Uncovering the Perspectives of Educators Regarding the STEM Practices in Schools

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Abstract

STEM education is a crucial aspect of preparing students for the demands of the 21st century workforce. The present study aims to explore the perspectives of STEM practitioners on their teaching practices. To achieve this aim, we employed a descriptive qualitative approach, utilizing both qualitative content analysis and thematic analysis. The study involved eight STEM practitioners who participated in individual semi-structured interviews. The research questions posed in the study focused on the features of STEM practices and practitioners, the educational value of STEM practices, and the evaluation process of STEM practices. The results revealed four themes and 52 subthemes, highlighting the importance of a STEM teacher's knowledge of the field, pedagogy, engineering, and integration. The study emphasizes the significance of using technology during STEM practices, encouraging collaborative work, ensuring cooperation, providing critical thinking, increasing productivity, ensuring interdisciplinary solidarity, increasing creativity, strengthening communication, providing peer agreement, providing cognitive thinking, and attempting to solve contemporary problems. The findings of this study contribute to the ongoing discourse on STEM education and provide insights into the perspectives of STEM practitioners.

Keywords: *STEM, STEM education, qualitative research, teacher views*

Eğitimcilerin STEM Uygulamalarına ilişkin Görüşlerinin Belirlenmesi

Öz

STEM eğitimi, öğrencileri 21. yüzyıl iş gücü gereksinimlerine hazırlamada önemli bir yere sahiptir. Bu çalışma, öğretmenlerin STEM eğitimi konusundaki görüşlerini ortaya koymayı amaçlamaktadır. Bu hedefe ulaşmak için, çalışmada betimsel nitel yaklaşım benimsemiş olup, nitel içerik analizi ve tematik analiz yöntemleri kullanılmıştır. Çalışma verileri yarı yapılandırılmış birebir görüşmeler yoluyla elde edilmiştir. Araştırma soruları, STEM uygulamaları ve uygulayıcıların özellikleri, STEM uygulamalarının eğitimsel değeri ve STEM uygulamalarını değerlendirme sürecine odaklanmıştır. Elde edilen sonuçlar dört tema ve 52

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alt tema ortaya çıkarmış ve bu temalar STEM öğretmeninin alan bilgisi, pedagoji, mühendislik ve entegrasyon konularındaki bilgisinin önemine işaret etmektedir. Bulgular incelendiğinde, STEM uygulamaları esnasında teknoloji kullanımının önemi, iş birliğinin teşvik edilmesi ve sürdürülmesi, eleştirel düşünmenin teşvik edilmesi, üretkenliğin artırılması, disiplinler arası dayanışmanın sağlanması, yaratıcılığın artırılması, iletişimin güçlendirilmesi, akran onayının sağlanması ve güncel sorunları çözmeye katkı sağlaması gibi kavramlar STEM eğitimi açısından öne çıkan kavramlardır. Araştırma bulgularının, STEM eğitimi çalışmalarına katkı sağlaması ve STEM uygulayıcılarına ışık tutması beklenmektedir.

Anahtar Kelimeler: *STEM, STEM eğitimi, nitel araştırma, öğretmen görüşleri*

Introduction

Today it is more important how talented and knowledgeable students are than how much information they possess because information can be easily obtained. It seems difficult for students who only rely on knowledge to survive in the future world, as large part of the world in the future will consist of components such as artificial intelligence and robotics (Xu & Ouyang, 2022). Therefore, the development of 21st-century skills such as collaboration, creativity, critical thinking, and problem-solving at an early age is important (Hebebci, 2022). STEM (Science, Technology, Engineering, Mathematics) is a significant paradigm shift applied to the educational field and it is a strategy to acquire these skills. STEM education is acquiring the knowledge and skills required by the corporate world of the 21st century and has gained significant attention over the last two decades (Land, 2013). The importance of integrating interdisciplinary knowledge and skills to solve complex problems in daily life is widely acknowledged (Bybee, 2010). STEM translated into Turkish as FeTeMM (Çorlu, 2012), was first introduced in the 1990s (Sanders, 2009). Later, when it was brought up again by Dr. Judith Ramaley in 2001, it attracted the attention of many researchers (Bybee, 2010; English, 2016; Thibaut et al., 2018). Finally, the publication of the "Next Generation Science Standards" study in the United States in 2013 marked a significant milestone in the growing interest and recognition of STEM fields (Yager & Brunkhorst, 2014). According to Yıldırım (2016) STEM education is an educational strategy in which science, technology, engineering, and mathematics are taught together and related to real-world applications. This method also emphasizes the development of 21st-century skills of students. STEM education is used in various forms in many countries today, and numerous studies have been conducted on the subject (Banks & Barlex, 2014; MoNE, 2016). STEM education is an educational approach that is supported by 21st-century skills and is related to daily life (Yıldırım, 2016). Furthermore, STEM education is important because it allows for interdisciplinary work, has practical applications in daily life (Banks & Barlex, 2014). STEM education has made its presence felt not only in developed countries but also in Türkiye, with various implementations and initiatives. One of the primary goals of STEM activities in Türkiye is to prioritize national needs and tailor the approach accordingly, rather than blindly adopting practices from other countries.

This objective aims to equip students with the necessary skills for the 21st century by incorporating relevant implementations, providing guidance in science and mathematics education, and offering flexible curricula. By doing so, students can develop the competencies required for the evolving workforce and contribute to the growth and development of Türkiye (Çorlu, 2017). In recent years, there have been concerns about the academic performance of Turkish students in the fields of science and mathematics, as evidenced by the results of international assessments such as the Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA) conducted by the Organisation for Economic Cooperation and Development (OECD), as well as domestic examinations carried out by the Student Selection and Placement Center (ÖSYM) (Han, 2015; OECD, 2012). Efforts to align the Turkish Educational System with European Union standards can be traced back to the implementation of curriculum reforms based on a constructive approach in 2005 (Akgündüz, 2016). These reforms aimed to improve the quality and effectiveness of education in Türkiye. The results of PISA and TIMSS highlight the importance of STEM education, which emphasizes the practical application of mathematical and scientific knowledge, throughout the entire educational journey from early childhood to higher education (Akgündüz, 2016). STEM practices, encompassing science, technology, engineering, and mathematics, holds immense significance in today's society. As we navigate the complex challenges of the 21st century, STEM education equips individuals with the necessary skills to understand, analyze, and solve problems effectively.

The integration of STEM practices in schools is of paramount importance for several reasons. Firstly, it fosters critical thinking and problem-solving abilities, enabling students to approach real-world issues with innovation and creativity. Secondly, STEM education promotes curiosity, encouraging students to explore and inquire, thus nurturing a lifelong love for learning. Moreover, STEM education promotes collaboration and teamwork, instilling essential social and communication skills that are vital in the modern interconnected world. Lastly, with technology being an integral part of our daily lives, STEM equips individuals with the knowledge to embrace and adapt to the rapid advancements shaping our society. Overall, the incorporation of STEM practices in schools is essential for preparing the next generation to be competent, adaptable, and capable contributors to a technologically advancing world. In this context, the present study aims to provide information and raise awareness about STEM education among individuals and institutions. Specifically, the study seeks to determine the views of teachers who apply STEM practices in their classes. The research questions focus on the general characteristics of STEM practices in schools, the characteristics of STEM leader teachers or practitioners, the educational value of STEM practices, and the evaluation process of STEM practices. The study employs a qualitative research design, utilizing semi-structured interviews to gather data from eight STEM practitioners. The findings of this study contribute to the ongoing discourse on STEM education and provide insights into the perspectives of STEM practitioners. In line with this purpose, the following research questions are addressed through the study:

1. What are the characteristics of STEM practices at school?
2. What are the characteristics of the STEM practitioners at school?
3. What are the views on the educational value of STEM practices at school?
4. What is the evaluation process of STEM practices at school?

Theoretical Background

The acronym STEM has traditionally denoted the disciplines of science, technology, engineering, and mathematics. However, in recent times, there have been variations of the acronym, such as STEAM, that encompass additional areas of study like agriculture, the arts, the environment, economics, education, and medicine. These extended versions of the acronym reflect a growing recognition among governments, educators, businesses, communities, and industry leaders that there is a pressing need to equip students with comprehensive knowledge and skills for better education. A holistic understanding of STEM has become increasingly crucial as our world is significantly shaped by advancements in science and technology (Zollman, 2012). Over the past decade, the field of STEM education has witnessed significant advancements, as evidenced by the notable increase in research publications in this area (Li et al., 2020). STEM education and its associated disciplines are no longer mere buzzwords within educational systems, but have gained substantial attention and importance. This surge in interest is evident through increased public engagement, national initiatives prioritizing STEM education, and a growing body of research, transforming it into a global educational movement with remarkable enthusiasm (Li et al., 2020). However, it is important to acknowledge that STEM education encompasses various dimensions, ranging from disciplinary to multidisciplinary, interdisciplinary, or even transdisciplinary approaches to STEM (Vasquez et al., 2013). STEM education involves an interdisciplinary approach where multiple disciplines are integrated to create a holistic learning experience. The conceptual framework of STEM practices is based on an interdisciplinary approach that emphasizes a student-centered and real-life relevant learning experience. FeTeMM is the Turkish acronym for STEM, and it has been translated into Turkish to represent the essence of the STEM concept (Çorlu, 2012).

There is a strong relationship between STEM and 21st-century skills (Sivrikaya, 2019). However, the previous research argued that teachers are lack of sufficient knowledge about STEM (Biçer et al., 2018). To address this knowledge gap, Ministry of National Education (MoNE) in Türkiye has launched a STEM Integrated Teaching Framework (STEM ITF) and teachers registered in the STEM Leader Teacher Professional Development Program (STEM LTPDP) to receive their STEM training

(MoNE, 2016). In the initial year of the STEM LTPDP, conducted 2016 in Türkiye, 39 teachers participated from five different cities. Subsequently, in the 2017, the program's training sessions were held in satellite locations across eight cities, attracting 250 educators. The completion rate of the program prerequisites and attainment of diplomas by participating teachers stood at 78%. In 2018 the program, which included approximately 1000 STEM Leader Teacher (STEM LT) candidates, exhibited a completion rate of 68%. The subsequent year 2019, witnessed the continuation of the program with around 1000 STEM LT candidates, achieving a completion rate of 62%. In the 2020 academic year, 350 teachers sustained their involvement in the program, and 63% of them were granted graduation rights. The program persisted in the 2021 academic year with nearly 1000 STEM LT candidates, demonstrating a completion rate of 54%. Continuing into the 2022, the program engaged approximately 1090 teachers, with 273 of them successfully graduating and earning the esteemed title of STEM LT.

Within the realm of STEM education, there are two main categories: traditional STEM Practices and integrated STEM Practices. Traditional STEM education is commonly employed in contemporary educational systems, where the individual STEM disciplines are treated as separate entities (Guzey et al., 2016; Sanders, 2009). On the other hand, integrated STEM education involves the integration of theoretical knowledge from science and mathematics with practical applications in technology and engineering (Akgündüz, 2016; Sanders & Wells, 2010). Effective integrated STEM teaching necessitates teachers to possess a diverse range of knowledge bases, specifically pedagogical content knowledge for STEM (PCK for STEM). Shulman (1986) introduced the concept of PCK, describing it as the specialized knowledge required for teaching a subject and the ability to represent and formulate that subject in a way that is understandable to others. Building upon the ideas of various scholars such as Saxton et al. (2014), PCK for STEM has been proposed and conceptualized, consisting of five key components. These components encompass how teachers perceive and conceptualize STEM education, their understanding of the role of STEM within curriculum standards and educational materials, the incorporation of STEM concepts into student learning objectives, a comprehensive understanding of students' existing conceptions and challenges related to STEM, the development of effective STEM teaching strategies and instructional materials, and the assessment of student learning outcomes through STEM instruction. The explanation of the five principles that Vasquez et al., (2013) suggest being followed when implementing STEM education is as follows:

1. Emphasize Integration: Students can better understand the connections between ideas and problems when two or more disciplines are combined. Whether it is combining science with engineering or social sciences with mathematics, integrating two or more STEM subjects enhances students' understanding of concepts and themes.

2. Make It Relevant: Students often do not know where and how they will use the knowledge they have learned. Therefore, it is important to show them how the learned topics are important and how they relate to real life or current problems. Students may ask themselves questions such as "Why is this topic important?" "How does it relate to a real life or current problem?" "Do I need to learn more about this topic because of a regional or global issue?" "Will my knowledge and expertise in this area increase my chances of finding a better job?" Providing clear answers to such questions is crucial.

3. Emphasize 21st Century Skills: The most important skill for the future world is not knowledge alone but the ability to access information when needed, creatively solve problems, and generate new ideas. Teachers must create scenarios in which students can apply these skills.

4. Challenge Students at Their Readiness Level: Students should be presented with tasks that challenge them according to their level of readiness. Giving children tasks that are too easy or too difficult for them is very important. If they are presented with a challenge beyond their level, there will not be sufficient engagement, and events such as dropping out of school may occur. If a simpler task is provided, the desired success may not be achieved.

5. Combine Various Teaching Techniques with STEM Education: Using various teaching techniques in STEM education is crucial. For example, in problem-based learning, students can come up with original solutions to the given problem. As part of project-based learning, the student creates, designs, and completes their own project.

In conclusion, the exploration of STEM educators' views and the implementation of the five principles proposed by Vasquez et al. (2013) hold significant importance in the field of STEM education. By understanding how teachers perceive and conceptualize STEM education, we can gain insights into their beliefs, attitudes, and practices, which can ultimately shape the quality of STEM instruction. Additionally, uncovering teachers' understanding of the role of STEM within curriculum standards and educational materials is crucial for effective integration of STEM concepts into student learning objectives. This ensures that students can better understand the connections between different STEM disciplines and see the relevance of what they are learning to real-life or current problems. Moreover, emphasizing 21st-century skills and challenging students at their readiness level are essential for preparing them for the future world, where problem-solving, creativity, and critical thinking are highly valued. Finally, the use of various teaching techniques in STEM education, such as problem-based learning and project-based learning, allows students to actively engage in the learning process and develop their own solutions and projects. Overall, the research on STEM educators' views and the implementation of these principles contribute to the enhancement of STEM education by providing valuable insights and strategies for effective instruction. By incorporating these principles into their teaching practices, educators can foster students' understanding, engagement, and success in STEM subjects, ultimately preparing them for the demands of the 21st century.

Method

This study employed a descriptive qualitative research design, utilizing qualitative content analysis and thematic analysis, to explore the viewpoints of STEM practitioners regarding STEM practices in schools. Descriptive research aims to provide straightforward descriptions of experiences and perceptions, particularly in areas where limited knowledge exists about the topic being investigated (Sandelowski, 2010). A qualitative descriptive design is deemed appropriate when the subjective nature of participants' experiences is crucial, and their diverse experiences directly relate to the research questions (Bradshaw et al., 2017).The primary objective of descriptive research is to meticulously and clearly describe a phenomenon and its characteristics, while employing descriptive data analysis techniques that involve analyzing, describing, and summarizing events or phenomena derived from interviews or direct field observations (Damayanti et al., 2022). Qualitative descriptive research generates data that depict the "who, what, and where" of events or experiences from a subjective perspective (Kim et al., 2017). Philosophically, this approach aligns with constructivism and critical theories, which employ interpretative and naturalistic inquiry methods (Lincoln & Guba, 1985). Consequently, the researchers collected STEM practitioners' perspectives on STEM practices through an open-ended questionnaire. Descriptive qualitative research aims to characterize a phenomenon, focusing on "what" rather than "how" or "why" something occurred (Gall et al., 2007; Smith et al., 2011; Vaismoradi et al., 2013).

Procedure

Eight STEM educators with previous STEM training were chosen and invited to take part in the research voluntarily. To gather primary data, formal semi-structured questionnaires were employed during face-to-face individual interviews conducted between February and March 2023. The interviews lasted between 35 and 45 minutes and were recorded for transcription purposes. Verbatim transcriptions were produced for all interviews. The interview guide encompassed five demographic questions (age, gender, teaching experience, field of expertise, STEM experience) and four open-ended questions. These questions aimed to investigate the participants' experiences and viewpoints regarding STEM practices in educational settings. The study strictly adhered to the ethical principles laid out in the Declaration of Helsinki to protect the well-being of the human subjects involved. Written informed consent was obtained from all participants, signifying their voluntary participation and agreement with the data collection, analysis, and use of the resulting data. Participants were free to discontinue or terminate the interview at any point without needing to provide a justification. The study received ethical approval (2023-05) from the Hitit University Ethics Committee of Non-Interventional Studies.

Participants

Descriptive research studies, including qualitative ones, often employ non-probability sampling methods, and purposive sampling is commonly used (Palinkas et al., 2015). Purposive sampling entails selecting participants who possess relevant knowledge and experience pertaining to the phenomenon under investigation. While qualitative descriptive research typically involves small sample sizes, it is crucial to gather sufficient data to achieve the study's objectives (Ritchie et al., 2013). Sample size determination in qualitative research is often guided by data saturation, which depends on the research design and population size (Fusch & Ness, 2015). In this particular study, the sample consisted of eight STEM practitioners employed in private high schools in Istanbul, Turkey. The participants were assigned code numbers STEMP1 to STEMP8, as indicated in Table 1. The participants' ages ranged from 28 to 45, with an average age of 33.7. Seven of the participants were female, and one was male. The participants had a minimum of 3 years and a maximum of 15 years of teaching experience, with an average of 8.8 years. All participants worked at private high schools. Their STEM experience varied from 1 to 4 years, with an average of 2.8 years. Regarding their fields of expertise, six participants were science teachers, while the remaining two were mathematics teachers.

Table 1.
Characteristics of Participants

Code Names	Age	Gender	Teaching Experience	Field of Expertise	STEM Experience
STEMP1	32	F	8	Biology	3
STEMP2	30	F	8	Biology	3
STEMP3	45	M	15	Physics	4
STEMP4	33	F	8	Physics	3
STEMP5	28	F	3	Chemistry	1
STEMP6	34	F	8	Chemistry	4
STEMP7	34	F	11	Mathematics	3
STEMP8	34	F	10	Mathematics	1

Data Collection and Analysis

Qualitative descriptive research aims to explore the "who, what, and where" aspects of phenomena (Sandelowski, 2010). When conducting this type of research, face-to-face interviews are often considered the most suitable approach (Ward et al., 2015). Thus, the predominant method for data collection is semi-structured individual face-to-face interviews (Kim et al., 2017). In this study, data was gathered by conducting individual face-to-face interviews, utilizing a semi-structured questionnaire comprising four open-ended research questions. The construction of these research questions followed established principles of question formulation, and a pilot test was undertaken to ensure the comprehension of the questions by the participants in the sample. The pilot participants provided written feedback specifically about the research questions, allowing the researchers to revise or modify the questions based on their concerns (Berg & Lune, 2015; Creswell, 2007, 2012, 2015; Stake, 2010; Yin, 2011).

In qualitative descriptive research, the analysis of data follows a data-driven approach that does not depend on an existing theoretical framework (Lambert & Lambert, 2012). For this purpose, qualitative content analysis and thematic analysis were employed as techniques to analyze the textual data and identify recurring themes (Braun & Clarke, 2022). These techniques involve a systematic process of coding, interpreting meaning, and providing a comprehensive description of the social reality through the identification of themes (Gall et al., 2007). In the present study, the process of analyzing the qualitative data in a descriptive manner entailed the categorization of data and the identification of major themes (Berg & Lune, 2015; Creswell, 2007, 2012, 2015; Stake, 2010; Yin, 2011). In this study, the data analysis process included the seven steps framework proposed by Newell and Burnard (2011). These are as follows: (1) Transcribing and sorting the data: The data were first transcribed into a written format and then sorted into meaningful units, such as sentences, paragraphs, or themes. (2) Giving codes to the initial data obtained from interviews: The coded data were then examined to identify patterns and commonalities. (3) Adding comments/reflections etc.: The coded data were then annotated with comments and reflections to provide additional insights into the data. (4) Trying to identify similar phrases, patterns, themes: The coded data were then analyzed to identify similar phrases, patterns, and themes. (5) Taking these patterns, themes to help focus the next wave of data collection: The identified themes were then used to focus the next wave of data collection, which helped to ensure that the data were relevant to the research questions. (6) Gradually elaborating a small set of generalizations that cover the consistencies you discern in the data: The identified themes were then used to develop a small set of generalizations that covered the consistencies in the data. (7) Linking these generalizations to a formalized body of knowledge in the form of constructs or theories: The generalizations were then linked to a formalized body of knowledge in the form of constructs or theories. The assurance of trustworthiness in qualitative descriptive studies is crucial and applies to all research designs. Lincoln and Guba (1985) have outlined four essential criteria for establishing trustworthiness: credibility, dependability, confirmability, and transferability. In order to ensure the trustworthiness of the current study, a two-fold strategy was implemented by the researchers. Firstly, a comprehensive protocol for data collection was meticulously followed. Secondly, all transcripts were shared with the participants to allow for their review and correction, enhancing the dependability and confirmability of the findings.

Results

This section of the study presents research findings related to features of STEM practices and STEM practitioners, educational value of STEM practices and evaluation process of STEM practices. The results of the qualitative content analysis are presented as in vivo codes, while the thematic analysis results are presented in Figures 1, 2, 3, and 4. The in-vivo codes and figures provide a comprehensive overview of the data collected and analyzed, highlighting key themes and patterns that emerged from the data.

Teacher Views on Features of STEM Practices

Participants mostly emphasized that STEM involves using technology, encouraging collaborative work, facilitating help, promoting critical thinking, increasing productivity, providing interdisciplinary solidarity, enhancing creativity, strengthening communication, promoting peer understanding, integration of disciplines, promoting cognitive thinking and meta cognition and working to solve current problems. Some of the participants views were given below:

STEMP1: "The aim is to enable students to use today's technology to solve current problems in physics, chemistry, biology, and mathematics courses. It promotes peer understanding, cognitive thinking, problem-solving, strengthens communication, and indirectly promotes mutual support."

STEMP2:"It is a learning system created by combining mathematics, science, engineering, and technology departments. It enables critical thinking. It is focused on problem-solving and increases productivity."

STEMP5: "STEM, which is a learning system created by combining science, mathematics, engineering, and technology departments, enables students to find solutions to real-life problems and turn them into products."

STEMP6: "It should provide interdisciplinary collaboration, encourage collaborative work, increase creativity, and promote critical thinking."

STEMP8: "It involves preparing a joint project between different science branches. In this way, consensus is reached between disciplines."

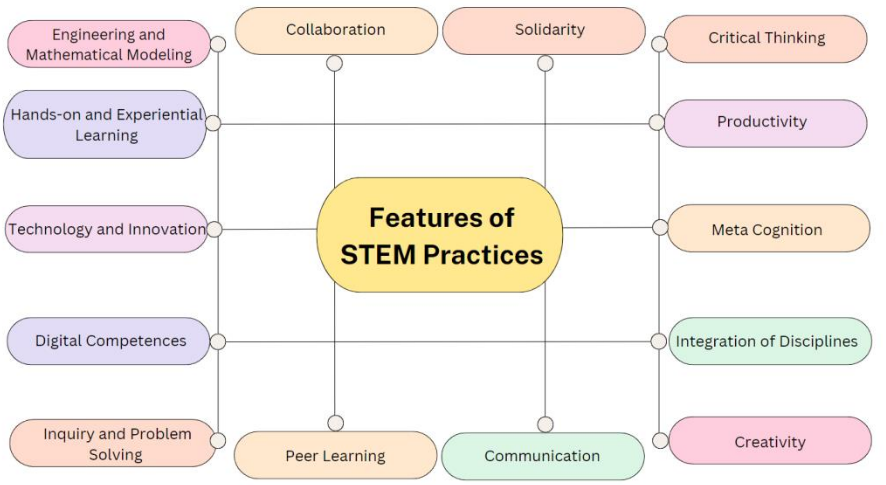

Figure 1. Themes and subthemes emerged from the Features of STEM Practices

The findings presented in Figure 1 indicate that the theme of features of STEM practices includes fourteen subthemes such as collaboration, solidarity, critical thinking, productivity, meta-cognition, integration of disciplines, creativity, communication, peer learning, inquiry and problem solving, digital competences, technology and innovation, hands-on and experiential learning, engineering and mathematical modeling. It can be concluded that STEM practices heavily focused on meta-cognitive skills.

Characteristics of STEM Practitioners

This section aims to describe characteristics of STEM practitioners. Participants generally emphasized that STEM practitioners should have a curiosity about the profession, be a good instructor, be solution-oriented, have strong communication with students, know how to relate their fields to other subjects, encourage critical thinking, know how to effectively use mathematics in engineering, train individuals who can carry out activities suitable for the digital age, have a broad imagination, have a high level of general knowledge, be innovative, have analytical thinking, be disciplined, and patient. The in-vivo codes and Figure 2 provide a comprehensive overview of the key themes and patterns that emerged from the data.

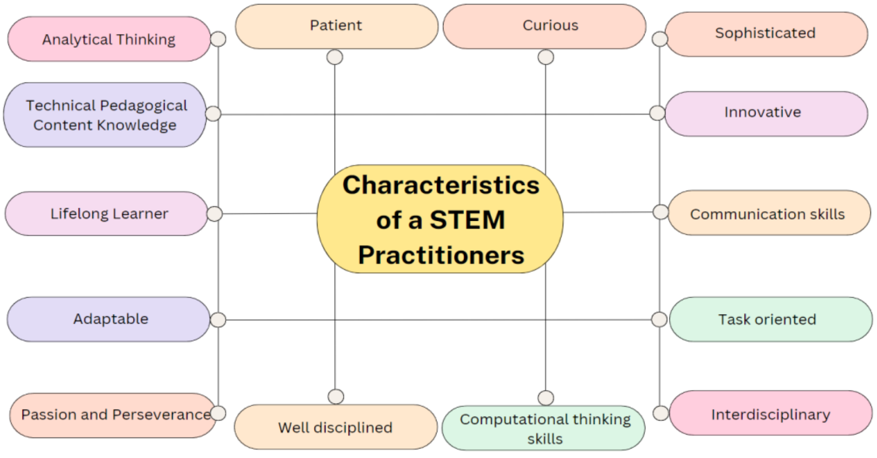

Figure 2. Themes and subthemes emerged from the characteristics of STEM practitioners

STEMP1: "As a math teacher, a STEM teacher should know how to effectively use math in engineering. Application teachers should know how to relate their fields to other subjects. They should encourage students to think analytically and critically with different questions."

STEMP2: "A STEM teacher should contribute to the process of educating individuals who will conduct studies that meet the requirements of the digital age."

STEMP3: "They should have an interest in their profession, strong student communication skills, and be solution oriented. Additionally, they should be able to use technology well and have good knowledge of computer programs. However, as many teachers lack these skills, it can create difficulties in some STEM programs."

STEMP4: "They should encourage students to succeed both in daily life and in school, be analytical, innovative, and solution oriented."

STEMP5: "They should have a broad imagination, be disciplined, patient, and most importantly, have a high level of general knowledge."

Figure 2 illustrates one theme and fourteen subthemes associated with the characteristics of STEM practitioners. According to subthemes STEM practitioners should be patient, curious, sophisticated, innovative, task oriented, well disciplined, adaptable, lifelong learner, and interdisciplinary. Additionally, STEM practitioners should have communication skills, computational thinking skills, passion and perseverance, technical pedagogical content knowledge and analytical thinking. The theme is related to various characteristics of STEM practitioners, the unique nature of

STEM. It can be estimated that characteristics of STEM practitioners are multifaceted, encompass various dimensions and requires analytical thinking skills.

Educational Value of STEM Practices

Regarding the educational value and contribution of STEM practices in the educational process, participants emphasized that STEM practices contribute to peer collaboration, transferring knowledge and skills acquired throughout the education life to work life, starting to enjoy a subject that the student previously had no interest in, being involved with technology and science, providing the opportunity to better understand the relationship between events, the contribution of mathematics and engineering education, and discovering new inventions.

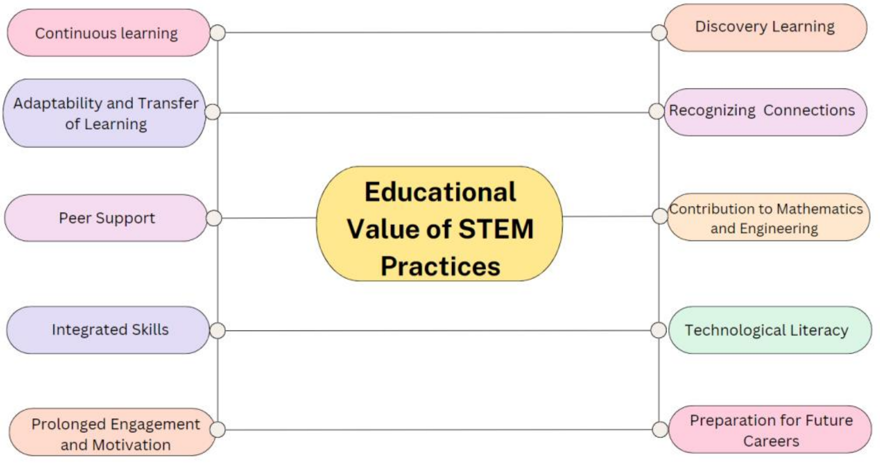

Figure 3. Themes and subthemes associated with educational value of STEM practices

STEMP1: "I noticed that students expressed different views and their curiosity was aroused in the relationship between traffic lights and logic, which was our first quarter homework. The collaboration process was very positive. They saw the contribution of the project to the education they received in mathematics and engineering."

STEMP3: "It allows students to discover new inventions and better understand the relationship between events."

STEMP5: "It is effective in students developing themselves and gaining experience. The knowledge and skills gained during the education are transferred to the business life and students are brought to a certain level. STEM is very effective in this regard."

STEMP7: "It also provides peer support, problem-solving skills, and being intertwined with technology and science for students."

STEMP8: "Since it combines two different lessons, it attracts students' attention more. They begin to love the lesson they are not interested in this way."

Based on Figure 3, the results show that there is one main theme and ten subthemes under the educational value of STEM practices. The main subcategories include continuous learning, continuous learning, adaptability and transfer of learning, peer support, integrated skills, prolonged engagement and motivation, discovery learning, recognizing connections, contribution to mathematics and engineering, technological literacy, preparation for future careers. It can be extracted from the results that educational value of STEM practices is related to the nature of STEM, the characteristics of students, the distinctive features of teaching and requires critical thinking skills.

Assessment of STEM Practices

In this section, the strategies, methods, and techniques employed by STEM practitioners to evaluate STEM applications, as well as their opinions, were delineated. The participants mostly emphasized that the strategies, methods, and techniques used to evaluate STEM applications include rubrics, design activities such as product demonstration videos and presentations, tests related to the topic, open-ended questions, peer assessment tools, brainstorming, semi-structured interviews, true/false questions, and student documents. These assessment techniques were given in Figure 4 and in the following excerpts.

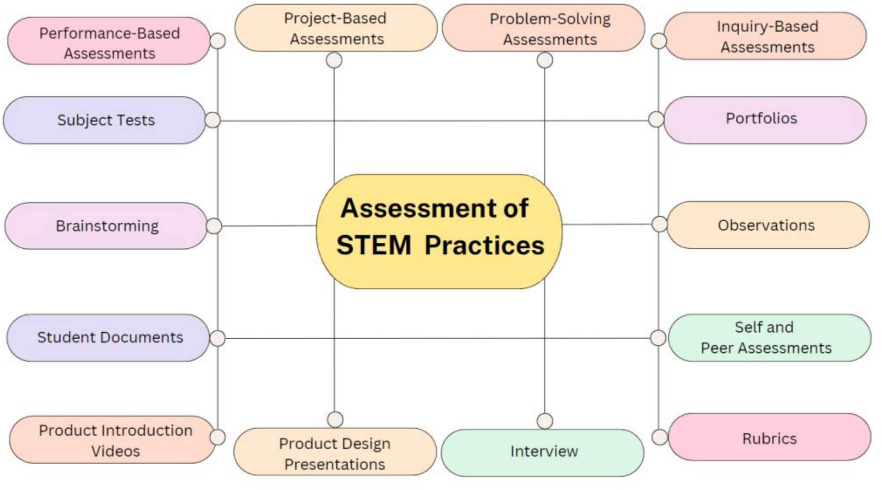

Figure 4. Themes and subthemes associated with the assessment of STEM practices

STEMP1:"The most effective method I used was to let students work alone in the STEM workroom for certain time periods. I noticed that more creative ideas emerged when they were free from a teacher's constant direction."

STEMP2:"I used rubrics, product introduction videos, and product presentations."

STEMP3:"Social gain rubric, teamwork rubric, and a test related to the topic were applied."

STEMP4:"Question-answer method, brainstorming, and collaborative learning were applied."

STEMP5:"Original ideas are important. Rubrics, short question-answer sessions, performance evaluations, and a small number of tests can be used for evaluation."

Figure 4 illustrates one theme and fourteen subthemes associated with the assessment of STEM practices. According to subthemes assessment of STEM practices can be based on performance-based assessments, project-based assessments, problem-solving assessments, inquiry-based assessments, self and peer assessments, portfolios, observations, rubrics, interview, product design presentations, product introduction videos, student documents, brainstorming, subject tests. The theme revolves around the diverse and distinctive characteristics of assessing STEM practices. It can be deduced that the assessment of STEM practices is intricate and encompasses multiple dimensions.

Discussion, Conclusion, and Implications

STEM practices emphasize the ability to ask questions, investigate problems, and develop solutions. This involves critical thinking, analysis, and experimentation to explore and understand phenomena. STEM practitioners often work in teams to solve complex problems. Effective collaboration involves sharing ideas, working together, and leveraging each team member's expertise. Communication skills, both written and oral, are essential for sharing findings and presenting solutions. It is important to note that assessing STEM practices goes beyond traditional tests and exams. It involves a combination of formative and summative assessment methods that provide a comprehensive picture of students' knowledge, skills, and abilities in STEM domains. Assessments should align with the goals and objectives of STEM education, promoting a deeper understanding of concepts, critical thinking, problem-solving skills, and the application of knowledge to real-world situations. This study aims to delineate characteristics of STEM practices and STEM practitioners, educational value of STEM practices and evaluation process of STEM practices. Descriptive content and thematic analysis were used to identify themes, subthemes and in vivo codes.

The Features of STEM Practices

In the present study, the participants emphasized that STEM applications generally involve using technology, encouraging collaborative work, promoting mutual assistance, fostering critical thinking, increasing productivity, facilitating interdisciplinary solidarity, enhancing creativity, strengthening communication, promoting peer understanding, and encouraging cognitive thinking to address contemporary problems. Felix and Harris (2010) highlighted the importance of STEM subjects and pedagogical knowledge for teachers. Acar et al., (2018) prioritize students' skills and levels of competence over their amount of knowledge, given that access to information is relatively straightforward in today's environment. It is evident that students who rely solely on acquiring knowledge will not be able to participate in the future world, as a significant part of the world in the near future will consist of components such as artificial intelligence, augmented reality, and robotics. 21st-century skills are now at the center stage. It is crucial for students to develop skills such as collaboration, creativity, critical thinking, and problem-solving at an early age. The STEM approach is a strategy to acquire these skills. STEM education is a collaborative work philosophy that is based on the application of knowledge and provides students with in-depth and valuable real-world experiences. STEM education typically focuses on science and mathematics but also includes technology and engineering, based on these two principles (Bybee, 2010; Gomez & Albrecht, 2014).

The Features of STEM Practitioners

Participants emphasized that a STEM practitioners should have a curiosity about the STEM profession, be a good educator, be solution-oriented, have strong student communication skills, know how to relate their field to other subjects, promote critical thinking, know how to effectively use mathematics in engineering, develop individuals who work in line with the requirements of the digital age, have a broad imagination, possess a high level of general culture, be innovative, think analytically, be disciplined, and patient. The literature in the field also supports the data obtained in this study. In the literature review, teachers highlighted the need for understanding the subject matter, pedagogical knowledge, engineering knowledge, and integrative knowledge to become a STEM LT (Saxton et al., 2014; Shulman, 1986). Additionally, a good STEM LT strongly emphasizes 21st-century skills, patience, and efficient time management. A talented STEM LT should also be familiar with the STEM pedagogical content when the literature is evaluated (Saxton et al., 2014; Shulman, 1986). Teachers have also claimed that the education provided in colleges is insufficient for STEM education. It is acknowledged that there are significant gaps in education, especially in engineering and technology. In this sense, our study is differentiated. Because our study includes interviews with teachers who have undergone the STEM LTPDP, that is, teachers who have received STEM education. Teachers need to be particularly skilled in areas such as education and teamwork. Kennedy et al., (2008) claim that a solid understanding of materials and methodology is necessary for competent STEM education. Findings of the present study is concurrent with existing literature.

Educational Value of STEM Practices

The views of teachers on the contribution of STEM applications to the education process are explored. Participants underscored that STEM applications provide peer support, enable the transfer of knowledge and skills acquired throughout the educational life to the world, help students to start liking a subject they are not interested in, ensure being involved in technology and science, enable the discovery of new inventions, provide the opportunity to understand the relationship between events better, contribute to the education received in mathematics and engineering, and enable the discovery of new inventions. When the studies in the literature are examined, it is seen that problem-solving skills are individually addressed, and students receiving STEM education are more successful in mathematics and problem-solving (Çorlu & Aydın, 2016). Students specializing in STEM fields are master problem solvers who apply their expertise in new environments. When testing the capacity to answer non-routine questions, routine, well-structured activities were used to measure students' skills in mathematics and science. STEM education helps students to achieve desired results in the problem-solving process when they are presented with non-routine challenges they may encounter in daily life (Çorlu & Aydın, 2016). Thus, it can be said that children who gain problem-solving skills with non-routine problems will easily solve routine problems and be successful in mathematics. In addition, the relationship between mathematics achievement and science problem-solving skills can also be interpreted as STEM education being based on an interdisciplinary approach, so an increase in problem-solving skills in one lesson can affect the success of another lesson. In this sense, the literature in the field also supports the data obtained in this study.

Assessment of STEM Practices

The strategies, methods, and techniques used by teachers to evaluate STEM applications and their views were explored. The participants emphasized that they used strategies, methods, and techniques such as rubrics, product showcasing videos, product presentations, topic-related tests, open-ended questions, peer evaluation tools, brainstorming, semi-structured interviews, true-false questions, and student documents to evaluate STEM applications. When asked about the strategies, methods, and techniques they used most during STEM applications, the teachers expressed that they used presentation-based learning and research-based learning strategies; problem-based learning and project-based learning methods, and presentation techniques. In STEM education, especially problem-based, project-based learning, and research-based teaching are used (Yıldırım, 2016). The basis of using these strategies and methods is that students face real-world problems by connecting daily life. When the literature is reviewed, a similar situation is encountered (Felix & Harris, 2010). Alumbaugh (2015) investigated the views of elementary school teachers on STEM education. Project-based learning is especially used by elementary school teachers who state that it helps children develop critical thinking and problem-solving skills. The same study emphasized that using STEM education, especially in student-centered, research-based learning, and project-based learning, has more advantageous results (Gao et al., 2020). Research-based instruction and practical applications will produce the best results in STEM education (Yıldırım, 2018). According to Odabaşı (2018), alternative assessment and evaluation tools that can be used in STEM education are: diary, observation journal, poster, concept map, V diagram, checklist, grading scale, rubric, group evaluation, peer evaluation, and self-evaluation. Assessment and evaluation in STEM education are multidimensional and distributed throughout the process. In our study, in contrast to the research findings in the literature, design activities such as presenting product videos and product presentations stand out based on the responses provided by the practitioners.

This study has several contributions. Firstly, it provides a comprehensive overview of STEM practices. Secondly, it offers a clear understanding of the features of STEM practices and STEM practitioners, educational value of STEM practices and evaluation process of STEM practices. However, this study also has some limitations. Firstly, the study was conducted with only private high school STEM practitioners in İstanbul, and no public school or secondary school STEM practitioners were recruited. The experiences and perceptions STEM practitioners may differ between public and private high school and also those in secondary schools. Thirdly, it is important to acknowledge that the study's sample size, although providing rich descriptions of STEM practitioners perceptions and experiences through semi-structured interviews, is limited. Future research in the field of STEM should strive for broader participant inclusion through the utilization of quantitative and mixed methods approaches. Enlarging the participant pool would enhance the generalizability and statistical strength of the findings. Additionally, to gain a more comprehensive comprehension of the underlying mechanisms that elucidate STEM practices, further research endeavors are warranted. It is essential to delve deeper into the factors and processes that shape the outcomes of STEM practices. Furthermore, considering the exploratory nature of the present study, future research stands to benefit from the development and validation of methodologies that effectively capture the diverse needs of both STEM practitioners and their students within the context of STEM practices.

The purpose of the present study was bilateral. Firstly, it aimed to explore features of STEM and characteristics of STEM practitioners. Secondly, it sought to identify the educational value and assessment of STEM. In general, participants emphasized that STEM aims to use technology, encourage collaborative work, promote critical thinking, increase productivity, facilitate interdisciplinary solidarity, enhance creativity, strengthen communication, establish peer agreement, foster cognitive thinking, and work towards solving today's problems. Participants will generally be interested in becoming STEM practitioners, good teachers, solution-oriented, possess strong student communication skills, understand how to relate their field to other subjects, develop critical thinking, and understand effective use of mathematics. They emphasized the need to conduct research in the field of engineering and to conduct research in line with the requirements of the digital age. They stressed the need to educate independent, creative, well-cultured, innovative, analytical, disciplined, and patient individuals. Participants generally use strategies, methods, and techniques to evaluate STEM applications, design activities, and related tests. They emphasized that they are student-centered and use graded scoring keys, product introduction videos, product presentations, open-ended questions, peer evaluation tools, brainstorming, semi-structured interviews, and true-false questions. Overall, it would be helpful to add a new field called STEM Leader Teacher Training to the education process in faculties of education so that teachers can receive STEM Leader Teacher Training. The findings of the research highlighted that STEM education includes using technology, promoting teamwork, collaboration, critical thinking, increasing productivity, promoting interdisciplinary solidarity, encouraging creativity, strengthening communication, promoting peer understanding, promoting cognitive thinking, and addressing contemporary problems. In this context, it is necessary to review the curricula of faculties of education in the light of the advantages of STEM education. Especially, including courses related to engineering and technology education in faculties of education is crucial. Regarding technology education, it is clear that placing classes where students will receive education on contemporary concerns, especially coding education, is of paramount importance.

As a conclusion, our results hold implications for policy makers and educators. Policy makers need to ensure that STEM practitioners and STEM practices. Educators need to be aware of STEM practices and its value for educational processes. Additionally, the results provide invaluable contributions to the field of STEM education and will be used to improve the quality of STEM education. Finally, it is essential STEM Leader Teacher Training programs to overhaul their curricula to increase prospective STEM practitioners' skills and competence.

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Genişletilmiş Türkçe Özet

STEM eğitimi, öğrencileri 21. yüzyıl iş gücü gereksinimlerine hazırlamada önemli bir yere sahiptir. Bu çalışma, öğretmenlerin STEM eğitimi konusundaki görüşlerini ortaya koymayı amaçlamaktadır. Çalışma özellikle STEM uygulamalarını sınıflarında uygulayan öğretmenlerin görüşlerini belirlemek için, okullardaki STEM uygulamalarının genel özelliklerine, STEM lider öğretmen veya uygulayıcılarının özelliklerine, STEM uygulamalarının eğitimsel değerine ve STEM uygulamalarının değerlendirme sürecine odaklanmaktadır.

Bu çalışmada, STEM uygulayıcılarının okullardaki STEM uygulamalarına ilişkin bakış açılarını ortaya koymak için içerik analizi ve tematik analiz yöntemlerini kullanan betimsel nitel araştırma modeli kullanmıştır. Çalışma verileri, 8 STEM uygulayıcısından yarı yapılandırılmış görüşmeler yoluyla toplanmıştır. Daha önce STEM eğitimi almış sekiz STEM eğitimcisi seçilmiş ve gönüllü olarak araştırmaya davet edilmiştir. Araştırma verileri Şubat ve Mart 2023 tarihleri arasında gerçekleştirilen yüz yüze bireysel görüşmeler yoluyla elde edilmiştir. Görüşmeler 35 ila 45 dakika sürmüş ve deşifre amacıyla kaydedilmiştir. Katılımcılara STEMP1'den STEMP8'e kadar kod numaraları verilmiştir. Katılımcıların yaşları 28 ile 45 arasında değişmektedir ve ortalama yaşları 33,7'dir. Katılımcıların yedisi kadın, biri erkektir. Katılımcıların ortalama 8,8 yıl olmak üzere minimum 3 yıl ve maksimum 15 yıl öğretmenlik deneyimi bulunmaktadır. STEM deneyimleri 1 ile 4 yıl arasında değişmekte olup, ortalama 2,8 yıldır. Betimsel araştırma, özellikle araştırılan konu hakkında sınırlı bilginin olduğu alanlarda, deneyimlerin ve algıların doğrudan açıklamalarını sağlamayı amaçlar (Sandelowski, 2010). Bu amaç doğrultusunda çalışmada aşağıdaki araştırma sorularına cevap aranmıştır:

1. Okuldaki STEM uygulamalarının özellikleri nelerdir?
2. Okuldaki STEM uygulayıcılarının özellikleri nelerdir?
3. Okuldaki STEM uygulamalarının eğitsel değerine ilişkin görüşler nelerdir?
4. Okuldaki STEM uygulamalarının değerlendirme süreci nasıldır?

Çalışmada, dört açık uçlu araştırma sorusundan oluşan yarı yapılandırılmış anket kullanılarak bireysel görüşmeler yoluyla veriler toplanmıştır. Verileri analiz etmek ve tekrar eden temaları belirlemek için nitel içerik analizi ve tematik analiz kullanılmıştır (Braun & Clarke, 2022). Bu teknikler sistematik bir kodlama, anlam yorumlama ve temaların tanımlanması yoluyla sosyal gerçekliğin kapsamlı bir tanımını sağlama sürecini içerir (Gall ve diğ., 2007). Betimsel nitel veri analizi süreci verilerin kategorize edilmesini ve ana temaların belirlenmesini içermektedir (Berg ve Lune, 2015; Creswell, 2007, 2012, 2015; Stake, 2010; Yin, 2011).

Çalışmanın veri analiz süreci, Newell ve Burnard (2011) tarafından önerilen analiz sürecine dayanmaktadır. Bu süreçler: (1) Verilerin deşifre edilmesi ve tasnif edilmesi: Veriler önce yazılı bir formata dönüştürülmüş ve ardından cümleler, paragraflar veya temalar gibi anlamlı birimler halinde tasnif edilmiştir. (2) Görüşmelerden elde edilen ilk verilere kod verilmiş ve daha sonra kodlanan veriler incelenerek örüntüler ve ortak noktalar tespit edilmiştir. (3) Yorum/düşünceler eklenmiş ve kodlanmış veriler daha sonra, verilere ilişkin ek içgörüler sağlamak için yorumlar ve düşüncelerle açıklanmıştır. (4) Benzer ifadeler, kalıplar, temalar belirlemiş ve kodlanan veriler daha sonra benzer ifadeleri, kalıpları ve temaları belirlemek için analiz edilmiştir. (5) Belirlenen temalar daha sonra, araştırma sorularıyla eşleştirilmiştir. (6) Belirlenen temalar ortaya çıkarılmıştır. Mevcut çalışmanın güvenirliğini sağlamak için araştırmacılar tarafından ikili bir strateji uygulanmıştır. İlk olarak, veri toplama için kapsamlı bir uygulama protokolü titizlikle takip edilmiştir. İkinci olarak, bulguların güvenilirliğini artırmak için tüm yazılı metinler katılımcılar tarafından kontrol edilmiştir.

Araştırma bulguları incelendiğinde: STEM uygulamalarının özelliklerine ilişkin öğretmen görüşleri temasında 14 alt tema ortaya koyulmuştur. Katılımcılar çoğunlukla STEM uygulamalarının: teknoloji kullanımı, işbirliğine dayalı öğrenme, dayanışma, eleştirel düşünmeyi teşvik etme, üretkenliği artırma, disiplinler arası çalışmayı sağlama, yaratıcılığı geliştirme, iletişimi güçlendirme, akran dayanışmasını geliştirme, disiplinleri bütünleştirme, üst bilişsel düşünmeyi teşvik etme ve mevcut sorunlara çözüm üretme kavramlarını içerdiğini vurgulamıştır. STEM uygulayıcılarının özellikleri temasında 14 alt tema ortaya koyulmuştur. Katılımcılar genel olarak STEM uygulayıcılarının: mesleğe merak duyması, iyi bir eğitmen olması, çözüm odaklı olması, öğrencilerle iletişimi kuvvetli olması, alanıyla diğer konular arasında ilişki kurmasını bilmesi, eleştirel düşünmeyi teşvik etmesi, matematiği etkin kullanmayı bilmesi, mühendislikte dijital çağa uygun faaliyetleri yürütebilmesi, geniş hayal gücüne sahip olması, genel kültür düzeyi yüksek olması, yenilikçi olması, analitik düşünebilmesi, disiplinli ve sabırlı olması gerektiğini vurgulamışlardır. STEM uygulamalarının eğitsel değeri ve eğitim sürecine katkısı temasında 10 alt tema ortaya koyulmuştur. Katılımcılar: STEM uygulamalarının akran iş birliğine, eğitim hayatı boyunca edinilen bilgi ve becerilerin iş hayatına aktarılmasına, öğrencinin daha önce ilgi duymadığı bir konudan zevk almaya başlamasına, teknoloji ve bilim ile iç içe olmasına, olaylar arasındaki ilişkiyi daha iyi anlamasına, matematik ve mühendislik eğitimine ve yeni buluşlar tasarlamasına katkı sağladığını vurgulamışlardır. STEM uygulamalarının değerlendirilmesi temasında 14 alt tema ortaya koyulmuştur. Katılımcılar: STEM uygulamalarını değerlendirmede kullanılan strateji, yöntem ve tekniklerin çoğunlukla dereceli puanlama anahtarları, ürün tanıtım videoları ve sunumları gibi tasarım etkinlikleri, konuyla ilgili testler, açık uçlu sorular, akran değerlendirme araçları, beyin fırtınası, yarı yapılandırılmış görüşmeler, doğru/yanlış soruları ve öğrenci doküman ve dosyaları olduğunu vurgulamışlardır.

Sonuç olarak, STEM uygulamaları, soru sorma, sorunları araştırma ve çözüm geliştirme becerilerine vurgu yapmaktadır. Olguları keşfetmek ve anlamak için eleştirel düşünme, analiz ve deney yapmayı içermektedir. STEM uygulayıcıları genellikle karmaşık sorunları çözmek için ekipler halinde çalışırlar. Etkin işbirliği, fikir paylaşımı, birlikte çalışma ve her ekip üyesinin uzmanlığından yararlanmayı içermektedir. Bulguları paylaşmak ve çözümler sunmak için hem yazılı hem de sözlü iletişim becerileri gereklidir. STEM uygulamalarını değerlendirebilmek geleneksel değerlendirme araçlarının ötesine geçmek gerektiğinin farkında olmak gereklidir. Öğrencilerin STEM alanlarındaki bilgi, beceri ve yeteneklerinin kapsamlı olarak ortaya koyan süreç ve sonuç odaklı değerlendirme yöntemlerinin bir kombinasyonunu içermektedir. Değerlendirmeler, STEM eğitiminin amaç ve hedefleriyle uyumlu olmalı, kavramların daha derinden anlaşılmasını, eleştirel düşünmeyi, problem çözme becerilerini ve bilginin gerçek dünyadaki durumlara uygulanmasını teşvik etmelidir. Araştırma bulguları politikacılar ve eğitimciler için anlamlı çıkarımlar barındırmaktadır. Eğitim politikalarına yön veren karar vericiler ve eğitimciler, STEM uygulayıcılarını ve STEM uygulamalarını eğitime egemen kılmak için çalışmalar yapmalıdır. Eğitimcilerin STEM uygulamalarının ve eğitim süreçleri için değerinin farkında olmaları önemlidir. Ayrıca, araştırma sonuçları STEM eğitimi alanına önemli katkılar sağlayacak ve STEM eğitiminin kalitesini artırmak için kullanılabilecektir. Son olarak, STEM Lideri Öğretmen Yetiştirme programlarının, müstakbel STEM uygulayıcılarının beceri ve yeterliliklerini artırmak için eğitim programlarının gözden geçirmeleri önem arz etmektedir.