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Nefise Özok Bulut
Istanbul Gedik University, Türkiye

Serap Erdoğan
Anadolu University, Türkiye

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STEM in Early Childhood: A Phenomenological Perspective on Teachers' Views, Experiences, and Professional Development Needs

Nefise Özok Bulut, Serap Erdoğan

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Abstract

The implementation of STEM education in early childhood has become increasingly important for the development of children's 21st-century skills. However, the effective realization of this interdisciplinary approach is directly related to teachers' theoretical knowledge and practical competencies. In this study, the views, implementation experiences, and professional development needs of preschool teachers regarding STEM education were examined. The study, conducted using a phenomenological design, a qualitative research method, included 16 preschool teachers selected through criterion sampling. Data were collected through two online focus group interviews and analyzed using the content analysis method. The findings indicate that teachers define STEM as an interdisciplinary approach but have some misconceptions. While all teachers emphasized that STEM education is important and necessary for children, it was found that they do not implement it. The main factors hindering STEM education include a lack of professional support, insufficient knowledge, materials, and resources, time constraints, and inadequate administrative and family awareness. The research findings show that teachers need practical training, mentoring support, professional learning communities, and guiding resources and materials. The study also offers recommendations to improve the quality of STEM implementation in early childhood.

Introduction

The rapid technological and societal transformations of the 21st century require individuals not only to access information but also to apply it effectively in complex and dynamic contexts. This situation has increased the need for educational approaches that holistically support 21st-century skills such as problem-solving, critical thinking, creativity, collaboration, and communication (OECD, 2023). STEM (Science, Technology, Engineering, and Mathematics) education, with its interdisciplinary nature, provides a strong response to these demands and plays a strategic role in preparing individuals for future professions (English, 2016; NSF, 2013).

Early childhood represents a critical developmental period in which neural connections are most actively formed, learning capacity is at its peak, and foundational cognitive, socio-emotional, and motor skills are established (Thompson, 2024). Children's innate curiosity, inquiry, and exploratory tendencies offer unique opportunities for STEM learning (Helm & Katz, 2016). Research indicates that early STEM experiences have lasting effects on later academic achievement, problem-solving skills, and interest in STEM careers (NRC, 2009). Furthermore, STEM education supports children's scientific process skills, mathematical thinking, and social, language, and motor development in a holistic manner (Clements & Sarama, 2016; Gonzalez & Freyer, 2014; NRC, 2015). International reports also emphasize that early childhood STEM education is a strategic investment not only for individual learning outcomes but also for countries' long-term innovation capacity and economic development (OECD, 2023; UNESCO, 2020). However, the effectiveness of such investments depends on teachers' competencies in both content knowledge and pedagogical skills (Wang & Mihai, 2024).

Preschool teachers are central actors in implementing STEM, designing learning environments that maintain children's curiosity and guiding them through the learning process (MacDonald et al., 2021; MoNE, 2018a). Effective integration of STEM requires teachers to accurately understand the approach and plan learning experiences based on children's curiosity, inquiry, and prior knowledge (Fusaro & Smith, 2018; NRC, 2011). Learning environments enriched with accessible materials that promote creative problem-solving and collaboration allow children to develop multiple solutions and learn through hands-on experiences (Çetin & Demircan, 2020). In this process, teachers who engage in reflective and consistent communication serve as important role models throughout inquiry, experimentation, and application stages (Bewan et al., 2017).

Despite generally positive attitudes toward STEM, the literature indicates that teachers encounter challenges such as limited time, materials, resources, subject knowledge, and insufficient experience in engineering and technology, which constrain classroom implementation (Amsbary et al., 2024; Brenneman et al., 2019; Demircan, 2022; MacDonald et al., 2021; Nikolopoulou, 2023; O'Neill et al., 2023; Yıldırım, 2021). Consequently, STEM often remains limited to science activities, child-centered and inquiry-based approaches are not fully adopted, and children may acquire inaccurate information from uncontrolled sources such as social media (Early Childhood STEM Working Group, 2017; Koyunlu-Ünlü & Dere, 2018). These findings highlight the importance of systematically analyzing teachers' needs and challenges and developing policy recommendations to ensure the sustainability and expansion of STEM education at the preschool level.

In the Turkish context, early childhood education has recently attracted growing policy attention, with MoNE initiatives aiming to expand access and improve quality. Although STEM education has become a global priority, its integration into early childhood education in Turkey is still emerging. Policy documents such as MoNE's 2023 Education Vision emphasize inquiry-based learning, interdisciplinary approaches, and the development of 21st-century skills, yet the translation of these principles into preschool practice has been limited (MoNE, 2018b). The more recently updated 2024 Preschool Education Program incorporates STEM-aligned competencies such as observation, inquiry, data collection, problem-solving, and mathematical reasoning (MoNE, 2024). This update signals a stronger policy-level commitment to interdisciplinary learning in early childhood. However, engineering design processes and systematic technology integration remain underrepresented, resulting in a gap between curricular objectives and classroom realities (Ata-Aktürk & Demircan, 2021; Güldemir & Çınar, 2021).

Professional development opportunities in STEM are often centralized and not specifically designed for the unique pedagogical needs of early childhood teachers (Düşkün, 2021; Salihoğlu & Yayla, 2023).

Taken together, these findings suggest that although Turkey's preschool education framework increasingly incorporates STEM-oriented content, the successful implementation of STEM education largely depends on teacher preparedness, access to context-specific professional development, and the availability of supportive learning environments. This underscores the importance of investigating preschool teachers' experiences, perspectives, and professional development needs through phenomenological research that captures the nuances of practice in the Turkish context. The current study aims to fill this gap by examining preschool teachers' experiences and perceptions of STEM education from a phenomenological perspective. Specifically, the study addresses the following research questions:

1. How do preschool teachers define and conceptualize STEM education?
2. What are preschool teachers' perspectives on STEM education?
3. What are preschool teachers' experiences related to STEM education?
4. What challenges do teachers encounter in implementing STEM education?
5. What are preschool teachers' professional development needs regarding STEM education?

The findings are expected to inform the design of teacher-centered and sustainable professional development programs for preschool STEM education, thereby contributing to the enhancement of STEM practices in early childhood education in Turkey.

Method

Research Design

This study employed a phenomenological research design to explore preschool teachers' perspectives and needs regarding STEM education. Phenomenology is a qualitative research approach that seeks to describe and interpret how individuals experience specific phenomena in a systematic, careful, and in-depth manner (Patton, 2015).

Participants

Purposeful criterion sampling was used to select participants for this study. In this sampling method, criteria are predetermined, and cases that meet these criteria are reviewed (Creswell & Creswell, 2018). The criteria for participant selection were as follows:

- Currently working in early childhood education institutions affiliated with the Ministry of National Education,
- Graduated from a preschool teaching undergraduate program,
- Having more than one year of professional experience.

Based on these criteria, the study included 16 preschool teachers as participants. Regarding demographic characteristics, the majority of the sample were women (n = 15; 93.75%), while there was only one male participant (n = 1; 6.25%). The age distribution showed that half of the teachers were between 31–35 years old (n = 8; 50%), while the remaining participants were evenly distributed across the 36–40 and 41–45 age groups (n = 4; 25% each). In terms of educational background, most participants held a bachelor's degree (n = 10; 62.5%), while others had a master's degree (n = 5; 31.25%) or a doctorate (n = 1; 6.25%). Regarding professional experience, the largest group consisted of teachers with 11–15 years of experience (n = 7; 43.75%), followed by those with 6–10 years (n = 5; 31.25%) and 16–20 years of experience (n = 4; 25%). Concerning the type of institution, most participants worked in independent preschools (n = 10; 62.5%), while fewer were employed in preschool classrooms within primary or middle schools (n = 6; 37.5%). Finally, when examining the age groups they taught, the majority of participants taught 4-year-old children (n = 9; 56.25%), followed by teachers of 5-year-olds (n = 4; 25%) and 3-year-olds (n = 3; 18.75%).

Data Collection Tools and Procedures

Data for this study were collected using a Personal Information Form and a Semi-Structured Focus Group Interview Form. First, a flyer containing information about the research process was prepared and shared online with preschool teachers. Teachers who wished to participate were asked to provide consent through a Voluntary Participation Form and complete the Personal Information Form via Google Forms. The Personal Information Form gathered data on teachers' gender, age, educational background, professional experience, type of institution, and the age group they taught.

Initially, a total of 22 preschool teachers completed the forms, and all were contacted via email. Nineteen teachers responded to the email. However, three teachers were unable to participate on the scheduled interview dates, resulting in a final sample of 16 teachers. Participants were divided into two heterogeneous focus groups based on their personal information to ensure diversity. Each focus group interview lasted approximately 120 minutes and was audio-recorded.

The interviews employed a semi-structured form developed by the researchers, consisting of ten questions designed to explore teachers' perspectives, knowledge, and needs regarding STEM education. After the initial draft, five experts in early childhood education reviewed the form and provided feedback. One example of the feedback concerned the question, "If you were to participate in a STEM Professional Development Program, what kind of process would you like to be involved in? How frequently would you like to meet? What would be your expectations from this process?" The recommendation was to first ask, "If you were to participate in a STEM Professional Development Program, what kind of process would you like to be involved in?" and then, based on participants' responses, to ask the follow-up questions sequentially if necessary.

Data Analysis and Validity and Reliability

Content analysis was used to analyze the data. As a method that allows systematic examination of qualitative data, content analysis enables researchers to uncover both explicit and implicit meanings. It aims to identify themes, patterns, and meaningful structures within qualitative data. In this process, data are coded and categorized in an organized manner to derive meaningful interpretations (Yıldırım & Şimşek, 2021). The research questions and the semi-structured interview questions were used as a framework for the analysis. Initially, audio recordings of the interviews were listened to and transcribed. Then, the data were coded independently by two researchers to identify themes. Inter-coder reliability was calculated at 86%, which exceeds the 70% threshold and is thus considered reliable (Miles & Huberman, 2018). Findings were supported with direct quotations, with teachers assigned codes such as T1, T2 for reporting purposes.

Several strategies recommended by Creswell and Creswell (2018) were applied to enhance the validity and reliability of the qualitative data. First, member checking was conducted; the findings and researcher interpretations were shared with participants to confirm accuracy and consistency through their feedback. Additionally, data were presented with rich, detailed descriptions to reflect the context. Finally, an external audit was conducted to reinforce reliability. The research process, data analysis, and findings were reviewed by an expert in qualitative research to ensure methodological rigor and integrity.

Results

This section presents the findings derived from the content analysis of the qualitative data collected in the study. During the analysis process, participants' statements were carefully examined, meaningful units of data were coded, and codes with similar content were grouped together to form overarching themes. As a result of the analysis, six main themes were identified:

1) Definition of STEM education,
2) The importance and necessity of STEM education,
3) Competencies of teachers implementing STEM education,
4) STEM education practices,
5) Barriers to the implementation of STEM education,
6) Teachers' needs regarding STEM education

These themes were structured in accordance with the research questions. Findings are supported by direct quotations from participants, which enhances the contextual validity of the results and provides a multidimensional perspective on STEM education practices.

Definition of STEM Education

This study examined teachers' perceptions of STEM education and the meanings they attributed to this concept. As shown in Table 1, participants' definitions of STEM education varied. Some teachers described STEM as integrated activities and an interdisciplinary approach, while others focused more on components such as coding and robotics applications, the use of technology, and experiments. Additionally, some definitions emphasized algorithmic thinking and project-based approaches.

Table 1. Definition of STEM Education

Sub-themes	Codes	Sample Quotations
Integrated activities	Integrated activities (n=12)	"STEM also addresses multiple points simultaneously, like an integrated plan." (T3)
Coding and robotics applications	Coding (n=6) Robotics applications (n=3)	"When I think of STEM, robotics applications and coding come to mind." (T8) "I don't know much, but from what I've heard here and there, I think of coding." (T15)
Interdisciplinary approach	Definition of STEM education (n=3) Interdisciplinary approach (n=4)	"STEM is the abbreviation for science, technology, engineering, and mathematics." (T6) "It forms a meaningful whole from an interdisciplinary perspective." (T7)
Use of technology	Use of technological tools (n=6)	"I think of children using technological tools and watching educational videos." (T1)
Experimentation	Experimentation (n=5)	"When I say STEM education, I think of experiments carried out in stages." (T4)
Algorithmic thinking	Algorithmic thinking (n=2)	"I do algorithmic exercises at the beginner level of coding. That comes to mind." (T2)
Project-based approach	Project-based approach (n=2)	"I think of projects in the Reggio Emilia approach." (T14)

Importance and Necessity of STEM Education

According to the findings of the study, all preschool teachers indicated that STEM education offers various benefits for children and, given its significance, should begin in the early years. These benefits were categorized under the sub-themes of 21st-century skills, cognitive development, lasting learning, and enjoyment (see Table 2). Teachers particularly emphasized that STEM education supports children's 21st-century skills and cognitive development. Additionally, they noted that because STEM provides concrete experiences and encourages active participation, it fosters lasting learning. Finally, teachers highlighted that STEM education creates an enjoyable learning environment by stimulating children's curiosity and sense of exploration, thereby increasing their engagement and making learning more pleasurable.

Table 2. Importance and Necessity of STEM Education

Sub-themes	Codes	Sample Quotations
21st-century skills	Problem solving (n=6) Productivity (n=6) Curiosity and exploration (n=6)	"It is a process in which curiosity and the desire to explore are emphasized. Early STEM education is important to sustain these feelings." (T6) "STEM includes skills such as problem solving, creativity,

Sub-themes	Codes	Sample Quotations
	Creativity (n=5) Collaboration (n=4) Communication (n=4) Self-confidence (n=4) Critical thinking (n=3)	collaboration, and productivity, making it an enjoyable learning experience for children." (T7) "Problem-solving, creative thinking, and communication skills develop. When they create something, they gain self-confidence." (T9)
Cognitive development	Cognitive (n=9)	"I believe it will have positive contributions to children, especially supporting cognitive development." (T13) "I think it will support cognitive skills such as reasoning and inquiry." (T15)
Retention of learning	Retention of learning (n=6)	"Rather than being passive, children learn more easily and retain knowledge longer by doing, experiencing, and reflecting." (T5)
Enjoyment	Enjoyment (n=4)	"Since exploration and curiosity are emphasized, I think it will be enjoyable for children." (T2)

Competencies of Teachers Implementing STEM Education

Within this theme, the competencies required for teachers to effectively implement STEM education were examined based on participants' perspectives (see Table 3). Most participants (n=14) emphasized that teachers implementing STEM should be open to development and innovation. Additionally, participants highlighted the necessity for teachers to possess knowledge about STEM education and its disciplines (n=7) and to understand children's developmental characteristics in order to plan age-appropriate activities (n=7). Other frequently mentioned competencies included being curious (n=6), investigative (n=4), creative (n=4), and able to identify problems (n=3).

Table 3. Competencies of Teachers Implementing STEM Education

Sub-themes	Codes	Sample Quotations
Open to development and innovation	Open to development and change (n=10) Innovative (n=4)	"A teacher open to development and change." (T1) "Teachers implementing this education should be innovative." (T16)
Knowledgeable	Knowledgeable about STEM (n=4) Knowledgeable about disciplines (n=3)	"The teacher needs to have knowledge about the disciplines that make up this education." (T3) "They should be innovative, open to new ideas, and knowledgeable about these disciplines." (T13)
Aware of children's developmental characteristics	Able to plan according to children's development (n=7)	"Teachers should know how children can better perceive and actively participate, so they must know the children very well." (T2)
Curious	Curious (n=6)	"Teachers should be curious, because STEM—math,

Sub-themes	Codes	Sample Quotations
		coding, IT—comes alive in my mind." (T12)
Investigative	Investigative (n=4)	"The teacher needs to be both inquisitive and curious." (T14)
Creative	Creative (n=4)	"A teacher with developed creative thinking skills." (T8)
Able to identify problems	Able to identify problems (n=3)	"A teacher able to recognize problems in their surroundings." (T6)

STEM Education Practices

Under this theme, teachers' experiences in implementing STEM education, learning environments, assessment methods, and family involvement were examined. The study found that only four teachers reported actively implementing STEM education, although all incorporated science and mathematics activities. It was also observed that classrooms generally lacked dedicated STEM learning centers, with most teachers (n=10) having only a science center. Supporting teacher statements include:

> *I don't implement STEM education. I only include science and math activities. There is no STEM center in my classroom; only a science center exists, but we have very few materials (T8).*
> *I try to implement STEM activities occasionally, but I don't feel adequate. We don't have a STEM center. We have a block center and a dramatic play center (T9).*

Regarding assessment, the majority of teachers (n=13) reported using the question-and-answer technique, while some also used product evaluation (n=4), drawing (n=3), and play-based assessment (n=1). Teachers explained:

> *We usually have assessment questions. For example, after an experiment, we ask questions. We mostly use the question-and-answer method for assessment (T3).*
> *I evaluate the final product of the process. I also use drawings and question-and-answer techniques to assess the process (T6).*

All participating teachers emphasized the importance and usefulness of family involvement in STEM education. During interviews, all teachers stated that they tried to involve families several times per term, often asking them to plan and implement activities. Some teachers also reported involving families through career presentations (n=3), home-based activities (n=2), observer participation (n=2), and collection displays (n=1). Teachers explained:

> *I think family involvement is important and effective. I try to include families every term. Usually, I invite them to the classroom. When they come, they can present their professions, but mostly they plan and implement an activity (T12).*
> *Family involvement in early childhood is very important. It benefits both the child and the family. I usually ask them to come to the classroom and implement a planned activity, often an experiment (T14).*

Finally, the majority of teachers (n=14) stated that their knowledge and skill levels were insufficient for effectively conducting STEM education, and emphasized their need for support in this area.

Barriers to Implementing STEM Education

This theme explores the factors that teachers perceive as limiting or hindering the implementation of STEM education (see Table 4). All teachers (n=16) reported feeling professionally unsupported in this area and highlighted a lack of knowledge about STEM education (n=6) as well as a sense of inadequacy (n=7). In addition, a large number of teachers indicated that resource shortages (n=12) and insufficient materials (n=9) prevented them from conducting STEM activities. Some participants also identified the limited awareness and support from school administration (n=8) and families (n=7) as barriers to implementing STEM practices. Finally, teachers noted that lack of time (n=6) and inadequate physical conditions of the school (n=4) were additional factors restricting the effective application of STEM education.

Table 4. Barriers to Implementing STEM Education

Sub-themes	Codes	Sample Quotations
Lack of professional development	Lack of professional support (n=16)	"STEM was not available during my undergraduate studies; it came later. This is the biggest challenge for teachers. New educational approaches emerge, but we struggle to understand and implement them because we are not adequately supported professionally." (T9) "The insufficient in-service training and its theoretical nature make it challenging for me professionally." (T11)
Insufficient knowledge	Lack of knowledge (n=6) Feeling of inadequacy (n=7)	"Not knowing how to implement it and feeling inadequate prevents us from applying STEM education." (T1) "We cannot fully implement this education without knowing what the STEM disciplines mean and how to convey them to children." (T10)
Lack of resources	Lack of example activities (n=10) Lack of guidance (n=2)	"We have difficulty finding age-appropriate resources for preschool. There are a few activities online, but we are unsure of their accuracy. There are no guiding resources." (T2)
Lack of materials	Lack of materials (n=9)	"Robotics and coding attracted a lot of interest from the children. However, due to lack of materials, we couldn't implement STEM effectively in our school." (T8)
School administration	Approach of administrative staff (n=5) Opinions of administrative staff	"When the administrative staff is not encouraging or providing motivational support regarding STEM and considers it unimportant, we cannot apply new approaches." (T12)

Sub-themes	Codes	Sample Quotations
	(n=3)	
Families	Families' perspective (n=4) Family participation (n=3)	"When activities are staged and family participation cannot be ensured, implementation becomes difficult." (T4) "Among the obstacles, families not understanding or seeing STEM education as unnecessary is an issue." (T5)
Insufficient time	Insufficient time (n=6)	"Trying to cover too much in a short time causes problems. There is no time left for STEM activities." (T3) "STEM activities take too long, leaving no time for other activities. For this reason, I cannot implement them." (T13)
Physical conditions of the school	School facilities (n=2) School conditions (n=2)	"The technological infrastructure in schools is also important. Since STEM activities involve technology, lacking adequate infrastructure in the classroom inevitably causes gaps and problems." (T6) "Factors like the school yard, physical conditions, and the location of the school also create separate challenges in implementing STEM." (T15)

Needs for STEM Education

Within this theme, teachers' perspectives regarding the support areas required to implement STEM education effectively and ensure its sustainability were examined (see Table 5). All participants (n=16) emphasized the need for mentorship-based, practice-oriented professional development programs that promote active participation. Accordingly, participants highlighted the importance of receiving systematic feedback from mentors (n=12) and having the process monitored (n=10).

A large portion of teachers reported a need for collaboration with colleagues within STEM education (n=13), access to guiding resources (n=12), and provision of necessary materials (n=12). Teachers also indicated that enhancing family involvement in STEM education is crucial; in this regard, they requested support for sharing different family participation techniques (n=14) and for actively involving families in the process (n=10). Similarly, teachers expressed the need to acquire knowledge about various assessment techniques (n=10) and noted challenges in appropriately assessing children with special needs in STEM activities (n=5). Finally, some participants identified administrative support (n=8) as an important area of need.

Table 5. Needs for STEM Education

Sub-themes	Codes	Sample Quotations
Professional development program	Practice-based trainings (n=16) Trainings ensuring active participation	"Coming from a heavily rote-based education system, we find it difficult to implement interdisciplinary practices. First, we need experiences and perspectives like these in our own lives. We need practice, not theory. Therefore, we

	(n=14)	require support through a program that provides these opportunities." (T10) "We have faculty members working on STEM, but especially in early childhood education, faculty should offer workshop-style training to willing teachers. There should be both theoretical and practical training. For example, a book could be published, teachers divided into groups, and scenarios discussed on how to solve problems; this way, we would learn better and be ready to implement." (T9)
Mentorship support	Mentorship support (n=16) Receiving systematic feedback (n=12) Monitoring the process (n=10)	"I would like someone to observe and evaluate me regularly throughout this process. I would like to meet with an expert continuously and be able to ask questions whenever I have doubts." (T15) "We need a program where teachers learn by doing and experiencing, and it should be monitored by field experts. Training should not end once it is delivered; the process must be tracked to see if we can apply it in our classrooms. There should be a system for receiving feedback periodically and staying in contact with a field expert to ask questions when stuck." (T14)
Collaboration with colleagues	Collaboration with colleagues (n=13)	"One of our needs is to come together with colleagues who have good examples of what and how to do things. I would like to participate in their concrete examples." (T7) "There is definitely a need for collaboration among teachers. If we work together, we automatically support each other. This way, we can implement STEM more effectively." (T14)
Guiding resources	Example activities (n=10) Guiding resources(n=2)	"When I searched online, I found a few video-based activities on social media. But I don't know if they truly qualify as STEM. I cannot trust and implement them. We need sample activities suitable for early childhood." (T8)
Material support	Provision of necessary materials (n=12)	"We cannot just rely on materials anymore. We need basic tools like simple dynamos, and access to these is not easy." (T4)
Family involvement	Different family participation techniques (n=14) Ensuring family involvement (n=10)	"I have difficulty ensuring family participation. I don't know how to involve families in STEM activities, and I need support in this regard." (T1)

Assessment	Different assessment techniques (n=10) Assessment of children with special needs (n=5)	“Normally, I use the question-and-answer technique frequently, but because STEM activities involve multiple disciplines, I don’t know how to evaluate everything. I would like support on this.” (T11) “I need to learn both different assessment techniques and how to evaluate children with special needs in STEM activities.” (T3)
Administrative support	Support from administrative staff (n=8)	“I consider it important that school administration provides encouragement, motivation, and supportive guidance for teachers regarding STEM.” (T6)

Discussion, Conclusion and Recommendations

This study aimed to examine early childhood teachers’ perceptions, experiences, and professional development needs regarding STEM education. The findings indicate that while some teachers define STEM as an interdisciplinary and integrated educational approach, others restrict the concept to technology-based applications (coding, robotics, digital tools) or experiments alone. Notably, even teachers who reported implementing STEM activities demonstrated such conceptual misunderstandings, suggesting that STEM education is not being applied accurately in practice. The teachers’ expressions of feeling inadequate and requesting support further reinforce this observation. Consistent with the literature, previous studies reveal that early childhood teachers often associate STEM education with abstract concepts and technology-focused activities, believe that implementing STEM requires expensive materials, and frequently exhibit misconceptions about the concept (Günşen et al., 2019; Erol & İvrendi, 2025; Nikolopoulou, 2023; O’Neill et al., 2023; Ültay & Ültay, 2020). The absence of a systematic STEM curriculum in early childhood settings may contribute to this situation (Wang & Mihai, 2024). Additionally, as teachers noted, the limited availability of online and printed resources, the potential inaccuracy of existing content, and the predominance of theoretical rather than practical training delivered by field experts exacerbate the problem. Research also emphasizes that such deficiencies hinder teachers’ ability to effectively learn STEM and integrate it into their practice, indirectly shaping children’s attitudes and beliefs toward STEM (Early Childhood STEM Working Group, 2017; MacDonald et al., 2021; Yıldırım, 2021). In this context, supporting teachers with structured professional development programs that include mentorship and peer collaboration starting from the undergraduate level is considered essential. These programs should provide hands-on, practice-oriented experiences, opportunities for reflective feedback, and guidance from field experts to ensure that teachers develop the necessary competencies to implement STEM education effectively and foster positive STEM attitudes in young children.

The findings of this study, consistent with previous research, indicate that teachers perceive STEM education as important and beneficial for children’s development (Amsbary et al., 2024; Erol & İvrendi, 2025; O’Neill et al., 2023; Özcan-Döğücü, 2024). Teachers emphasized that STEM particularly supports 21st-century skills, cognitive development, long-term learning, and motivation for learning. These multifaceted contributions position STEM not merely as a pathway to academic achievement but as a holistic educational approach that also fosters cognitive, social, and emotional development. Furthermore, teachers' emphasis on fun and curiosity-driven learning environments highlights that STEM can be integrated with play-based learning and aligns with the developmental principles of early childhood education (Bers, 2020).

The study also shows that teachers identify both knowledge-based and personal attributes as essential competencies for effectively implementing STEM education. Specifically, teachers highlighted the importance of being open to innovation, inquisitive, creative, and curious, alongside possessing a strong pedagogical foundation grounded in STEM disciplines and child development knowledge. This indicates that the teacher's role extends beyond mere implementation to designing learning environments, structuring problem-based situations, making sense of interdisciplinary interactions, and understanding pedagogical practices. The literature similarly emphasizes that effective STEM implementation requires multidimensional competencies, including interdisciplinary thinking, critical perspectives, and pedagogical expertise, rather than theoretical knowledge alone (Erol & İvrendi, 2025; Margot & Kettler, 2019; Wang & Mihai, 2024). Within this framework, for STEM education to be effectively implemented in early childhood, teacher education programs must focus not only on subject content but also on developmentally appropriate integration of these contents, highlighting a critical component of professional preparation.

The findings indicate that teachers experience various challenges in implementing STEM education. Although most participants expressed curiosity about STEM, they reported that their practices were limited, primarily focusing on science and mathematics activities. This aligns with previous studies, which note that early childhood teachers worldwide show interest in STEM but often do not implement it due to knowledge gaps, pedagogical competency issues, and the need for professional support (Abanoz & Deniz, 2021; Amsbary et al., 2024; Demircan, 2022; Erol & İvrendi, 2025; MacDonald et al., 2021; Nikolopoulou, 2023; O'Neill et al., 2023; Özcan-Döğücü, 2024; Yıldırım, 2021).

Teachers also reported that their classrooms lacked dedicated STEM learning centers, with most having only science centers and limited materials. Such environments are valuable as natural learning spaces for early childhood development and STEM education (Moomaw, 2013). Assessment practices were similarly constrained, with teachers predominantly using question-and-answer techniques and employing alternative or authentic assessment methods only minimally. STEM education, however, requires multidimensional assessment approaches that evaluate not just the product outcomes but also problem-solving processes, reasoning, and collaborative skills (Bers, 2022). Reliance on traditional assessment methods thus conflicts with the process-oriented nature of STEM and limits the quality of implementation (NRC, 2014).

The findings further highlight that teachers recognize the importance and benefits of family involvement in STEM education. However, the frequency and nature of participation are limited. Most teachers reported inviting families to the classroom only a few times per term and primarily expecting them to plan and implement a single activity. This suggests that family engagement is largely event-based rather than continuous or multifaceted. Effective family involvement, when conducted regularly, in multiple forms, and aligned with pedagogical objectives, can significantly enhance children's learning experiences (Dunst, 2002; Epstein, 2011). Literature also emphasizes that families should participate not merely as activity implementers but as observers, providers of materials, home-based learning supporters, or in career introduction roles, in an ongoing, collaborative manner (Fan & Williams, 2010). Home-based activities, in particular, enrich learning processes and help connect problem-solving skills to real-life contexts (Tippett & Milford, 2017). Therefore, limiting family engagement to classroom events reduces the potential benefits of the process and keeps school-family collaboration at a superficial level. These findings suggest that teachers require guidance to plan family involvement in a more systematic, diversified, and inclusive way. Given that early childhood learning occurs both at school and at home, family participation is a critical component for the sustainability and effectiveness of STEM education.

The research findings reveal that teachers face various pedagogical, environmental, and structural barriers in implementing STEM education. Participants particularly identified lack of professional support, insufficient knowledge and experience, limited access to materials and resources, time constraints, inadequate physical conditions of the school, and low awareness of STEM among school administrators and families as key obstacles. Previous studies similarly indicate that teachers' lack of knowledge and self-confidence, difficulties in accessing age-appropriate resources, limited time and materials, and insufficient administrative support are significant barriers (Amsbary et al., 2024; Demircan, 2022; Jamil et al., 2018; MacDonald et al., 2021; Nikolopoulou, 2023; O'Neill et al., 2023; Ültay & Ültay, 2020; Wang & Mihai, 2024). Limited awareness of STEM pedagogy among school administration and families hinders its integration into school culture and complicates school-family collaboration. Similarly, insufficient physical environments and lack of appropriate materials restrict teachers' pedagogical initiatives and may negatively affect the quality of learning environments.

Another significant finding is that teachers experience difficulties accessing STEM-related resources. Participants reported that STEM books, activity examples, and guidance materials suitable for early childhood education were inadequate both in content and quantity, while online resources were often questionable in terms of reliability. This situation negatively impacts teachers' preparation for implementation and makes it difficult to base STEM on solid pedagogical foundations. Prior research also supports this finding, showing that the lack of structured and developmentally appropriate STEM resources in early childhood education negatively affects teachers' confidence in implementation and perceived pedagogical competence (Erol & İvrendi, 2025; Park et al., 2017). Accordingly, it is crucial to develop STEM resources tailored to early childhood, grounded in scientific principles, emphasizing interdisciplinary integration and inquiry-based learning, and to provide these resources systematically to teachers. In addition to providing materials, guidance on how and with which pedagogical approaches to use them should be considered a critical component of professional support mechanisms.

The study further revealed that teachers' professional development needs align with these findings. All participants emphasized the necessity of practice-oriented, mentorship-based, and actively engaging professional development programs. Supportive elements such as regular feedback, process monitoring, collaboration among colleagues, and access to guidance materials are considered critical factors for the sustainability of STEM education. Numerous studies worldwide also highlight similar needs, emphasizing that enhancing the quality of STEM practices requires not only content knowledge but also practice-based experiences and collaborative learning environments (Abanoz & Deniz, 2021; Amsbary et al., 2024; Erol & İvrendi, 2025; Günşen et al., 2019;

Intisari et al., 2024; MacDonald et al., 2021; Nikolopoulou, 2023; O'Neill et al., 2023; Özcan-Döğücü, 2024; Park et al., 2017; Yıldırım, 2021). Collectively, these findings indicate that STEM education can be sustained not only through individual effort but also through multi-dimensional support mechanisms and holistic policies (Margot & Kettler, 2019).

The study has certain limitations that should be considered, as they may affect the generalizability and scope of interpretation of the findings. First, due to the qualitative nature of the research, the findings are not generalizable. Future studies involving larger samples, including teachers from different regions and socio-economic contexts, would be valuable in enhancing the diversity and generalizability of the findings. The research data were obtained solely through semi-structured interviews. This data collection method, which relies on participants' self-reports, does not allow for the evaluation of potential implicit practices, as the implementation processes were not directly observed. In future research, the use of additional data sources, such as classroom observations, document analysis, and video recordings, could provide a more comprehensive examination of teacher practices.

Based on the study results, it can be suggested that both pre-service and in-service training should emphasize not only theoretical knowledge transfer but also practice-based learning, mentorship support, collaborative work models, and feedback mechanisms. Furthermore, it is important to develop STEM materials, guidance resources, and digital content for early childhood education that are scientifically grounded and aligned with children's developmental characteristics, and to ensure teachers have access to these resources. To enhance the reliability of existing materials and resources, the involvement of subject-matter experts is recommended.

National-level strategic plans should be developed to promote the widespread implementation of STEM education in early childhood, ensuring effective collaboration among policymakers, subject-matter experts, and practitioners throughout this process. Future research should particularly focus on practice-oriented topics, such as the development of early childhood-specific STEM resources, the design of mentorship-based professional development programs, and the systematic evaluation of the effectiveness of these programs.

Additionally, it is anticipated that the use of artificial intelligence (AI) applications by teachers will become more widespread in the future. In this context, measures should be taken to ensure that AI-based educational tools provide high-quality and pedagogically appropriate content. It is essential for teachers to systematically monitor and guide these applications, as well as to support the development of platforms that ensure content is delivered reliably and updated regularly.

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Author Information

Nefise Özok Bulut	Serap Erdoğan
https://orcid.org/0000-0002-2070-7797	https://orcid.org/0000-0001-6149-4460
Istanbul Gedik University	Anadolu University
Türkiye	Türkiye
Contact e-mail: *nefise.ozok@gedik.edu.tr*	