of their pedagogical technological content knowledge, equipping them with the requisite competencies for the seamless integration of technology into their instructional practices. Adequate resource allocation is equally paramount to the sustenance of STEM education, necessitating the provision of adequate funding for materials, equipment, and technology, thereby ensuring the availability of well-equipped STEM classrooms and laboratories that afford students hands-on experiences conducive to deeper comprehension. The implementation of flexible scheduling is another valuable strategy, permitting extended class periods that enable educators to delve more profoundly into intricate STEM topics, thereby facilitating a more comprehensive understanding among students. To nurture innovation and creativity within the STEM educator community, a cultural shift that venerates these attributes is indispensable, underpinned by the recognition and reward of innovative teaching practices and the provision of opportunities for pedagogical experimentation with novel methods. The cultivation of effective communication skills is foundational to STEM educators' efficacy, given their vital role in conveying complex concepts and sustaining student engagement; thus, the cultivation of robust communication abilities should constitute a central component of STEM teacher preparation programs. To further cultivate a dedication to research, STEM educators must be afforded opportunities for collaborative engagement with peers and industry experts, accompanied by incentives for pursuing advanced degrees or certifications, thereby sustaining their enthusiasm for research. Moreover, infusing real-world relevance into STEM education necessitates curriculum and pedagogical approaches that accentuate practical applications, fostering heightened student motivation and comprehension. Facilitating peer collaboration within the STEM educator community is a potent instrument for professional growth, engendering a supportive environment wherein best practices, resources, and experiences can be exchanged freely, fostering the innovation of teaching strategies. Lastly, assessments in STEM education must align with the multidimensional nature of the field, extending beyond the confines of content knowledge to encompass the evaluation of problem-solving skills, creativity, and interdisciplinary understanding. This holistic approach to assessment ensures that students are thoroughly prepared to confront the multifarious challenges inherent to STEM disciplines. By embracing and operationalizing these recommendations, educational institutions and policymakers can collectively labor toward the enhancement of STEM education, thereby ensuring that students are equipped with the competencies and knowledge requisite for success within an increasingly technology-driven world.

References

Bal, A. P., & Bedir, S. G. (2021). Examining teachers' views on stem education. *European Journal of Education Studies*, *8*(3).

Bozkurt, A., Ucar, H., Durak, G., & Idin, S. (2019). The current state of the art in STEM research: A systematic review study. *Cypriot Journal of Educational Sciences*, *14*(3), 374-383.

Buber, A., & Unal Coban, G. (2023). STEM project-based activity: Bio-efficacy of microalgae, *Science Activities*, *60*(2), 1-19. doi: 10.1080/00368121.2023.2168246

Chai, C. S. (2019). Teacher professional development for science, technology, engineering and mathematics (STEM) education: A review from the perspectives of technological pedagogical content (TPACK). *The Asia-Pacific Education Researcher*, *28*(1), 5-13.

Cochran-Smith, M. (2003). Learning and unlearning: The education of teacher educators. *Teaching and Teacher Education*, *19*(1), 5–28.

Czajka, C. D., & McConnell, D. (2016). Situated instructional coaching: A case study of faculty professional development. *International Journal of STEM Education*, *3*(1), 1–14. https://doi.org/10.1186/s40594-016-0044-1

Dailey, D., Bunn, G., & Cotabish, A. (2015). Answering the Call to Improve STEM Education: A STEM teacher preparation program. *Journal of the National Association for Alternative Certification*, *10*(2), 3-16.

Diana, N. (2021). Analysis of teachers' difficulties in implementing STEM approach in learning: a study literature. In *Journal of Physics: Conference Series*, 1806(1), 012219. IOP Publishing.

El-Deghaidy, H., & Mansour, N. (2015). Science teachers' perceptions of STEM education: Possibilities and challenges. *International Journal of Learning and Teaching, 1*(1), 51–54. https://doi.org/10. 18178/ijlt.1.1.51-54

Ersoy, H. (2016). Durum çalışması. In M.Y.Ö. and L.D. Editors (Eds.), *Eğitimde Üretim Tabanlı Çalışmalar için nitel araştırma yöntemleri*. Anı Yayıncılık.

Goodnough, S. P. K., & Stordy, M. (2014). Effective professional development in STEM education: The perceptions of primary/elementary teachers. *Teacher Education and Practice*, *27*(2/3).

Hebebci, M. T. (2022). Secondary school students' hopes and goals for STEM education. *Proceedings of ICEMST*, 175-180.

Kaleci, D., & Korkmaz, Ö. (2018). STEM education research: Content analysis. *Universal Journal of Educational Research*, *6*(11), 2404-2412.

Kolikant, Y. B. D., Martinovic, D., & Milner-Bolotin, M. (Eds.). (2020). *STEM teachers and teaching in the digital era: Professional expectations and advancement in the 21st century schools*. Springer Nature.

Madani, R. A. (2020). Teaching challenges and perceptions on STEM implementation for schools in Saudi Arabia. *European Journal of STEM Education, 5*(1), 1–14. https://doi.org/10.20897/ejsteme/8468.

Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: a systematic literature review. *International Journal of STEM education*, *6*(1), 1-16.

Maxwell, J. A. (1996). Qualitative research design. *Newbury Park*, CA: Sage.

Miles, MB., & Huberman, A.M. (1994). Qualitative Data Analysis (2nd edition). Thousand Oaks, CA: Sage Publications.

Nowikowski, S. H. (2017). Successful with STEM? A qualitative case study of pre-service teacher perceptions. *The Qualitative Report*, *22*(9), 2312.

Pitt, J. (2009). Blurring the boundaries – STEM education and education for sustainable development. *Design and Technology Education: An International Journal*, *14*(1), 37–48.

Ramli, N. F., & Talib, O. (2017). Can education institution implement STEM? From Malaysian teachers' view. *International Journal of Academic Research in Business and Social Sciences*, *7*(3), 721-732.

Schreier, M. (2014). Qualitative content analysis. In U. Flick (Ed.), The SAGE Handbook of Qualitative Data Analysis. SAGE.

Sungur-Gul, K., & Tasar, M. F. (2023). The Design, implementation, and evaluation of a STEM education course for pre-service science teachers. *Journal of Education in Science Environment and Health*, *9*(2), 85-100.

Thomasian, J. (2011). Building a science, technology, engineering, and math education agenda: An update of state actions. *NGA Center for Best Practices*.

Unal Çoban, G., & Buber, A. (2021). Modeling with STEM and Examples in Science Education. Ed: Hakan Şevki Ayvacı. In *Models and Modeling Science Instruction* Pegem Academy, Ankara, Turkey

Yıldırım, A., & Şimşek, H. (2003). Sosyal bilimlerde nitel araştırma yöntemleri [Qualitative research methods in the social sciences]. Ankara: Seçkin Yayınları.

Yıldız, E. P., Alkan, A., & Cengel, M. (2019). Teacher Candidates Attitudes towards the STEM and Sub-Dimensions of STEM. *Cypriot Journal of Educational Sciences*, *14*(2), 322-344.

Wang, H. H., Moore, T. J., Roehrig, G. H. ve Park, M. S. (2011). STEM integration: Teacher perceptions and practice. *Journal of Pre-College Engineering Education Research (J-PEER)*, *1*(2), 2.

Williams, J. (2011). STEM education: Proceed with caution. *Design and Technology Education*, *16*(1), 26-35.