PRE-SERVICE MATHEMATICS TEACHERS’ VIEWS AND EXPERIENCES IN DESIGNING STEM LESSONS

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

BÜŞRAGÜL ÇELİK KAYA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
MATHEMATICS EDUCATION IN MATHEMATICS AND SCIENCE EDUCATION

SEPTEMBER 2023

Approval of the thesis:

PRE-SERVICE MATHEMATICS TEACHERS' VIEWS AND EXPERIENCES IN DESIGNING STEM LESSONS

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ABSTRACT

PRE-SERVICE MATHEMATICS TEACHERS' VIEWS AND EXPERIENCES IN DESIGNING STEM LESSONS

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Master of Science, Mathematics Education in Mathematics and Science Education
Supervisor: Prof. Dr. Didem Akyüz

September 2023, 156 pages

This study aims to investigate the views of pre-service mathematics teachers pertaining to STEM education and the challenges encountered during the process of lesson planning. The primary objective of the study is to provide guidance to enhance the efficiency of STEM education practices within mathematics courses. In this study, qualitative research method was utilized for in-depth analysis, and three pre-service mathematics teachers studying at a university in Ankara were interviewed. The data were collected in approximately four months during the Spring Semester of the 2021-2022 Academic Year. Three semi-structured interviews were conducted, and the participants were asked to prepare a STEM lesson plan. Following the initial interview, STEM education practices were conducted by the researcher. Then, the STEM lesson plans prepared by the participants were analyzed. The analysis of the findings revealed a remarkable progress in the pre-service teachers' comprehension of STEM education following the intervention. Furthermore, it was observed that the participants were able to integrate mathematics and science into their lesson plans and did not have as much difficulty in this integration as other disciplines. Conversely, it was found that challenges were more pronounced when it came to the integration of engineering principles. The participants who stated that the integration of mathematics and technology was not challenging were weak in this integration. Finally, the participants stated that STEM education is an essential educational approach within the field of mathematics education, expressing their intentions to incorporate STEM activities into their future lesson plans.

Keywords: STEM Education, Pre-service Mathematics Teachers, Lesson Planning, Interdisciplinary Approach, Challenges

ÖZ

MATEMATİK ÖĞRETMEN ADAYLARININ STEM DERS PLANI TASARLAMAYA İLİŞKİN GÖRÜŞ VE DENEYİMLERİ

Çelik Kaya, Büşragül
Yüksek Lisans, Matematik Eğitimi, Matematik ve Fen Bilimleri Eğitimi
Tez Yöneticisi: Prof. Dr. Didem Akyüz

Eylül 2023, 156 sayfa

Bu çalışmanın amacı, matematik öğretmen adaylarının STEM eğitimine ilişkin deneyimlerini ve ders planı hazırlamada yaşadıkları zorlukların incelenmesidir. Ayrıca, bu çalışmanın STEM eğitimi uygulamaları matematik derslerinin verimliliğini arttırmak için yol gösterici olması amaçlanmıştır. Konunun derinlemesine araştırılması için nitel araştırma yöntemi kullanılmıştır. Araştırmaya Ankara'daki büyük bir devlet üniversitesinde okuyan 6 öğretmen adayı katılmıştır. Bu katılımcılar arasında derinlemesine inceleme yapabilmek amacıyla 3 tane öğretmen adayı seçilmiştir. Çalışmanın verileri 2021-2022 Eğitim ve Öğretim Yılı Bahar Döneminde yaklaşık dört ayda toplanmıştır. Veri toplama aracı olarak katılımcılarla üç tane yarı yapılandırılmış birebir görüşme yapılmıştır ve katılımcılardan STEM ders planı hazırlamaları istenmiştir. Birinci görüşmeden sonra katılımcılara araştırmacı tarafından STEM eğitimi uygulamaları yapılmıştır. Katılımcıların hazırladığı STEM ders planları 'Entegre STEM Eğitiminin Kavramsal Çerçevesi' kullanılarak analiz edilmiştir. Bulgulara göre öğretmen adayları STEM eğitimi hakkında yeterli deneyim sahibi değilken yapılan müdahale sonrasında STEM ders planı hazırlayacak düzeye gelmişlerdir. STEM ders planı hazırlama sürecinde katılımcıların matematik ve fen bilimleri bağlantısını ders planlarına entegre edebildikleri ve bu entegrasyonda diğer disiplinler kadar zorluk yaşamadıkları görülmüştür. Buna karşın, mühendislik entegrasyonunda daha çok zorluk yaşadıkları tespit edilmiştir. Matematik ve teknoloji entegrasyonunun zor olmadığını belirten katılımcılar, bu entegrasyonda zayıf kalmışlardır. Son olarak katılımcılar, göreve başladıklarında okullardaki altyapı yetersizliği ve öğrencilerin STEM eğitimine alışkın olmamaları nedeniyle STEM eğitim uygulamalarının zor olabileceğini ama matematik eğitimi için çok önemli bir eğitim yaklaşımı olduğunu ve STEM eğitimi aktivitelerine kendi ders planlarına yer vereceklerini belirtmişlerdir.

Anahtar Kelimeler: STEM eğitimi, Matematik Öğretmen Adayları, Ders Planı Hazırlama Süreci, Disiplinler Arası Yaklaşım, Zorluklar

To my beloved Family

ACKNOWLEDGMENTS

Firstly, I would like to express my deepest gratitude to my supervisor Prof. Dr. Didem AKYÜZ for her endless guidance, advice, criticism, encouragements, insight throughout the research and belief in me. For spending her precious time whenever I need, she deserves the sincerest thanks.

I would like to thank dear committee members Assoc. Prof. Dr. Engin KARAHAN and Assist. Prof. Dr. Merve KOŞTUR for their willingness to serve on the committee and their suggestions, feedback, and contributions to improve my study.

I would like to thank my mother Rabia ÇELİK and my father Nazım ÇELİK. I always felt your love, encouragement and believe in me throughout my life. I always felt your support which makes me stronger and happier. Thank you for cheering me up when I felt down and raising me to be the person I am today. I owe everything I have to you.

I would like to thank my big sister Ummahan Esra CEYLAN. Thank you for being the most wonderful guide to me with your success and for keeping my mood high with your realistic comments. Knowing that you were always there for me whenever I needed you always gave me strength. I also would like to thank my big brother Hasan CEYLAN for his support and hospitality every time I came to Ankara.

I would also like to thank my brother Numan ÇELİK and his wife Özlem ÇELİK.

I would like to thank my cute little nephews Ahmet Salih, Mehmet Arif, Alperen, and Muhsinalp for always putting a smile on my face.

Last, but by no means least, extra special thanks go to my best friend, my lovely husband, Mustafa Berkay KAYA for always being there for me. Thank you for your everlasting love, support, and patient. Thank you for sharing all my excitement, joy, and tears during this process. This study would not have been finished without you

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ABBREVIATIONS

MoNE: Ministry of National Education

STEM: Science, Technology, Engineering and Mathematics

CHAPTER 1

INTRODUCTION

In this era, people are expected to keep up with the rapid advancement of technology (Chai et al., 2020). We need to stay current with change and be a part of it in all areas, including those of personal nature that have an impact on our daily lives. STEM education aims to propel economic progress and raise creative leaders who can catch up with the information and knowledge age (Wijaya et al., 2022). According to Akgündüz et al. (2015), in the 21st century, STEM (Science, Technology, Engineering, Mathematics) education is one of the most important paradigms in the world. Furthermore, STEM education is of great importance in terms of transforming theoretical knowledge into tangible products and fostering the acquisition of indispensable 21st century skills such as creativity, strong communication skills, critical and analytical thinking, and the ability to cooperate. Countries that are able to produce, develop, and effectively utilize knowledge will enjoy a distinct advantage in terms of economic indicators. The foundation for attaining this advantage lies in cultivating a qualified workforce proficient in STEM disciplines, particularly mathematics (Dinçer, 2014). Looking ahead, there is a clear likelihood of an increasing demand for individuals educated in STEM disciplines, encompassing a holistic understanding of diverse fields. For a productive generation and economy, it is important to raise a generation that is interested in STEM fields, innovative, and creative. Achieving this outcome requires the establishment of an educational culture that gives students responsibility, encourages critical thinking, allows students to make mistakes, engages students with technology, and values community.

Furthermore, individuals are required to engage with various disciplines in their everyday lives. In other words, this pertains not solely to mathematics, science, or engineering. It is incorrect to assert that this situation solely concerns engineering or exclusively involves mathematics. All of these disciplines are intricately interwoven. A common concern in mathematics education is that students memorize the formulas and do not relate contents with real life. Consequently, findings from national and international assessments and reports indicate a poor performance by students in the fields of science and mathematics (Akgündüz et al., 2015). If students grasp the interrelationship among various disciplines, they can readily connect the content to real life, leading to an increase in their motivation towards the subject matter. Yıldırım and Altun (2015) assert that STEM education constitutes an instructional approach that integrates various disciplines to apply existing knowledge in daily life, enhance life skills, and cultivate critical thinking.

The objective of an educational program should be to unearth students' inherent talents and equip them with skills and competencies tailored to their individual aptitudes. It is essential to integrate and implement interdisciplinary programs throughout K-12 levels and beyond in higher education, enabling students to acquire these essential skills and competencies. Research by Aydagül and Terzioğlu (2014) highlights the pivotal role of STEM education and STEM skills in fostering sustainable development in Turkey. Furthermore, STEM education plays a crucial role in enhancing mental processes, nurturing entrepreneurship, and honing product development skills. Consequently, a targeted effort to enhance STEM skills is imperative across all tiers of the education system. STEM education aims to increase students' interest and energy in ways that can be of service to society. It exposes students to problems that will encourage them to learn and gives them the opportunity to engage in diverse scenarios (Tytler, 2020; Zhang & Zhu, 2023). Furthermore, STEM education plays a crucial role in facilitating the conversion of theoretical knowledge into practical applications, products, and new inventions (MoNE, 2016). In order to provide students with this opportunity, teachers must also be well-educated. In other words, teachers should possess a comprehensive understanding of other disciplines and embrace an interdisciplinary approach for a more effective education. Within the realm of STEM education, it is important to create environments that foster a lack of fear towards mistakes and the development of self-confidence. Furthermore, there is no single expected output in STEM education. Therefore, teachers should encourage students and provide the necessary opportunities for improvement. Thus, students should be given the idea that development is a continuous process.

As seen, for an effective STEM education application, teachers must know about STEM education since teachers observe and guide students. Moreover, teachers must be competent in the preparation and implementation of lesson plans (Coşkun, 2018). In order to comprehend STEM education, teachers should also actively engage in the lesson planning process. It is not enough only to participate in the practice. The process of preparing the lesson plan should also be taken into consideration. However, this path is not without its challenges. Many teachers have encountered difficulties in mastering the art of teaching STEM subjects, as highlighted by Maiorca and Mohr-Schroeder (2020). One of the primary hurdles they face is the challenge of seamlessly incorporating STEM education into their curriculum, often stemming from a lack of adequate knowledge in the fields of technology and engineering, as noted by Chai et al. (2020). Additionally, Butt (2008) argues that crafting effective lesson plans can prove to be a formidable challenge, particularly for less experienced educators. Considering STEM education, it is thought that some disciplines may take precedence in STEM education practices, and it may be difficult to integrate other disciplines equally. Therefore, this study seeks to examine the processes involved in pre-service teachers' formulation of STEM lesson plans.

1.1 Purpose of the Study

Pre-service mathematics teachers often graduate with limited exposure to STEM activities and a deficiency in their capacity to formulate and execute STEM-focused lesson plans. The art of crafting effective lesson plans is a skill that hinges on practical experience, and it is expected that pre-service teachers will accumulate this experience prior to graduation. However, expecting pre-service teachers, who have traditionally been educated in mathematics, to generate imaginative and interdisciplinary content in their lesson plans may not be realistic. Proficiency in producing creative content and incorporating diverse disciplines into lesson plans typically develops through practice. The issue arises when educators lacking knowledge and experience in interdisciplinary education fail to integrate effective STEM education practices into their teaching. The deficiency in teachers' understanding and expertise in STEM education represents a genuine concern that necessitates attention and resolution.

The purpose of this study is to analyze pre-service mathematics teachers’ experiences in STEM education and the challenges they encounter in STEM lesson planning. Although STEM education is the idea of integrating four disciplines, some disciplines are given less focus and are more challenging to integrate while preparing STEM related lesson plans. This study further aims to determine the kind of difficulties pre-service elementary mathematics teachers encounter in each discipline while preparing a STEM education lesson plan and the discipline they generally have difficulty integrating.

Moreover, the rationale behind the examination of the lesson planning process in this study results from the recognition that possessing the knowledge of how to execute STEM education activities is insufficient on its own. While there are instances of courses or seminars dedicated to the practical application of STEM activities, it is essential to recognize that effective STEM activities encompass more than just implementation. Successful integration of STEM principles requires teachers to know how to prepare cohesive STEM lesson plan as well. Focusing only on the application phase of STEM activities can prove insufficient and ineffective for students. The lesson planning process is as important as the application process. Therefore, this study explores pre-service teachers’ lesson planning process for STEM education, along with their corresponding experiences.

1.2 Research Questions of The Study

The research questions for the study are outlined as follows:

1. What are the views and knowledge of pre-service mathematics teachers about STEM education?

2. How do pre-service mathematics teachers design and implement STEM lessons through microteaching?

3. What challenges do pre-service mathematics teachers face in the process of preparing a lesson plan for STEM education?

4. What difficulties do pre-service mathematics teachers encounter within individual disciplines while developing a STEM education lesson plan?

1.3 Significance of The Study

STEM education is an area open to research, especially in mathematics education research, because the analysis of the existing literature reveals a notable emphasis on science and engineering disciplines. Although mathematics is regarded as a fundamental discipline for STEM education, it is mostly used as a necessary tool for other disciplines. Considering the developing technology and understanding of education, STEM education emerges as a potent and indispensable framework for facilitating mathematics learning and instruction. McKay (2020) asserts that STEM education is a powerful method for teaching critical thinking processes, making judgments, and making decisions. STEM education provides students with the opportunity to use theoretical knowledge about mathematics and science in daily life. Additionally, according to Bybee (2010), students are aware of what is going on in a real STEM education. Therefore, it can be said that STEM education serves as a compass, effectively portraying the essential relevance of mathematics. STEM education helps students understand why they are learning these contents, and understanding the purpose behind the lessons positively affects students' motivation.

STEM education offers pre-service teachers a valuable reservoir of knowledge concerning various learning approaches and effective methodologies (Wijaya et al., 2022). Nevertheless, research by Pimthong and Williams (2021) has shed light on a prevalent shortcoming: many pre-service teachers possess an inadequate grasp of the fundamental principles underpinning STEM education. The imperative for well-prepared educators in the realm of STEM education is emphasized by Çalış (2020). In order to provide an efficient STEM education environment for students and to facilitate the formulation of comprehensive lesson plans, it is important and necessary to train pre-service teachers in this domain. Given that teachers' proficiency and experiences in STEM fields significantly influence students' learning outcomes, the professional development of educators assumes a pivotal role in advancing STEM education (Margot & Kettler, 2019; Zhang & Zhu, 2023). Furthermore, Basu et al. (2021) contends that collaborative engagement with pre-service teachers holds substantial promise for propelling the development of STEM education. For this reason, conducting this study with pre-service teachers enrolled in elementary mathematics education programs becomes not only appropriate but also potentially transformative for the field of elementary mathematics education.

Considering the importance of STEM education and teacher education, this study examines the lesson planning process for STEM education in detail. By revealing the challenges encountered during the formulation of STEM lesson plans, the findings of this research hold valuable implications for teacher educators and researchers. Furthermore, based on the research findings, the incorporation of STEM education courses within elementary mathematics education undergraduate programs is proposed. As a result, this study not only furthers the comprehension of the STEM education lesson planning process but also constitutes a notable contribution to the existing literature in this domain.

1.4 Definition of Important Terms

The important terms used in this study are given below with their definitions:

STEM: The acronym for Science, Technology, Engineering, and Mathematics. It signifies the combination of these four distinct disciplines into an integrated approach (Pimthong & Williams, 2018).

STEM Education: 'STEM education is an interdisciplinary learning approach that combines challenging academic concepts with real-world lessons. The application of science, technology, engineering, and mathematics in contexts that connect school, society, business, and global enterprise' (Holmlund et al. 2018, p. 2).

STEM Lesson Plan: An interdisciplinary lesson plan prepared with STEM education approach.

Interdisciplinary: The idea of integrating more than one discipline in the teaching and learning process.

Technological Pedagogical Content Knowledge (TPACK): Teachers' knowledge of how to integrate technology into education (Koehler & Mishra, 2009)

Interactive Activities: It can be defined as the in-class activities that require active participation of students and the teacher. Group work, exploratory or productive activities can be given as examples.

Practice Teaching: It is a course taken in the senior year and designed to give pre-service teachers school experiences and supervised teaching practice during elementary mathematics education program. It includes preparing two lesson plans and presenting one of them in the class.

1.5 Motivation for the Study

During my senior year in the METU Elementary Mathematics Education Program, I enrolled in a course titled “Nature of Mathematical Knowledge”. In that course, we were preparing STEM lesson plans. We had to prepare two lesson plans as a group. Although our teacher was providing sample activities, it was very difficult to generate new ideas for a STEM lesson plan. Furthermore, in each lesson, two distinct groups were engaged in STEM activities. At that time, I realized how interesting STEM education was and how incompetent I was in this field. As a graduate of METU and a teacher, I recognized the necessity to prepare myself for the innovative aspects of mathematics education.

Upon completing my undergraduate studies, my dream was always to train idealistic teachers. As a step towards realizing this dream, I decided to pursue a master's degree. At the same time, I sought opportunities within private schools to gain experience in the field. Private institutions are renowned for their progressive approaches and a particular emphasis on innovative methodologies, including the integration of STEM lesson plans. Seeing this, I realized that STEM education is promising, and a teacher should possess a comprehensive mastery of this field.

Under the guidance of my supervisor, Prof. Dr. Didem AKYÜZ, who is an expert in the field of technology and emphasizes the promising aspects of mathematics education, I embarked on an exploration of STEM education. The more I read about STEM education and attended trainings, the more my interest grew. I realized what a right and interesting thesis topic I chose. During one particular seminar, a visual was shown to explain what STEM education is and why it is needed. In the visual, different colors were used for each discipline- mathematics, science, technology, literature, engineering, and art. On the next slide, the concept of 'life' was shown, and all colors were intertwined in it. No color stood alone. This analogy impressed me profoundly and I thought about the mistakes made in teaching mathematics, including my own mathematics education. STEM education was an approach that could correct these inaccuracies. Students generally state that they do not like mathematics, deeming it boring and difficult. Moreover, I think, most importantly, they question where mathematics manifests in their daily lives. Although I appreciate this inquiry, I think teachers have difficulty in answering this question and cannot convince the students. On the other hand, STEM education makes mathematics fun by integrating mathematics directly in daily life.

Adopting a teacher's perspective, I think about my own inability to think creatively and the challenges I had in preparing STEM lesson plans. I believe a mathematics teacher should have this awareness before graduation and should be involved in STEM education. This realization bolstered my interest in STEM education, highlighting the necessity to equip educators with this knowledge. I enjoyed writing this thesis, reviewing the literature, and collecting the data, and I believe that both students and teachers will derive immense satisfaction from this approach.

CHAPTER 2

LITERATURE REVIEW

In this chapter, related literature will be reviewed based on the purpose of the study which is to explore the challenges experienced by pre-service elementary mathematics teachers while planning lessons for STEM education, and to analyze which discipline they generally have difficulty integrating. The literature was examined under four main headings: STEM education, integrating technology into mathematics lessons, interdisciplinary approach, and interactive activities in mathematics teaching.

2.1 STEM Education

As highlighted by Artsın and Deligöz (2019), the shift brought about by the industrial age has left its mark on the education system, just as it has influenced numerous other domains. The rise of capitalism brought different needs with it. In the past, capitalism necessitated the education of a proficient workforce through open education channels (Sian Hoon et al., 2022). Yıldırım (2015) states that due to the demands of a rapidly evolving economy and developing technology, human beings need well-educated people, and the importance of science, engineering, mathematics, and technology is increasing. Today, these needs are aimed to be fulfilled with science, technology, engineering, and mathematics education. In addition, there are increasing numbers of job opportunities that require STEM skills (Corlu et al., 2014; Lacey & Wright, 2009; Sian Hoon et al., 2022). To catch up with new advances, people must be willing to change and be open to learning and development (Bybee, 2013; Johnson, Peters-Burton, & Moore, 2016; Stehle & Peters-Burton, 2019). As a result, interest and demand in science, technology, engineering, and mathematics education is increasing very rapidly. A 2017 report by PwC underscores the necessity for effective collaboration among the public sector, private enterprises, and universities to cultivate a workforce proficient in STEM skills (PwC & TÜSİAD, 2017). Moreover, Kuenzi (2008) posits that STEM education should follow a teaching strategy that combines classroom objectives with societal economic expectations. Therefore, economic concerns, rather than educational concerns, are the origins of STEM education (Bybee, 2013). All these highlight the need for STEM education.

Academic competencies such as analysis and problem-solving serve as cognitive stimuli that sustain students' engagement (Farrington et al., 2012; Stehle & Peters-Burton, 2019). STEM education fosters the development of advanced problem-solving skills among students (Bybee, 2010; Yata et al., 2020). Moreover, STEM education is geared toward cultivating individuals who possess both personal and social competencies necessary for effective collaboration with peers from diverse disciplines (Pimthong & Williams, 2021; Zhang & Zhu, 2023).

Kelley and Knowles (2016) state that teachers find it challenging to establish links between STEM disciplines. Due to the lack of connection to overarching ideas and practical applications, students who learn science and mathematics in isolation frequently lose interest in these subjects. Similarly, Corlu et al. (2014) and Honey et al. (2014) state that educator may find it challenging to prepare STEM activities.

The acronym STEM denotes science, technology, engineering, and mathematics, encapsulating the integration of these four disciplines (Fitzallen, 2015; Marrero et al., 2014; Pimthong & Williams, 2018). STEM education involves an interdisciplinary education system in which science, technology, engineering, and mathematics are integrated. Generally, disciplines are presented separately in the curriculum and not enough attention is paid to the relationship between them. Conversely, STEM education proposes an integrated curriculum design (Green, 2014). The conventional approach of teaching disciplines as isolated entities often fails to mirror real-world practice, while STEM education actively seeks to fuse various disciplines together (Sian Hoon et al., 2022). The adoption of curriculum integration empowers teachers to embed contexts with comprehensive details from various disciplines, thereby establishing robust connections to real-life applications (Corlu et al, 2014). In essence, STEM education offers a unique opportunity to harmonize and amalgamate all academic disciplines, fostering an environment where students can engage in holistic learning experiences. The implementation of an integrated STEM education approach has been shown to enhance student learning (Anderson et al., 2020; Bartels et al., 2019).

Science, technology, engineering, and mathematics (STEM) education is a form of education that combines these subjects and shows learners how these fields are linked in real life scenarios (Johnson, 2012). When teachers use curriculum integration, the contexts can be given with all necessary details in other disciplines, establishing robust links to real-world applications (Corlu et al, 2014). Therefore, STEM education provides an opportunity to bring all disciplines together. Considering mathematics education, although mathematics is seen as an abstract course, it is actually directly related to real life (Ceylan & Karahan, 2021). In real life, the disciplines are intertwined, and the problems given to the students in the lessons should also be appropriate for real life. STEM education gives the opportunity to bring real-life problems to the lessons.

Moreover, as underscored by Corlu et al. (2014), the purpose of STEM education is to raise new generations with awareness of innovation. Through STEM education, students can learn interdisciplinary skills that are essential for life (Corlu et al, 2014; National Research Council, 2011)

Research on STEM education is increasing rapidly (Shamim et al., 2022). Researchers offer a generally consistent perspective on STEM education, albeit with nuanced variations. According to Bybee (2013) and Yıldırım (2015), the definition of STEM education is not clear. Although there are four disciplines in the definition of STEM education, the emphasis allocated to each discipline may exhibit variability

(Bybee, 2013). English (2015) underscores that STEM education focuses on mathematics and science, with engineering and technology receiving comparatively less attention. Some researchers focus on technology, some on science and engineering. In our country, STEM education comes to the fore more in science education, and mathematics is seen as a necessary tool in this framework. Interestingly, there are some ideas that mathematics should be invisible in STEM activities. Therefore, the use of STEM education in mathematics lessons is more limited than other disciplines, which affects the lesson planning process of mathematics teachers.

A substantial body of research highlights the advantages of STEM education. Researchers suggest that STEM education should be considered as an approach and be integrated into diverse subject matter. STEM education is directly related to life; therefore, according to Şahin (2020), it helps shape students’ perceptions about professions. Suratno et al. (2020) states that there is a positive relationship between students’ problem-solving skills and achievements with STEM education model. Moreover, Aydın (2020) posits that STEM education is an effective method to give students motivation and courage for creativity, problem solving and invention, especially in early grades. Similarly, both Anderson et al. (2020) and Zhang and Zhu (2023) affirm that STEM education equips students with the aptitude for innovative problem-solving when faced with challenging situations. Ceylan and Karahan (2021) conducted a STEM-oriented mathematics education study with high school students. Their study revealed marked improvements in students' knowledge and attitudes towards STEM disciplines, especially mathematics. This intervention also induced shifts in students' attitudes towards the mathematics subject, fostering increased enthusiasm and active engagement in lessons. Also, STEM education helped retain knowledge.

According to Özdemir (2016), STEM education is a constantly developing field and there are many different views in this field. The term "Engineering" defined by the letter "E" in the word STEM does not only mean engineering; it also means "design and production". The letter "S" in the word "Science" means not only natural sciences but also includes "social sciences". Science, technology, engineering, and mathematics should be used in real world problems (Kelley & Knowles, 2016). Additionally, according to Bybee (2010), STEM education, an interdisciplinary approach, must support literacy in each STEM discipline. Science and mathematics are disciplines that are typically offered as distinct courses. This segregation is reflected in the provision of separate science and mathematics education programs. in light of technological advancements, the significance of integrating technology into all academic domains has gained prominence. Conversely, within the realm of STEM education, engineering stands out as one of the disciplines lacking a dedicated primary-level course. Consequently, the interpretation and implementation of engineering integration within STEM education assumes particular importance (Yata et al., 2020). The definition of engineering varies among sources. Some researchers define engineering as a profession. However, in STEM activities, Yata et al. (2020) defines engineering as a creative activity. On the other hand, Kelley and Knowles (2016) define engineering as a design process.

Bircan and Çalışıcı (2022) conducted a study with 34 fourth grade students using a mixed method approach to investigate the contribution of STEM education to mathematics achievement and 21st century skills. The results of the study revealed that students found STEM education activities fun, and they developed 21st century skills such as communication, collaboration, and creativity. However, no significant difference was found in the level of mathematics achievement of the students. In contrast, Özdemir (2018), as a result of his experimental study with 64 high school students, concluded that there was a significant difference in mathematics achievement in favor of the experimental group. The study also observed that there was an increase in students' interest in STEM fields when contemplating their career and occupational preferences.

In conclusion, STEM education has many positive effects on students and has become a necessity in the 21st century. It requires individuals to have knowledge and skills in STEM fields when making decisions (Aydeniz, 2017). Since teachers are the key for a qualified and innovative generation, it is important that they have knowledge about STEM education. Corlu et al. (2014) concluded that in a developing world, a demand exists for proficiently qualified STEM educators.

2.1.1 STEM Education in Turkey

According to Corlu et al. (2014), the system of placing teachers in schools where they will work affects their approach to STEM education. In Turkey, there is an exam called ‘Public Personnel Selection Examination (PPSE)’. In this exam, are held accountable for subjects such as history, Turkish language, mathematics, geography, citizenship, and general culture regardless of their major (Özoğlu, 2010). As a result, upon their university graduation, teachers often prioritize preparing for this examination rather than focusing on honing their teaching skills in their respective disciplines. Corlu et al. (2014) highlight that this system also has an adverse impact on teachers' creativity and their recognition of the need for innovation. Consequently, deficiencies in the teacher education system contribute to diminished achievements in STEM education.

As outlined in the STEM Türkiye Report (2016), the 2015-2019 Strategic Plan included objectives aimed at enhancing the prominence of STEM education. It is seen that STEM objectives overlap, to a certain extent, with the objectives of the Technology and Design course. It can be said that the studies carried out at the 7th and 8th grade levels within the scope of the Technology and Design course are STEM-oriented.

According to the "Program for International Student Assessment" (PISA) OECD 2015 report, Turkey continues to perform below the OECD average in mathematics and science, despite the improvements in recent years. Similarly, according to the "Trends in International Mathematics and Science Study" (TIMSS) 2015 report, Turkey is below the TIMSS average in mathematics and science achievement tests.

To improve the results of such exams, STEM education should be prioritized in our country (MoNE, 2016).

In recent years, the importance of using mathematics in other disciplines and in daily life is increasing (Uluçay & Çakır, 2014). There has also been an increase in the number of projects related to STEM education in Turkey. For example, the STEM Workforce Report (TÜSİAD, 2014) emphasizes strengthening university STEM fields and increasing the qualified STEM workforce. On the other hand, the STEM Education Turkey report underlines the introduction and implementation of a high-quality STEM education within the K-12 curriculum (Akgündüz et al., 2015). Furthermore, there are universities in our country that include STEM education research and establish centers on this subject. BİLTEMM at Middle East Technical University was established with the goal of creating opportunities for education and standards in the STEM disciplines. It offers teacher workshops, projects, and training sessions with the goal of enhancing educational opportunities for schools, teachers, and students. Moreover, STEM research is carried out by the STEM Center (BAUSTEM) established at Bahçeşehir University. Istanbul Aydın University Center for Educational Sciences and Technologies established a STEM School in 2015 to increase the competencies of teachers and students in STEM fields. In addition, Openfab Istanbul, which was established at the STEM Academy within Özyeğin University with the aim of a productive generation, provides training programs for children. Hacettepe STEM and Maker Lab conducts studies in the field of STEM. The Ministry of National Education General Directorate of Innovation and Educational Technologies (YEĞİTEK) published a STEM Education Report to propose a model for the transition to STEM Education in Turkey (PwC & TÜSİAD, 2017).

To conclude, studies are being conducted in Turkey to improve STEM education, and teacher training programs stand out among them since teachers' competence in STEM fields enables them to give quality education to their students. These studies emphasize the importance of teacher education programs.

2.1.2 Pre-service Teachers’ Views on STEM Education

Teachers who eagerly delve into STEM education experience a noticeable boost in their teaching confidence throughout their educational journey. STEM education practices support pre-service teachers' self-confidence (Sian Hoon et al., 2022). Moreover, this process heightens their understanding of real-world contexts and underscores the pivotal role of a comprehensive education (Berlin & White, 2010; Corlu et. al., 2014; Darling- Hammond, 2006). Therefore, it is important that teacher education programs include STEM education in their curriculum.

For the successful implementation of STEM activities, firstly teachers must be familiar with it. It is important to understand what teachers and pre-service teachers think about STEM education. Hence, there is a substantial body of research dedicated to STEM education, and investigations concerning perspectives on STEM education hold a significant position within this field. According to Pimthong and Williams (2021), the absence of a robust emphasis on STEM education in pre-service teacher education programs hinders the effectiveness of pre-service teachers, particularly those trained in single disciplines, in adopting interdisciplinary approaches. Consequently, Pimthong and Williams (2021) advocate for affording pre-service teachers the opportunity to craft lessons and engage in STEM teaching before completing their education. In alignment with this perspective, Wijaya et al. (2022) assert that the integration of STEM education into teacher training programs is imperative for nurturing 21st century skills. Therefore, the inclusion of STEM education practices within teacher education programs becomes essential (Anderson et al., 2020). However, Zhang and Zhu (2023) argue that the current STEM learning experience within teacher education programs remains insufficient and requires enhancement.

Pimthong and Williams (2018) observed that pre-service teachers generally possess a conceptual understanding of STEM, with a majority of their study's participants incorporating the term "interdisciplinary" into their definitions. Nevertheless, the scholars noted a lack of detailed explanations regarding the interconnectedness of individual disciplines within STEM education. Parallel findings were reported by Bybee (2013), as well as Radloff and Guzey (2016) in their research studies.

Research delves into how pre-service teachers establish connections between STEM education and their respective majors. Pimthong and Williams (2018) highlight that candidates aiming to become science teachers tend to establish stronger associations between STEM and their major. Correspondingly, Eroğlu and Bektaş (2016) find that science educators perceive a correlation between science lessons and the fields of technology, engineering, and mathematics. Conversely, Özbilen (2018) posits that pre-service science and mathematics teachers collectively view STEM education as valuable to their domains, though the study does not explain the differentiation between science and mathematics teacher candidates in this regard.

Sian Hoon et al. (2022) investigated the role of the teacher in STEM education and concluded that teacher education plays a critical and indispensable role in the context of STEM education. Generally, qualitative research design is used to investigate pre-service teachers' views on STEM education. Cinar et al. (2015) conducted a study with 57 pre-service science and mathematics teachers to reveal their opinions about STEM education. Semi-structured interview method with open ended questions was used as a data collection tool, and content analysis methodology was utilized for data analysis. The results show that pre-service teachers have positive attitude towards STEM education. Similarly, the study by Sümen and Çalisici (2016) conducted with 42 pre-service teachers revealed that the pre-service teachers found STEM education fun and effective. Through a comprehensive analysis of mind maps, their investigation revealed that STEM education serves as a catalyst for enhancing and enriching their conceptual understanding.

There are many studies aiming to improve teachers' and pre-service teachers' knowledge and skills related to STEM education. Yıldırım and Türk (2018) conducted a study with 40 pre-service primary school teachers to investigate their views on STEM education. A semi structured interview form was used to collect data, and the content analysis method was used to analyze the data. The findings of the study revealed that STEM education should be used at kindergarten and primary school level. Likewise, the study that Erdogan and Ciftci (2016) conducted with 7 pre-service teachers suggest that teacher candidates should learn STEM education.

Gömleksiz and Yavuz (2018) conducted a study with 230 pre-service science teachers and found that the participants have positive thoughts about the concept of STEM, and they believe STEM education is appropriate for interdisciplinary education. In a qualitative study conducted by Yıldırım (2017) with 12 pre-service science teachers, it was concluded that in order for pre-service teachers to successfully implement an interdisciplinary science teaching when they graduate, there should be courses providing pre-service teachers with knowledge and experience about interdisciplinary education during their undergraduate education. The incorporation of STEM education courses into teacher education programs offers pre-service teachers the chance to create STEM lesson plans, providing them with valuable hands-on experience with STEM education practices before integrating them into their future lessons (Maiorca & Mohr-Schroeder, 2020). Furthermore, engaging in STEM activities within these programs enables pre-service teachers to enhance their self-confidence and teaching skills (Lewis et al., 2021).

Kurtuluş et al. (2017) conducted a study with 8 teachers to examine their views on STEM education. The teachers were given a presentation to provide information about STEM education, and then STEM education activities were implemented. As a result of the study, the teachers stated that STEM education concretizes the mathematics course and encourages students to think analytically with real-life situations. In addition to their positive opinions, the teachers also expressed negative opinions about aspects such as time management, classroom management and lack of facilities in schools. Rifandi et al. (2020) arrived at a similar conclusion through a different research approach. They conducted a study involving 48 pre-service mathematics and science teachers to delve into their perceptions of STEM education. The findings, derived from an online survey analysis, pointed towards a positive overall perception of STEM education among pre-service teachers.

Berisha and Vula (2021) investigated the STEM knowledge and awareness of pre-service teachers in a study with 40 pre-service teachers. In the study, the pre-service teachers participated in a workshop on STEM activities, and they were expected to prepare STEM projects as a group. Post-workshop analysis revealed a noteworthy improvement in the participants' STEM knowledge, leading Berisha and Vula (2021) to conclude that the workshop had a positive impact on enhancing pre-service teachers' understanding of STEM concepts. Furthermore, in a study involving 113 pre-service teachers, Sian Hoon et al. (2022) made a fascinating discovery. Despite limited prior experience with STEM activities, these pre-service teachers exhibited substantial dedication to advancing their own STEM proficiency.

To conclude, a substantial body of research has explored pre-service teachers' perceptions of STEM education, consistently revealing optimistic outcomes among teacher candidates. The prevailing consensus among researchers strongly advocates for the inclusion of STEM education within undergraduate teacher training programs. However, it must be noted that the majority of studies on this topic have primarily centered around pre-service science teachers, indicating a potential need for a more comprehensive exploration across various teaching disciplines.

2.1.3 STEM Lesson Plan

According to Pearson (2017), pre-service teachers should be encouraged to understand the combination of different disciplines. Engaging in STEM education initiatives is a valuable step, but effective implementation goes beyond mere participation. To achieve a truly successful STEM education application, teachers need to possess a profound understanding of STEM principles. The depth of their familiarity with interdisciplinary education greatly influences the efficacy of their growth and competence in this domain. The more they immerse themselves in and contemplate interdisciplinary approaches, the more powerful their progress and impact become. Teachers have the opportunity to observe the connections between science, technology, and engineering more clearly while preparing a lesson plan related to their field. This makes it easier for both them and students to see mathematics clearly in all areas of life. Therefore, preparing a STEM related lesson plan has a critical role for teachers to better understand STEM education. As highlighted by Corlu (2015), educators often commence their careers without the essential integrated teaching knowledge required for effective STEM education delivery. This underscores the pressing need for enhancements in teacher education with regard to STEM instruction.

As noted by Shamim et al. (2022), the integration of STEM disciplines can indeed pose significant challenges. In line with the findings of Shamim et al. (2022), this study also arrived at the conclusion that integrating various disciplines presented considerable challenges for the pre-service teachers involved. Kennedy and Odell (2014) state that, STEM education aims to integrate technology and engineering into the science and mathematics lessons. To achieve this, meticulous inclusion of design and inquiry processes within the STEM lesson plan is essential. Also, curriculum, instruction and assessment should be harmoniously incorporated into the lesson plan to foster scientific inquiry and the engineering design process, thus effectively engaging students in robust STEM education. In line with this, Nadelson et al. (2012) underscore that in STEM education, teachers must possess substantial content knowledge as well as pedagogical content knowledge to ensure effective teaching and learning.

Aykan and Yıldırım (2021) conducted a study to combine lesson study model and STEM education. A total of 24 science teachers prepared lesson plans as a group and the challenges they experienced were examined in detail. The findings demonstrated that the utilization of the lesson study model significantly enhances the quality of the STEM-related lesson planning process. Furthermore, Altan and Ucuncuoglu (2019) conducted a similar study with 7 pre-service science teachers who were asked to prepare STEM related lesson plan. Teacher candidates' competence in STEM-related lesson planning was assessed through the collection and in-depth analysis of their lesson plans. According to Maiorca and Mohr-Schroeder (2020), providing pre-service teachers with opportunities to experience engineering design problems may help them design integrated STEM lesson plans in their classrooms.

Lawson et al. (2021) conducted a study with 14 mathematics and 16 science pre-service teachers. The study examined the difficulties that pre-service teachers had in planning and implementing STEM lessons. The study's conclusion highlighted the pivotal role of collaborative lesson planning among pre-service teachers in overcoming a significant barrier. Drawing from the study's outcomes, it was recommended that various disciplines should collaborate on developing shared lesson plans. Shamim et al. (2022) also reported a similar result. Durmuş and Alpkaya (2019) offer a similar suggestion in this regard, emphasizing that to effectively implement an interdisciplinary approach, teachers should collaborate and engage in joint practice.

Saraç and Doğru (2021) recommend increasing the number of studies that provide opportunities for both teachers and pre-service teachers to engage directly in STEM education experiences. The study's outcomes revealed that pre-service teachers exhibited a favorable perspective toward the process of planning and implementing STEM education. In addition, it was determined that the STEM education process had a positive effect on pre-service teachers' STEM teaching self-efficacy beliefs.

STEM lesson plans require the integration of multiple disciplines. A comprehensive grasp of interdisciplinary integration is crucial. It is imperative to distinctly define the concept of engineering integration within the context of the lesson plan. With the integration of engineering into the STEM teaching model, it is expected that students will be able to conduct scientific research directly related to basic subjects at the K-12 level and perform engineering design projects by first asking students a problem from daily life and emphasizing how scientists find a solution to this problem (Aydın et al., 2017). The integration of engineering into STEM education aims to raise students as individuals who are open to communication, creative, successful in teamwork, have ethical values and can find the most appropriate solution to problems. Students are expected to create engineering design projects from an interdisciplinary perspective, assuming the role of engineers (Aydın et al., 2017; Guzey et al., 2014).

Maiorca and Mohr-Schroeder (2020) conducted an examination of pre-service teachers' lesson plans. In the context of this study, pre-service teachers engaged in a STEM education activity and subsequently crafted STEM lesson plans upon completing their field experience. The study's findings indicated that an impressive 15 out of 16 pre-service teachers incorporated problem situations necessitating engineering design and data collection into their lesson plans. Consequently, providing pre-service teachers with opportunities to participate in integrated STEM activities is likely to enable them to observe the positive impacts of STEM education firsthand.

The existing literature highlights a noticeable gap in the emphasis on the lesson planning process within STEM education. Moreover, the majority of the studies examining the preparation of lesson plans for STEM education focus on the field of science. Therefore, it becomes evident that the domain of STEM-related lesson planning remains an area of investigation that holds significant potential, particularly in the context of mathematics education.

2.2 Integrating Technology into Mathematics Lessons

The development of technology has affected education as well as many other fields. Education is now being delivered to a generation that grew up with technology. In today's world, where technology is present in every field, it has become difficult for students to learn with classical methods (Tezer & Deniz, 2009). Since technology has become a part of students' life, a lesson plan without any use of technology is incomprehensible.

According to the MoNE (2005), at both the national and international levels, students are required to develop their professional, intellectual, social, and personal skills. The Turkish Qualifications Framework (TQF) defines competencies as the spectrum of abilities students will need in the future. There are eight essential competencies that the TQF identifies and defines. Two of them are mathematical competence and core competencies in science/technology, and digital competency. The development and application of mathematical reasoning to address a variety of problems that come up in daily life is the concept of mathematical competence. Mathematical competency includes the capacity and motivation to employ mathematical representations, and logical and spatial thinking. Digital competency encompasses the essential and safe use of information and communication technology for industry, daily activities, and communication. This competence includes the use of computers for accessing and evaluating, storing, producing, presenting, and exchanging information, as well as participating in shared networks through the Internet, and through basic skills. Therefore, the use of technology is emphasized in Turkish mathematics curriculum.

The use of technology in education has become crucial in the twenty-first century (Wang et al., 2018). According to Boz and Özerbaş (2020), technological materials utilized in mathematics lessons should be appropriate for students' needs in order to increase their interest and motivation to learn. The use of technology provides opportunities for mathematics education (Baki, 2023). For instance, many students encounter challenges in mathematics due to its perceived abstract nature. Therefore, the integration of smartboards in mathematics lessons provides a tangible connection to reality. Similarly, Zengin et al. (2013) state that there is a need for concretization and visualization in mathematics activities since the mathematics concepts are abstract.

According to Öçal and Şimşek (2017), pre-service teachers stated that incorporating technology into lessons would provide valuable support for interdisciplinary studies. Furthermore, the use of technology plays a positive role in preventing mathematical misconceptions. Topal and Akgün (2015) posit that there is a relationship between pre-service teachers' experiences in technology use and their self-efficacy beliefs.

According to Akyüz (2016), the use of technology allows students to explore a wide range of situations that they would not be able to experience in a paper and pencil setting. Moreover, technology gives them the chance to understand the proof of fundamental concepts of mathematics. Similarly, Öçal and Şimşek (2017) underscore the benefit of using technology in mathematics lessons to visualize concrete concepts. Rendering mathematical concepts more tangible and facilitating increased problem-solving can be regarded as benefits of integrating technology into mathematics lessons. Employing technology within the mathematics curriculum enhances the coherence of information and fosters a smoother learning experience (Yeşilyurt & Çağlar Perçi, 2021).

Now in classrooms, there is an access to the Internet, the online source with the smart board. Students are familiar with the use of technology in the classroom in this way. However, the effectiveness of employing this technology is notably influenced by the teacher, as merely providing students with access to technology is not enough (McCulloch et al., 2018). If teachers use the smart board only to project the textbook, this is not an effective use of technology. The integration of technology into mathematics education should be done more efficiently and for this, teachers should be competent. They should have knowledge about technology integration in mathematics lessons. Similarly, Baki (2023) state that to take full advantage of the benefits of technology in mathematics lessons, both teachers and students need to be knowledgeable about the use of technology. Therefore, pre-service teachers need to understand how technology can be integrated to education (Tondeur et al., 2013). Bray and Tangney (2017) assert that technology integration in mathematics education can have some challenges. Challenging aspects include the teacher's ability to pose guiding questions that facilitate student comprehension of the subject matter or establishing a classroom environment conducive to seamless technology integration. In order to overcome these challenges and create an effective lesson, the teacher needs to know how to use technology (Baki, 2023; Gür & Temel 2022).

The use of technology also increases students' interest in the lesson. Tataroğlu (2009) conducted an experimental study with 124 high school students. The results of the 5-week study revealed a statistically significant difference in favor of the experimental group regarding students' attitudes towards mathematics when employing the smartboard during math lessons. Thus, it can be stated that students' attitudes towards mathematics can be improved with technology support. Similarly, according to the results of the study conducted by Taş et al. (2021) with 6 experienced teachers, teachers employ interactive whiteboards to enhance visualization and engage students' attention and curiosity. Moreover, the participants indicated that it is appropriate to integrate interactive whiteboards into mathematics lessons, with a particular emphasis on their use during geometry lessons.

Chai et al. (2020) underscore the heightened significance of technology integration and the growing demand for teachers to demonstrate their technological proficiency when crafting lesson plans. In the 21st century, technology and STEM education have assumed pivotal roles in the realm of education. Consequently, the inclusion of technology as a discipline within STEM lesson plans necessitates that teachers expand and enhance their technological expertise. Nevertheless, the integration of technology into lesson plans remains weak, primarily owing to teachers' limited technological knowledge.

When the use of technology in mathematics courses is examined, dynamic geometry software in mathematics education stands out. The effectiveness of dynamic software programs in mathematics lessons has been proven in many studies (Akyüz, 2014). According to Zengin et al. (2013), dynamic geometry software makes abstract mathematics concepts visible, hence these applications are important for mathematics education. In the research conducted by Tatar et al. (2013), pre-service teachers emphasized that the combination of interactive whiteboard technology and dynamic mathematics software facilitated the visual representation of lessons, enabling students to grasp concepts in an engaging and enjoyable manner. Similarly, Tatar et al. (2015) conducted a study with 14 pre-service mathematics teachers in which each participant was asked to make applications on the interactive board using dynamic mathematics software. Data for the study were collected through various assessment instruments administered to pre-service teachers both at the commencement and conclusion of the research period. The results of the study revealed that the integration of interactive whiteboards and dynamic mathematics software facilitated improved concept comprehension, graphical representation, and concretization within mathematics lessons. Moreover, Baki et al. (2012) stated that it is important to use GeoGebra dynamic software in the education of gifted students and that with the use of technology, effective teaching can be ensured.

In their research, Şahin and Kabasakal (2018) conducted a case study involving 15 gifted students. Their investigation unveiled the positive attitudes these students held towards the STEM education approach as well as the GeoGebra software. According to their findings, GeoGebra can effectively serve as a STEM resource. This underscores the potential of dynamic geometry software for an effective technology integration within STEM education.

Educators and researchers should actively track the ongoing advancements in educational technology (Zhang & Zhu, 2023). Consequently, research and development initiatives focusing on the integration of technology in mathematics education hold significant merit. In order to effectively incorporate technology into STEM courses, it is imperative for pre-service teachers to possess a solid foundation of technological knowledge and proficiency. Notably, the integration of technology into STEM courses encompasses various facets, including the utilization of the internet and robotics (Jocius et al., 2021).

2.3 Interdisciplinary Approach

In order for an individual to be successful in life by meeting today's needs, it is necessary to carry the knowledge acquired at school into life (Coşkun & Altun 2012). The changing conditions and problems of the twenty-first century have created a need for teamwork and interdisciplinary approaches (Corlu, 2015). Frequently, curricula tend to address individual disciplines in isolation. Disciplines, however, are connected in real life. It is possible to use an integrated curriculum approach to address the world's current issues such as energy, health, and the environment (Bybee, 2010; Kelley & Knowles, 2016; President's Council of Advisors on Science and Technology, 2010). Subjects such as science, mathematics, social studies, and foreign languages are often taught as separate disciplines. Nevertheless, achieving quality education demands a shift towards an interdisciplinary approach, necessitating collaborative curricula that go beyond the mere accumulation of knowledge across various subjects (Turna & Bolat, 2015). The amalgamation of courses offered by educational institutions plays a pivotal role in equipping students for real-world challenges. Consequently, this underscores the vital importance of embracing an interdisciplinary approach, and it is noteworthy that numerous countries are actively striving to integrate this approach into their curricula (Shamim et al., 2022)

The goal of integrating STEM disciplines is to contribute to the development of 21st century skills (Bergsten & Frejd, 2019; Bybee, 2013; Johnson et al., 2016; LaForce et al., 2016; Stehle & Peters-Burton, 2019; Sungur Gül & Taşar, 2020; Tytler, 2020). Gravemeijer et al. (2017) argue that today's curriculum is not sufficient to develop 21st century skills such as problem solving, collaboration, and critical thinking (Bybee, 2013). STEM education aims to provide students with knowledge and skills related to science, technology, engineering, and mathematics through interdisciplinary approaches (Karahan & Bozkurt, 2018). An interdisciplinary approach is necessary from early childhood education to secondary and higher education (Polat & Bardak, 2019).

As outlined by Kelley and Knowles (2016), employing a strategy that involves teaching STEM content from multiple STEM domains while concurrently integrating it with STEM practices within real-world contexts serves the purpose of enhancing students' comprehension of these subjects. However, if students are not good at each discipline, it might be challenging for them to connect ideas across fields. Students frequently fail to apply their disciplinary knowledge in integrated contexts (NAE & NRC, 2014). To ensure the successful execution of an impactful STEM lesson plan, students must possess sufficient comprehension of each discipline. Consequently, it becomes imperative to provide guidance to students while they are making interdisciplinary connections and designing scientific or engineering products.

Uluçay and Çakır (2014) state that mathematics is not only a discipline used in mathematics lessons. It is essential for students to be able to use mathematics, especially in science lessons. In this respect, it would be appropriate to design and work on educational games with interdisciplinary studies (Uluçay & Çakır, 2014; Young et al., 2012). Students who are aware of the connection of different disciplines in STEM education strategize, interpret, and assess their ideas while resolving the problems they encounter in their daily lives (Aydın et al., 2017; Yıldırım, 2013). This shows the importance of adopting an interdisciplinary approach and interactive activities in mathematics lessons.

The interdisciplinary approach enables individuals to be aware of what is happening around them, establishes a relationship by exchanging information between different disciplines and provides individuals with different perspectives (Durmuş & Alpkaya, 2019; Gür, 2003). This approach enables the examination of a subject from the perspective of different disciplines by establishing connections between disciplines (Coşkun & Altun 2012).

There are studies on the effect of adopting an interdisciplinary approach on student achievement and attitudes. Özçelik and Semerci (2016) conducted an experimental study involving 60 eighth graders and found that the interdisciplinary approach positively affected students' mathematics achievement compared to the traditional teaching method. Similarly, Coşkun and Altun (2012) concluded that the interdisciplinary approach positively affected mathematics achievement in a study involving 66 eighth graders. Durmuş and Alpkaya (2019) conducted an interdisciplinary experiment by merging physical education and mathematics lessons for a group of 34 sixth-grade students. The purpose was to assess the impact of this approach on students' attitudes toward the subjects. The study's outcomes indicated a noticeable enhancement in students' attitudes towards both the physical education and mathematics courses as a result of this interdisciplinary approach. Cengizhan and Balcı (2022) conducted a study with 9 students, 7 parents and 1 teacher and concluded that science practices based on the interdisciplinary approach contributed positively to the teaching and learning process.

The qualitative study conducted by Turhan Türkkan et al. (2017) involving eight mathematics and eight science teachers revealed that the majority of teachers did not have knowledge of interdisciplinary approaches. The researchers concluded that teachers should have more knowledge about the interdisciplinary approach. Similarly, Turan et al. (2020) conducted a study with 18 social studies teachers and concluded that the teachers have positive opinions about the interdisciplinary approach in terms of student development. However, the teachers also stated that they had problems in terms of teacher competence. They also highlighted that this approach might not be suitable for every subject and its effectiveness could vary depending on the students' proficiency level.

Özaydınlı and Kılıç (2019) conducted a qualitative study with 70 high school teachers, and they concluded that although teachers had positive attitudes towards interdisciplinary approach, they could not plan an interdisciplinary lesson. A significant number of teachers find it challenging to incorporate interdisciplinary practices into their lessons due to constraints related to time limitations and the density of the curriculum. Aslan-Tutak et al. (2017) recommended that teachers consider participating in seminars and courses designed to introduce them to the interdisciplinary approach, enabling them to recognize the potential benefits of educational innovations and apply them effectively in their teaching.

2.4 Interactive Activities in Mathematics Teaching

John Dewey is supportive of education by experiencing. According to John Dewey, life always requires learning new things, therefore, education should be appropriate for real life and should not be limited to school only. The knowledge taught in school is not enough on its own. Students need to be involved in their own learning processes, explore the issues, and research them. If students are not involved in their own learning process, it becomes difficult to achieve permanent learning (Yeşilyurt & Çağlar Perçi, 2021). Therefore, to achieve permanent learning, students should be active in their learning process.

Interactive activities increase student success and motivation (Tezer & Deniz, 2009). For students, mathematics lessons should be fun, and content should be presented in an interesting way and students should play an active role in the lesson (Atasoy & Yiğitcan Nayir, 2019). Yeşilyurt and Çağlar Perçi (2021) support this notion by stating that students participate more in interactive mathematics lessons than in the traditional mathematics lessons. Tezer and Deniz (2009) suggest that in the mathematics lesson, teachers should create environments that will attract the attention and interest of the students and enable them to explore. Classroom environments where students can work actively should be prepared, and opportunities should be offered to them to produce their own knowledge.

In a lesson with interactive activities, students are expected to generate and use their own solutions. Real-life problem solving requires students to solve problems using their own approach, which leads to meaningful learning (Shear et al. 2010; Stehle & Peters-Burton 2019; White & Frederiksen 1998). As a result of their experimental study with 42 sixth grade students, Başün and Doğan (2019) concluded that mathematics teaching with games was more effective than traditional teaching. Similarly, in a study conducted by Duran and Toptaş (2022) with 13 teachers, the participants stated that creative drama provides the opportunity to improve self-confidence by providing permanence, creativity, and active participation of students in mathematics lessons. In addition, according to the researchers, thanks to interactive activities such as creative drama, lessons become more fun.

Moreover, a crucial component of interactive activities involves students presenting their solutions, fostering a valuable skill where students learn to articulate and defend their ideas (Voss & Post, 1988). Uluçay and Çakır (2014) concluded that interactive activities in mathematics lessons contribute positively to the learning process by increasing students' motivation when prepared in accordance with the purpose. Additionally, Tatar et al. (2013) stated that interactive whiteboards used in mathematics lessons save time and facilitate teaching and learning for both the students and the teacher. Similarly, Birişçi and Çalık Uzun (2013) state that the interactive whiteboard is used in mathematics lessons for visualization and to concretize abstract concepts. Their study revealed that there are also teachers who think that interactive whiteboard is useful for solving a larger number of questions. Similarly, Tezer and Deniz (2009) conducted an experimental study with 60 eighth graders. They found that the experimental group using the interactive board was more successful in the mathematics lesson than the control group using the traditional method.

Macit and Aslaner (2019) conducted a study with 20 elementary mathematics teachers and found that according to the teachers, the use of interactive activities provides students with many benefits such as developing positive attitudes towards mathematics, increasing success and self-confidence, and developing responsibility. In addition, teachers mentioned some problems such as time management issues and different academic level of students. The teachers also expressed reservations about group activities, citing concerns that such activities might not align with every instructional objective and could potentially give rise to challenges during group work.

CHAPTER 3

METHODOLOGY

In this chapter, the methodology of the study is presented. The chapter includes the research design, participants of the study, context of the study, data collection tools, data collection process, data analysis, ethical considerations, assumptions, limitations, and trustworthiness of the study.

3.1 Research Design

Qualitative research method, multiple case study, was used in the data collection process. Qualitative research design provides a detailed understanding of the participants and the process. It does not only focus on the outcome, but also examines how participants understand the study and how the study affect their behavior (Maxwell, 2008). The obtained data from the semi-structured interview form was analyzed in according to the content analysis steps. Content analysis is a valuable technique for indirectly analyzing human behaviors as it enables the examination of participants' communications (Fraenkel et al., 2019).

In this study, pre-service elementary mathematics teachers' views on STEM education, their STEM lesson planning process, and the challenges they experience in the lesson planning process are examined. This study is conducted with three participants selected from among six volunteer participants. Therefore, qualitative research design and the multiple case study method were adopted.

3.2 Participants of the Study

Generally, qualitative research design involves a limited number of individuals (Maxwell, 2008). In this study, the convenience sampling method was utilized. In other words, the study was carried out with volunteer participants who met the desired conditions. The participants were selected from among the last year students at a big university in Ankara, the capital of Turkey. The participants were taking the Practice Teaching course in the 2021-2022 spring semester during the data collection period. Following an explanation of the study's objectives and data collection procedures, six participants willingly volunteered to take part. Subsequently, three participants were chosen based on the enthusiasm and detail evident in their lesson plans. These three individuals exhibited a notable eagerness to participate in the study, and their lesson plans offered more comprehensive insights. Consequently, the data derived from these selected participants proved to be richer. To protect their identities, pseudonyms were employed, and the participants were referred to as Robert, Claire, and Sarah, rather than their actual names.

3.3 Context of the Study

The senior students of METU Elementary Mathematics Education program take a practice teaching course and within the scope of this course, they visit a public school determined by the school as a trainee teacher. During the course, they must prepare two lesson plans and present one of them to the students at the school. In this study, the participants were asked to prepare their lesson plans, which were their homework assignments within the course, in line with STEM education. Although this may seem difficult for pre-service teachers who have never participated in a STEM education activity before, most of the class was eager to gain experience about STEM education before graduation. The timeline of the study is detailed in Table 3.1.

Table 3.1 The timeline of the study

Stage	Date
2021-2022 Academic Year Spring Semester Practice Teaching course starts.	07.03.2022
The researcher explains the purpose of the study and volunteer participants are selected.	14.03.2022
The first individual interview is conducted.	20.03.2022 – 25.03.2022
The participants prepare their first lesson plans.	11.04.2022 – 17.04.2022
Intervention The researcher implements four STEM activities.	18.04.2022 25.04.2022
The participants prepare a STEM lesson plan.	06.05.2022 – 12.05.2022
The participants present their STEM lesson plans within the scope of the practice teaching course through microteaching.	06.05.2022 – 12.05.2022
The second individual interview is conducted.	17.05.2022 – 26.05.2022
The participants present their STEM lesson plans at their internship school.	23.05.2022 – 30.05.2022
The third individual interview is conducted.	09.06.2022 – 13.06.2023
The data collection process ends.	13.06.2022

After the participants prepared their first lesson plans, the researcher implemented STEM education activities in the Practice teaching classroom in April. The researcher attended the participants' Practice Teaching course. A total of four STEM education lesson plans were implemented, with two in each of these classes. These teaching sessions were conducted with the participants' consent and were recorded for analysis. The schedule and the details of the lesson plans can be found in Table 3.2.

Table 3.2. The schedule and lesson plans applied in the intervention.

Date	Lesson Plan	Grade level	Topic
18.04.2022	Bungee Jumping	8th	Linear Equations
18.04.2022	Bridge Building	6th	Data Analysis
25.04.2022	Paper Airplane	6th	Ratio
25.04.2022	Snack Time	7th	Data Analysis

From the collection of STEM lesson plans, the researcher chose the top four plans that garnered the most positive feedback from their acquaintances who are mathematics teachers. These selected plans were then implemented as part of the intervention.

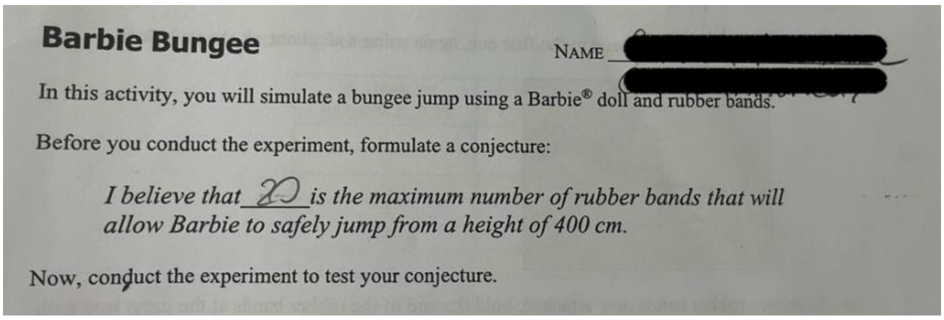
During the initial interviews with the participants, it was discovered that participants had not previously engaged in any STEM activities. To address this, the participants were offered the opportunity to partake in two weeks of STEM lessons. The objective was to enhance their understanding of STEM concepts and practices. Following each lesson, the participants were encouraged to share their thoughts on the lesson's content. They discussed what aspects could be improved and what aspects intrigued them. This allowed them not only to experience STEM activities but also to critically analyze a STEM lesson plan. Subsequently, all lesson plans were provided to the study participants. The intervention's specifics are elaborated upon below.

3.3.1 The First STEM Activity – Bungee Jumping

The first lesson plan is designed to explore linear equality through a bungee jumping activity. To start the lesson, the researcher shows a video about bungee jumping and encourages the students to share their opinions about extreme sports. This engaging introduction sets the tone for the lesson.

Next, the participants are divided into three groups, with each group assigned to its own station that was set up by the researcher prior to the lesson. At these stations, there is a meter on the wall, and participants are asked to envision this location as a bungee jumping platform. Each group is provided with an activity sheet, a rubber band, and a bottle, which were prepared before the lesson. Instead of using a doll, a bottle is used for this activity due to its easy accessibility and low cost. The groups, equipped with these materials, are then instructed to begin the activity. Their task is to calculate how many meters the bungee jumping station is above the ground by gradually extending the rubber band attached to the end of the bottle (as illustrated in Figure 3.1). Participants collect their own data over an ample period. Based on the data they gather; they are expected to respond to the guiding questions provided on the activity sheet.

Before moving on to the experiment, the participants are asked to estimate how many rubber bands are needed for the bottle to fall safely to 400 cm. At the end of the activity, they check the accuracy of this estimation with the equation they discover.



Barbie Bungee NAME [redacted]

In this activity, you will simulate a bungee jump using a Barbie® doll and rubber bands.

Before you conduct the experiment, formulate a conjecture:

I believe that 20 is the maximum number of rubber bands that will allow Barbie to safely jump from a height of 400 cm.

Now, conduct the experiment to test your conjecture.

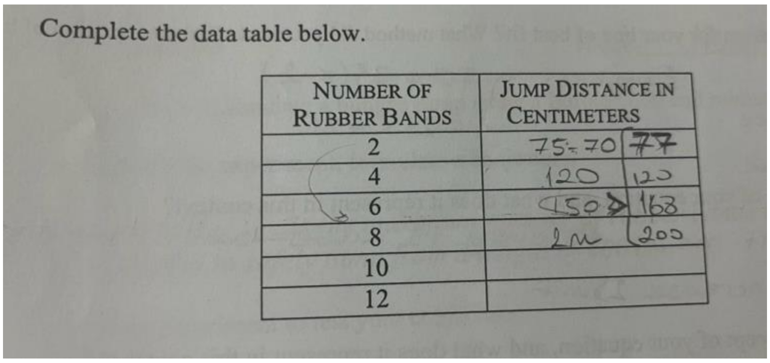
Figure 3.1. A sample estimation participants make before the experiment.

During the data collection phase, participants are asked to fill out a table in the activity. This table, as outlined in Table 3.3, requires them to determine the jump distance (in centimeters) by incrementally adding rubber bands, following the instructions provided.

Once they've collected the necessary data and completed the table, participants are instructed to create a scatterplot using their data points and clearly label the scales on each axis. After plotting the graph, participants are then prompted to sketch a line of best fit. An example of a graph drawn by one of the participants can be seen in Figure 3.4.

Figure 3.2. Each group conducting experiment at their designated bungee jumping station.

In Figure 3.2, as participants were collecting data by increasing the number of rubber bands, one participant mentioned that their bottles hit the floor. This raised concerns since the bottle symbolizes a person bungee jumping, and if it hits the ground, it implies an unsafe landing. Given that the problem's criteria emphasized a safe landing, they decided to conclude their experiment and proceeded to fill in the table presented in Figure 3.3.



Complete the data table below.

NUMBER OF RUBBER BANDS	JUMP DISTANCE IN CENTIMETERS	
2	75-70	77
4	120	120
6	150	168
8	2m	200
10		
12		

Figure 3.3. The table of number of rubber bands and the jump distance

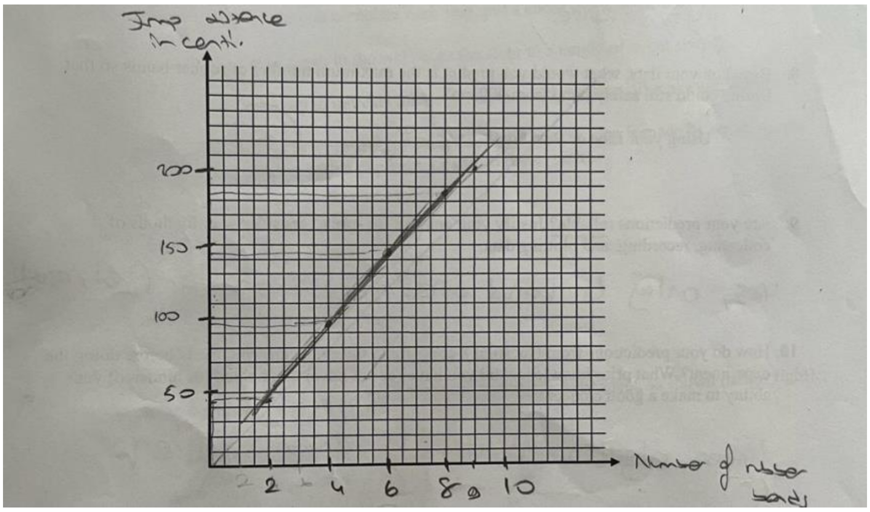
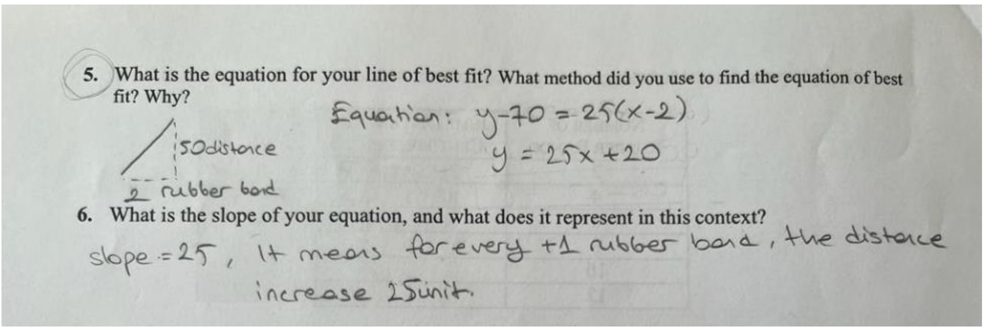


Figure 3.4. An example of a graph drawn by one of the participants

Figure 3.5. The second group presenting their data and drawing their graph on the board.

It was observed that the data collected by the second group closely resembled the data from the other groups. During the discussion, differences in the data were examined, and potential reasons were explored. One hypothesis put forward by the participants was that the weight of the "people" represented by the bottles might differ. Since the amount of water in each bottle could vary, the heavier bottle would fall lower. As a result, participants concluded that when ensuring a safe landing for bungee jumping, one's weight should also be taken into account.



5. What is the equation for your line of best fit? What method did you use to find the equation of best fit? Why?

Equation: y-70 = 25(x-2)

y = 25x +20

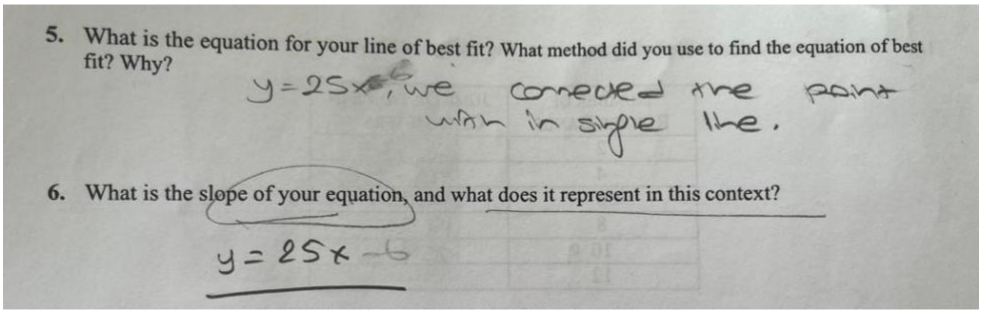
50distance

2 rubber band

6. What is the slope of your equation, and what does it represent in this context?

slope = 25, It means for every +1 rubber band, the distance increase 25unit.

Figure 3.6. The answer of the first group for the equation of best fit line and the meaning of the slope



5. What is the equation for your line of best fit? What method did you use to find the equation of best fit? Why?

y=25x-6, we connected the point with in single line.

6. What is the slope of your equation, and what does it represent in this context?

y = 25x -6

Figure 3.7. The answer of the second group for the equation of best fit line and the meaning of the slope

After the graph was drawn, the participants were asked to find the equation of the best fit line. Then, they were asked the slope of this equation and what this slope means. Although there are similarities in the equations (as shown in the Figure 3.6 and 3.7), one group added a constant to the equation and the other group did not. This led to a discussion regarding the appropriate form of the equation and the purpose of the constant. Some participants suggested that the constant represented the height of the model.

The groups argued about whether the length of the model should be included in the equation. The participants engaged in a discussion regarding how the model is dropped and whether they should incorporate body length into the equation. The central question for the participants revolved around the point at which the rope should be tied to the person: should it be tied to the feet or to the head? If it is attached to the head, this would not be a sensible bungee jumping experience. If it is attached to the feet, the height of the person is added every time the person falls. Therefore, it was concluded that the height of the person should be added as a constant if the model jumps with its feet tied to the rope at the bungee jumping station. Towards the end of the activity, the participants tested the estimation they made at the beginning of the lesson regarding the number of rubber bands needed to reach a drop of 400 cm using the equation they had derived.

At the end of the lesson, the participants discussed the lesson plan and the ways to improve it. It was stated that a clearer model was important for the course of the lesson.

3.3.2 The Second STEM Activity – Bridge Building

The second lesson plan was an activity aiming to develop table reading and making comparisons between two sets of data. The lesson started with a newspaper article. According to the article, a bridge in Minneapolis in 1967 collapsed with vehicles on it. The participants read this article, and the video about the bridge collapse in Minneapolis was shown. After the introduction to the lesson, the participants were asked to think about the characteristics of bridges and the factors that may be involved in the bridge collapse. In the main activity, the class was divided into 3 groups and activity sheets were distributed. Each group was told that they were the engineers who would rebuild this bridge. Four different types of bridges were presented, and they were expected to calculate the cost of each of these bridges, and each group chose a bridge according to their criteria. The participants were expected to present their bridge design at the end of the lesson. These criteria were the shortest time, lowest cost, and highest durability. After each group made a presentation, the best possible bridge type was selected.

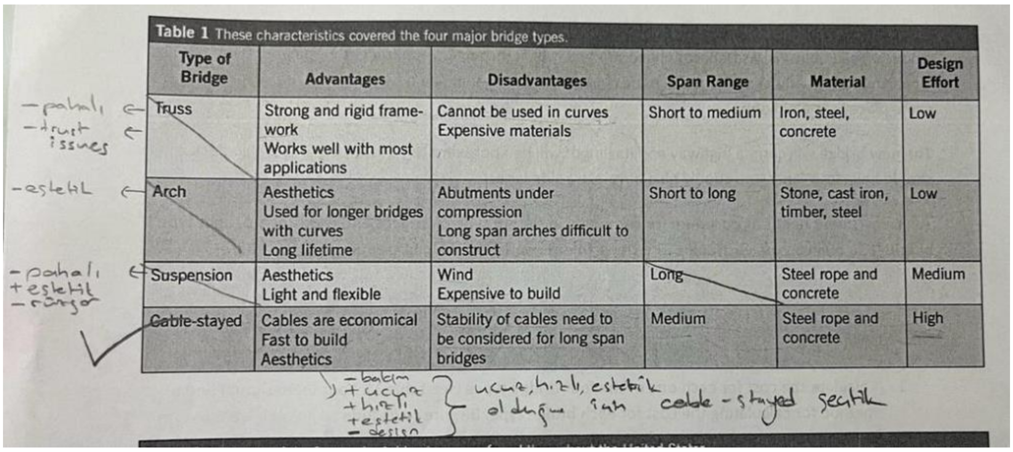


Table 1 These characteristics covered the four major bridge types.

Type of Bridge	Advantages	Disadvantages	Span Range	Material	Design Effort
Truss	Strong and rigid frame-work Works well with most applications	Cannot be used in curves Expensive materials	Short to medium	Iron, steel, concrete	Low
Arch	Aesthetics Used for longer bridges with curves Long lifetime	Abutments under compression Long span arches difficult to construct	Short to long	Stone, cast iron, timber, steel	Low
Suspension	Aesthetics Light and flexible	Wind Expensive to build	Long	Steel rope and concrete	Medium
Cable-stayed	Cables are economical Fast to build Aesthetics	Stability of cables need to be considered for long span bridges	Medium	Steel rope and concrete	High

Figure 3.8. One of the group's works on a table.

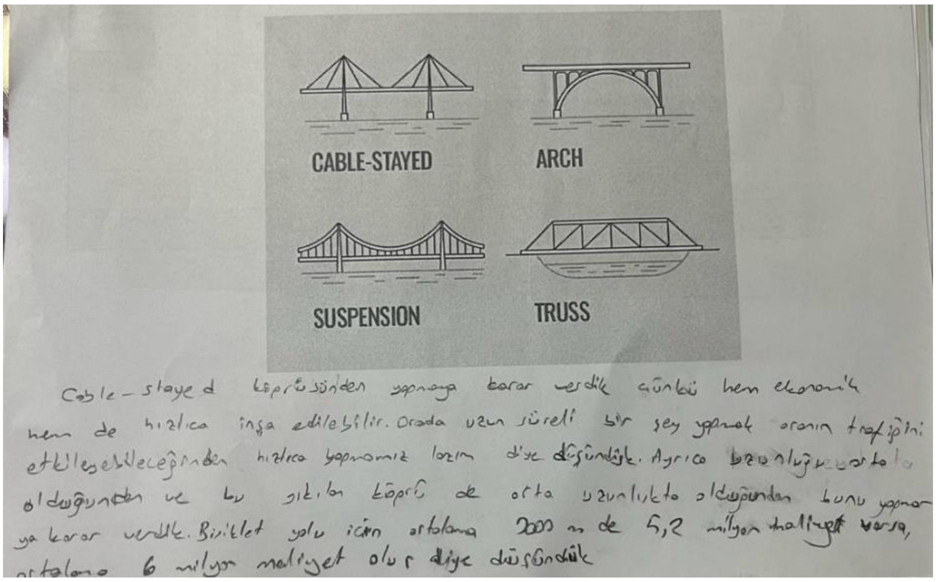


Figure 3.9. One of the group's works

The two groups, as depicted in Figures 3.8 and 3.9, selected the same bridge. One of the groups emphasized that this particular bridge option was not only more cost-effective but could also be constructed swiftly. They said that it was important to do it in a short time, since construction that takes a long time can cause trouble on such a busy road. They stated that if the bike path is not built, the cost will decrease, and it can be built for about 60 million dollars. The other group, who chose the same type of bridge, similarly stated that they paid attention to cheap and fast construction. In addition, this group argued that when choosing this bridge, they also considered its aesthetic appearance.

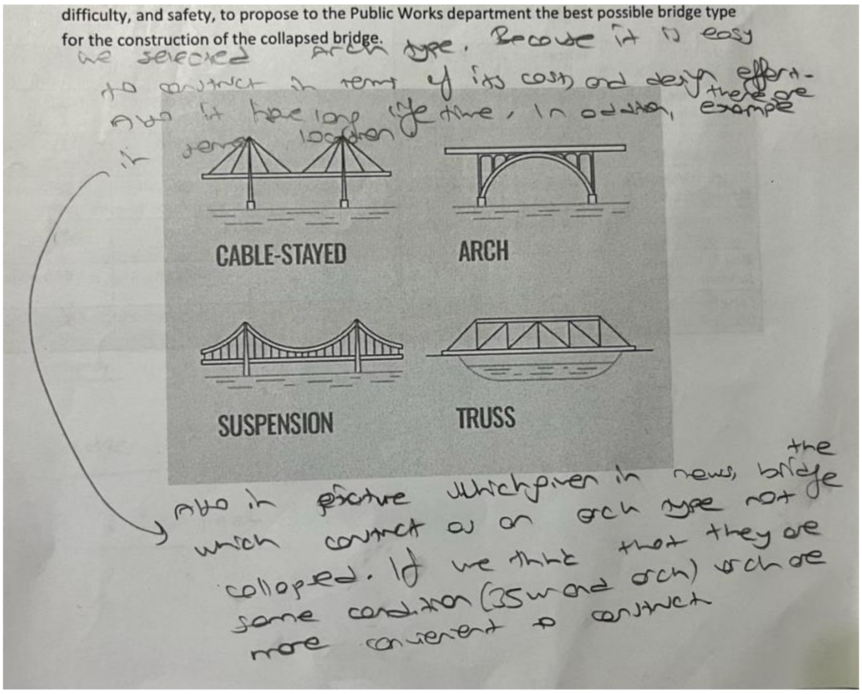


Figure 3.10. One of the group's works

The last group indicated a different approach, as shown in Figure 3.10. This group stated that the bridge chosen by the other groups was expensive and they chose a cheaper type of bridge. They stated that although it is difficult to construct, it would be worth the hard work to make this bridge last longer.

3.3.3 The Third STEM Activity – Paper Airplane

The third lesson plan is a ratio related activity. The lesson begins with the question of whether the participants have made paper airplanes, and a website is shown with many types of paper airplanes. This website contains information about the names of paper airplane models, their speed, flight time, distance, and ease of construction. How there can be so much variation about paper airplanes is discussed. Then, images from the furthest paper airplane competition are shared and the video of the winning paper airplane is watched. The paper airplane's impressive flight distance serves as an intriguing introduction, prompting participants to contemplate the variables influencing its speed. In the main activity, the class is divided into three groups and each group is given activity papers. In addition, the groups are given papers of various sizes and weights and an instruction on how to make an airplane with paper. Each group is asked to generate a hypothesis. For example, a lighter paper airplane travels longer distances or stays in the air longer. Then, the groups are expected to test their hypotheses. For this, they need to keep the variables other than the variable they use in the hypothesis constant and calculate the flight speed of the paper airplane they made. The groups move to the stations reserved for them in the classroom to experiment. Division of work is recommended for efficient group work like one person making the paper airplane, one person measuring the distance and one person keeping the time. A stopwatch is used for time measurement and floor tiles can be used for distance measurement. After the participants finish their experiments and write the variables they tested on the table, they calculate the speed of the planes from the paper they made. For this, they use the speed ratio relationship they have learned in science class. Here, the strategies they use when calculating are discussed. These strategies can be unit ratio, keeping the time same or keeping the distance same. Each group presents their own experiment.

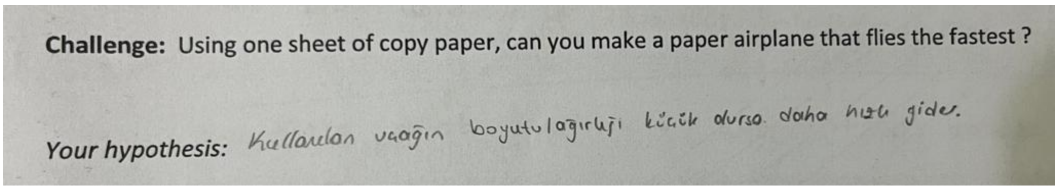


Figure 3.11. A hypothesis example tested by one of the groups (the smaller the size or weight of the paper plane, the faster it will travel)

Figure 3.12. The groups are making paper airplanes.

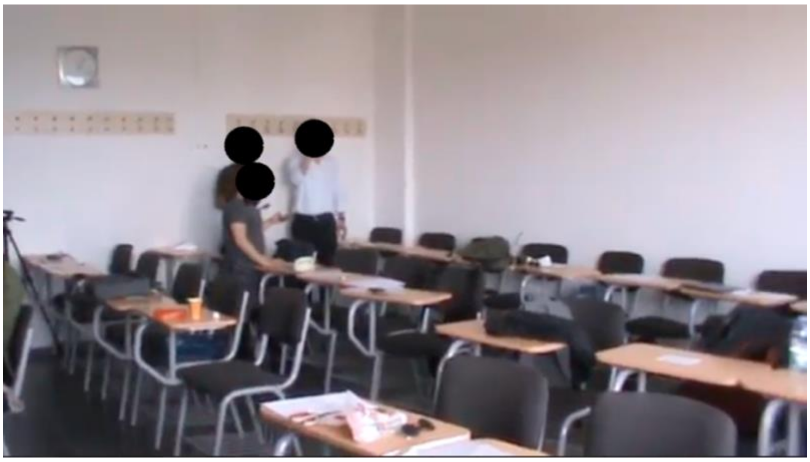


Figure 3.13. The groups launch paper airplanes they make in the air, collecting data to test their hypotheses.

While the groups were measuring, it was noticed that the area where they would launch the planes had to be empty. It was concluded that if the stations are prepared before the lesson and arranged in order, there will be less time wasted in the lesson. The participants paid attention to group work while measuring. It was observed that they shared the tasks of launching the plane, keeping the time, counting the tiles, and taking notes of the measurements. The participants stated that it can be difficult to do this activity in crowded and small classes. Furthermore, the participants stressed the challenge of maintaining classroom management to keep students engaged in the lesson rather than transitioning to paper airplane games.

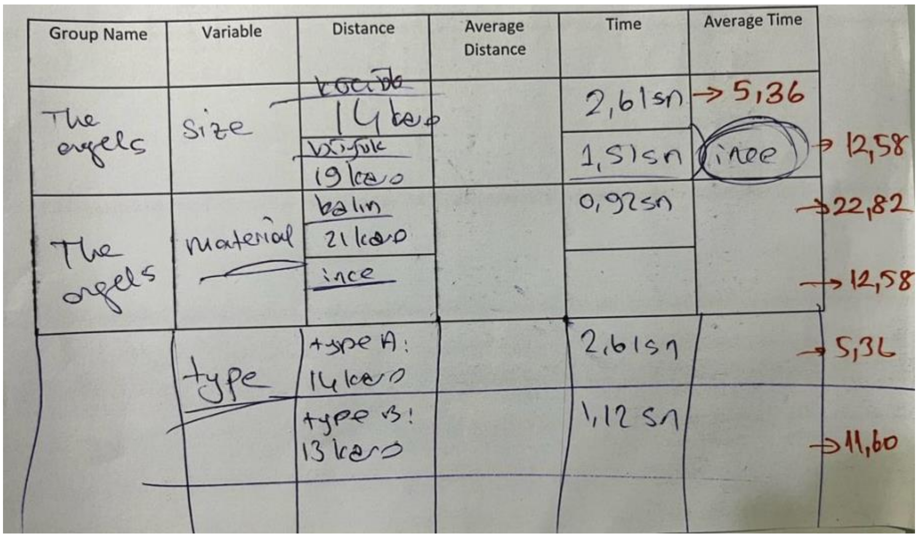
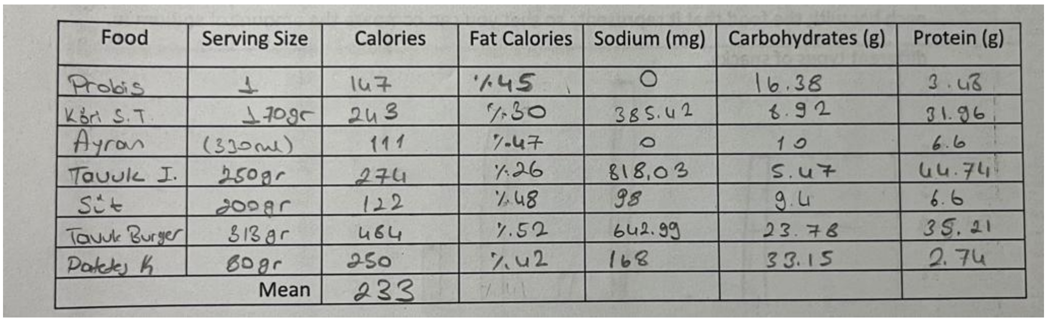


Figure 3.14. The table where one of the groups test the variables.

In the group work shown in Figure 3.14, the group named “Angels” tested the size, material, and the type of the paper airplane. According to the data they collected, the larger paper airplane traveled longer distance. After the measurements were made, the activity paper continued with the speed finding and strategy development questions.

3.3.4 The Fourth STEM Activity – Snack Time

The last lesson plan aimed to collect and interpret data in daily life. It is aimed at discovering that the numbers given in statistics have a counterpart in daily life. The lesson begins by talking about favorite snacks. Participants name their favorite dishes and snacks. Next, they inquire about their awareness of their daily calorie intake and how closely they pay attention to the nutritional values listed on the back of snacks. In the main activity, groups of two are formed and the activity sheet is given to each group. Participants are expected to use their phones for the activity. They are asked to open a website where they can find the nutritional values of foods. Using this website, they are expected to search the nutritional values (calories, fat calories, sodium, carbohydrates, protein) of their favorite foods and write these values in the table given in the activity sheet (Figure 3.15). After the groups finish collecting data and filling in the table, they find the mode, median, mean and range and interpret their own collected data.



Food	Serving Size	Calories	Fat Calories	Sodium (mg)	Carbohydrates (g)	Protein (g)
Probis	1	147	%45	0	16.38	3.48
Köri S.T.	170gr	243	%30	385.42	8.92	31.96
Ayran	(330ml)	111	%47	0	10	6.6
Tavuk I.	250gr	274	%26	818,03	5.47	44.74
Süt	200gr	122	%48	98	9.4	6.6
Tavuk Burger	313gr	464	%52	642.99	23.78	35.21
Patates K	80gr	250	%42	168	33.15	2.74
Mean		233				

Figure 3.15. Nutritional values table for one of the participant's favorite foods

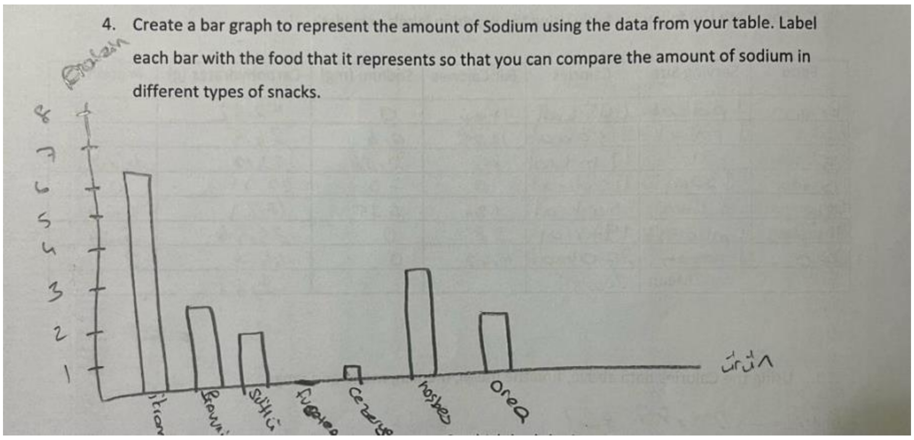


Figure 3.16. Graph of the amount of the protein of the foods chosen by the participant

3.4 Data Collection Tools

A semi-structured interview form developed by the researcher was used as a data collection tool. The questions in the instrument were checked by taking expert opinion. The first interview is an 8-question interview designed to gain an insight into the participants' knowledge of STEM education and their thoughts on preparing a STEM lesson plan. The first interview consisted of questions about the definition of STEM education, the importance of STEM education, the aim of STEM education and STEM lesson planning. The second interview was conducted after the STEM education application, during the lesson planning process. It is a 9-question interview prepared to learn about the change in their views, to examine the STEM lesson plan preparation processes and expectations before the lecture. In this interview, the lesson plan preparation experiences were questioned, and the challenges experienced and expectations about the lesson were questioned in detail. The third and the last interview is a 7-question interview. It was conducted after the participants presented their STEM lesson plans at their internship school. The purpose was to gather their experiences regarding whether the lesson met their expectations, any difficulties they encountered, and any changes they would like to make. During this interview, the participants were questioned in detail about their teaching experiences, including how the lesson unfolded, the feedback they received from their students, and the specific aspects of the lesson plan they felt needed modification. The questions in each interview are presented in Appendix A.

Based on the participants' responses, the researcher included additional questions to gain a deeper understanding. Furthermore, the participants were tasked with creating two STEM lesson plans and delivering them in the Practice Teaching course. These microteaching sessions were recorded with their consent and served as additional data for this study.

The interviews were conducted online via Zoom Meeting Application. With the permission of the participants, the interviews were recorded. Each interview lasted approximately 10-15 minutes and each participant was interviewed for a total of approximately 30-40 minutes. Detailed information regarding the interview duration is shown in Table 3.3.

Table 3.3 The duration and instrument of each interview

Participant	**Stage**	**Duration**	**Instrument**
Robert	The First Interview	9 minutes	Zoom Meeting
	The Second Interview	11 minutes	Application
	The Third Interview	16 minutes	
	Total	36 minutes	
Claire	The First Interview	8 minutes	Zoom Meeting
	The Second Interview	8 minutes	Application
	The Third Interview	11 minutes	
	Total	27 minutes	
Sarah	The First Interview	11 minutes	Zoom Meeting
	The Second Interview	10 minutes	Application
	The Third Interview	18 minutes	
	Total	39 minutes	

3.5 Data Collection Process

Before the study, ten participants from 'MSE418 - Practice Teaching' course in the 2021-2022 spring semester were asked to sign a consent form that includes the purpose of the research, the contact information of the researcher, the fact that the participant information will be used for academic purposes only and will not be shared with anyone. The researcher actively engaged in the class, providing an explanation of the study, and collecting contact information from volunteers. Six pre-service teachers volunteered to participate in this study.

After the interview questions were prepared and expert opinion was obtained, a pilot study was conducted. The pilot study was conducted with three pre-service teachers and information was obtained about the order of the interview questions and the way the questions were asked. The flow of the interview was revised according to the pilot study. After the interview questions and data collection process were determined, the study was initiated.

This study was conducted in five steps. There are three interviews, two lesson plans and two microteaching sessions. The schedule of each stage is given in Table 3.4 and Table 3.5. Firstly, the participants were given a semi-structured interview form.

Table 3.4 Dates, aims and tools of each interview.

Stage	Date	Aim	Tool
The First Interview	March 2022	To learn pre-service teachers' knowledge about STEM education.	Semi-structured interview questions
The Second Interview	May 2022	To learn pre-service teachers' knowledge about STEM education. To learn pre-service teachers' expectations before implementing the STEM lesson plan they prepared.	Semi-structured interview questions
The Third Interview	June 2022	To learn pre-service teachers' knowledge about STEM education. To learn pre-service teachers' reflections after implementing the STEM lesson plan they prepared.	Semi-structured interview questions

After the individual interviews, the pre-service teachers were asked to prepare a STEM lesson plan. With the permission of the participants, the lesson plans were recorded in microteaching and their thinking in this process was analyzed in depth. Afterwards, the participants were given STEM education practices by the researcher. This application was reported in detail in the Context of the Study section above. Following these practices, data were collected using a semi-structured interview form to obtain the participants' views on STEM education, and the pre-service teachers were asked to prepare a STEM lesson plan again. The participants were in contact with the researcher while preparing the STEM lesson plan and were given feedback by the researcher. The researcher had individual interviews with each participant during the lesson plan preparation phase. The lesson plans were recorded in microteaching and their way of thinking in this process was analyzed in depth. After preparing a STEM lesson plan, the participants presented these lessons at their internship school. Finally, one more semi-structured interview was conducted with the participants.

Table 3.5 Dates and aims of the stages in the study.

Stage	Date	Aim
The First Microteaching	March 2022	Participants discuss the lesson plan they prepared and receive feedback
Intervention	April 2022	To inform participants about STEM education and apply examples of STEM lesson plans
The Second Microteaching	May 2022	Participants discuss the lesson plan they prepared and receive feedback

3.6 Data Analysis

The STEM lesson plans that each participant prepared, and the microteaching videos were analyzed according to the conceptual framework of integrated STEM education (Kelley & Knowles, 2016; Roehrig et al., 2021). Seven characteristics of the framework used in this study are explained in detail below.

• Focus on Real-World Problems

For a lesson plan to be STEM education, it must consist of a real-world problem (Kelley & Knowles, 2016; Roehrig et al., 2021). Choosing a real-world problem is a challenging task because there are numerous variables that impact students' outcomes. Since one of the aims of STEM lessons is to the develop students' STEM skills, gender should be taken into consideration while choosing real-world problems. Moreover, problem statement should be inclusive and engaging for all students (Roehrig et al., 2021)

• Engagement in Engineering Design

Integrating engineering design to the lesson plan provides students with the opportunity to develop systematic problem-solving skills in situations they may encounter in STEM fields (Kelley & Knowles, 2016). Teachers must make sure that students get the chance to assess their designs and redesign using the information gathered. Cost, materials, functionality, and social and political aspects should all be considered while making design decisions (Roehrig et al., 2021). According to Kelley and Knowles (2016), a STEM lesson plan includes a problem that requires an engineering solution to integrate engineering design. Furthermore, students should identify the criteria and constrains and collect, analyze, and interpret data.

• Scientific Inquiry

Students learn how to ask questions, create hypotheses, and conduct studies using the accepted scientific methods through scientific inquiry, which trains them to think and act like a scientist. When given the chance to create their own questions about the science topic in the lesson, students start to research about the connections between disciplines and they take control of their own learning (Kelley & Knowles, 2016).

• Technology Use in STEM Lessons

In the STEM lesson plan, technology should be conceived as a tool that has positive impacts on culture, society, politics, economy, and environment. Teachers should give students the chance to consider technology critically, helping them to become technologically literate. Also, problem solving should be facilitated by using technology (Kelley & Knowles, 2016).

• Mathematical Thinking

Since students generally consider mathematics as an abstract topic that they never use in daily life, they are more engaged in an effective integrated STEM lesson and perform better on mathematics assessments. In addition to learning how to solve a mathematical problem, students want to understand the value of learning mathematics. They are curious about how mathematics relates to their daily life. STEM education provides students with this opportunity and students' interest and success in mathematics increase. Students should make sense of the mathematical problem and think about the solution to it. In a STEM lesson, students need to explain the meaning of a problem and look for entry points to a solution (Kelley & Knowles, 2016).

• Content Integration

Making connections between disciplines and between context is crucial to integration. Also, disciplines should be obvious to students. To help students understand these linkages, teachers must use interdisciplinary models and representations, and engage in deliberate facilitation and questioning (Roehrig et al., 2021).

• Twenty-First Century Skills and STEM Careers

In STEM education, students are given the opportunity to create their own solutions. If instructions are given by the teacher, there will be only one solution. However, STEM education contains more than one possible solution to a problem. Since the tasks are open-ended, teachers should guide students and make it easier for students to understand the problem situation and solution. To present and defend their solutions, students should apply data and use evidence-based reasoning. Students should also consider social and cultural aspects while searching for a solution (Roehrig et al., 2021). This is important to train students who think in multiple ways when finding a solution to a problem in their profession in the future. To foster 21st century skills like collaboration, critical thinking, creativity, analysis and assessment, teachers should design small group activities. To encourage equal engagement from all students, teachers should carefully facilitate small group work. Clear instructions on working in small groups must be given to students so that they can develop 21st century skills while problem solving with design thinking (Roehrig et al., 2021).

n a STEM lesson plan, it is important to highlight specific STEM occupations that are related to the subject matter. STEM activities provide students with the opportunity to explore and propose solutions to real-world challenges. As a result, students can gain a deeper understanding of the roles and responsibilities of STEM professionals (Roehrig et al., 2021).

3.7 Ethical Considerations of the Study

Firstly, to conduct this study, permission from Middle East Technical University Applied Ethics Research Center was obtained (See Appendix B).

Before starting the study, the purpose of the study and the data collection process were explained to the participants in detail verbally and in writing. The participants were provided with a consent form, as outlined in Appendix C, which detailed the study's purpose and process. This form explicitly stated that participation in the study was voluntary, and participants were under no obligation to take part. Both verbal and written consent were obtained from those who volunteered to participate in the study. The data collection phase was recorded with the permission of the participants and these recordings were not accessible to anyone other than the researcher and the supervisor. To protect confidentiality, the participants' names were kept hidden, and pseudonyms were used. The lesson plans that were implemented during the study were shared with the participants, and the results of the study can be made available to them upon their request.

3.8 Assumptions and Limitations of the Study

The current research was conducted based on some assumptions. Firstly, it was assumed that the interview questions were clear for the participants and the collected data are sufficient for the aim of this study. Secondly, it was assumed that the participants expressed their thoughts objectively and their experiences honestly during the interview. Finally, it was assumed that the researcher did not approach the participants with any prejudice about their knowledge during the data collection process.

There are some limitations in this study. Three participants were selected from among the senior students at Middle East Technical University, Department of

Elementary Mathematics Education. Since the number of participants is three and this is a qualitative study; the results of this research cannot be generalized to all pre-service teachers. Also, the lack of experience of the researcher can also be considered a limitation. In other words, due to the researcher's inexperience in qualitative research and individual interviews, the depth of the study may have been impacted.

3.9 Trustworthiness of the Study

There are four components of trustworthiness in qualitative research, which are credibility, dependability, transferability, and confirmability (Connelly, 2016; Lincoln and Guba, 1985). In this section, each component is explained in detail.

Credibility is the internal validity in qualitative research. That is, if the study was conducted in adherence to established qualitative research protocols, it would enhance the internal validity of the study (Connelly, 2016). According to Lincoln and Guba (1985), there are many techniques to ensure credibility. In this study, there are multiple data sources which are three interviews, two lesson plans and two microteaching sessions. Therefore, triangulation was used to enhance credibility. Additionally, prolonged engagement with the participants was employed, extending the data collection process over approximately four months. This extended engagement allowed ample time to build trust with the participants, further enhancing the study's credibility. The researcher was in constant communication with the participants during the data collection process. In this way, an environment of trust was created between the participants and the researcher.

Dependability in qualitative research is defined as the stability and consistency of research results (Connelly, 2016; Shenton, 2004). To ensure dependability in this study, a comprehensive description of the research methodology is provided in the sections above. Additionally, to enhance dependability, similarities in results are carefully identified, and the study's procedures are described step by step, ensuring that the research process can be replicated with consistent outcomes.

Transferability, in the context of qualitative research, addresses the question of when and under what conditions the study's results are valid (Kyngäs et al., 2019). It emphasizes the applicability of the findings to situations or contexts that share similarities with the one studied, rather than attempting to make broad generalizations to more diverse or dissimilar settings (Connelly, 2016). A thick description of the results from various data collection techniques can help achieve transferability. In this study, the thick description technique was used; that is, the participants, data collection tools and the data collection procedure were all thoroughly detailed in the sections above.

Confirmability is the measure used to ensure that participant or researcher bias did not affect the data and findings (Connelly, 2016; Kyngäs et al., 2019). To ensure confirmability, during the data collection process, the data was continuously checked. Furthermore, the data was analyzed using a detailed framework described in the section above.

CHAPTER 4

RESULTS

In this chapter, the results of the research are presented. First, the findings pertaining to the three participants are presented independently of each other. The comparison of the findings obtained from the participants is presented in the discussion section.

4.1 Participant 1: Robert

In this section, the findings obtained from Robert, one of the six participants of the study, are presented under two main headings. Robert was willing to participate in this study and at the end of the study, he expressed that he was happy to learn about STEM education before graduating thanks to this study. Robert's experience on STEM education and challenges in the STEM lesson planning are examined under two main headings: Views on STEM Education and STEM Plan.

4.1.1 Views on STEM Education

In this section, Robert's answers to the questions, " What is STEM education? What is the purpose of STEM education? Do you think STEM education is important for your field?" are presented.

In the first interview, Robert stated that he heard of STEM education, but he did not have any chance to attend a STEM activity before. He can define STEM education and what this acronym stands for. He said, 'STEM education is a cooperation between different sciences, and it stands for Science Technology Engineering

Mathematics.' Robert thinks that STEM education is important for elementary mathematics education, and he was willing to participate in this study.

In the first interview, Robert defined the aim of STEM education as follows: "The aim of STEM education is to provide students with a different perspective and teach them alternative methods of learning, rather than relying solely on traditional lectures."

However, in the second interview, Robert's response to the same question was as follows:

> 'STEM education is an interdisciplinary approach. We can say that STEM is actually an interdisciplinary lesson plan that combines disciplines such as Science Technology Engineering Mathematics. It is the blending and presentation of all of these in a lesson plan. In fact, these have the benefit that the students are not only learning but also practicing.'

Robert stated that STEM education is the integration of different disciplines and provides the opportunity not only to learn the subjects but also to apply them.

In the first interview, Robert did not mention the word "interdisciplinary." However, after the intervention and while attempting to prepare a STEM-related lesson plan, he emphasized the significance of an interdisciplinary approach. This shift in his perspective highlights how the intervention influenced his understanding of STEM education, particularly the importance of interdisciplinary connections. Robert expressed that an interdisciplinary approach can pose challenges for teachers during the lesson planning process. He also noted that implementing such an approach might be challenging if students are not familiar with the concept. His response to the question, "Would you have had any difficulties in preparing and implementing a STEM Lesson Plan?" indicates that intertwining various STEM areas can be challenging, and the success of implementation may depend on students' prior exposure to such an approach.

In Robert's STEM lesson plan, he had high expectations before the lesson and mentioned that he met those expectations after the lecture. In his reflection, he highlighted the students' strong interest in the lesson, noting that it was a STEM lesson plan that engaged students effectively.

Robert stated that the students played an important role in making the lesson productive and fun, and according to the feedback he received after the lesson, the students both learned and had fun. According to Robert, the students were aware that there was a different lesson plan.

In the microteaching session, Robert asked several questions about thermal insulation without waiting for the answers. Feedback was provided to him regarding this issue, suggesting that he ask one question and then wait for the answers before proceeding to the next question. This approach was recommended to improve classroom management and facilitate a better understanding of students' opinions. Additionally, the feedback discussion included how Robert assisted students in interpreting the table shown in Figure 4.13.

‘Students can give a lot of answers by looking at this table. It would take too long to interpret this table. You must guide them by asking questions. For example, you must ask them whether the chosen insulation material is interior or exterior. One group may say that we only considered exterior insulation because it is cheaper and protects them from the weather, or another group may say that we chose both interior and exterior because it is a two-sided insulation. You need to ask for details in the table to obtain these kinds of answers. Otherwise, students may choose only one material and finish and may not pay attention to other details in the table.’

Based on the feedback received, a decision was made to refine the table used in Robert's STEM lesson plan. It was determined that the table should only include information that could be effectively interpreted and utilized by students. Consequently, Robert chose to remove the last two columns of the table, which pertained to the "fields of use" and "lifetime of the material." This decision was made to streamline the table and enhance its clarity for students. The final table is given in

Figure 4.12 which includes insulation material, cost, environmental friendliness, combustion characteristics. This adjustment in table organization is anticipated to improve the guidance and supervision of students during the activity, thereby enhancing classroom management. Consequently, it can be inferred that the revised organization of the table in Robert's lesson plan was implemented with the aim of facilitating feedback and streamlining classroom management.

In addition, Robert's responses to the questions 'What challenges did you face while implementing a STEM lesson plan? How did you expect the lesson to go? How was the lesson, was it what you expected?' is be analyzed below according to his experiences.

Before the lesson, Robert was enthusiastic and excited to implement a STEM lesson plan at his internship school.

> 'The students like these kinds of things, but they are not used to it, but they will get used to it. The lessons that are a little bit different for the students are nice. They get out of the monotony, and they even tell us that they want us to teach them because we make them do activities in class. Students are very happy since they do not have to write all the time or learn from the blackboard. My expectations from the students are actually high; they can do group work. I think it will be good.'

Robert thought that since the students were not used to a different type of lesson, his lesson would be of interest to them.

After the lesson, Robert stated that the lesson went as he expected. According to him, students were willing to participate in the lesson. He mentioned the issue of time management. Robert stated that he could not make it in one class hour and the end-of-lesson presentation was left for the next day. In the first interview, he also stated that time management could be a problem.

In addition, Robert stated that there may be difficulties in controlling the groups while doing group work since students try to produce a product in groups. In his own internship experience, Robert stated that he did not have such a problem because he had fellow pre-service teachers in the class, but if he was alone, it might be difficult to control the groups. In summary, according to Robert, time management and group work might be challenging for STEM lesson plan.

4.1.2 Robert's STEM Lesson Plan

In this section, Robert's answers to the question, "Would you have had any difficulties in preparing a STEM Lesson Plan? Please explain your reasoning." will be presented relating those with the STEM education framework. The STEM lesson plan that Robert prepared, the microteaching and individual interviews conducted during the lesson planning process are analyzed according to the conceptual framework of integrated STEM education (Kelley and Knowles, 2016; Roehrig et al., 2021). The challenges observed in this study are explained according to the data obtained from the interviews. To examine the difficulties Robert experienced in lesson planning, his responses to the question 'What challenges did you face while preparing and implementing a STEM lesson plan?' are analyzed in the field of each discipline.

4.1.2.1 Description of the STEM Lesson Plan

The aim of Robert's second lesson was to integrate the shapes that students have learned to measure area into a real-world problem. In the introduction part, Robert reminded the students of the types of thermal insulation that they have learned in the science lesson. Then, the aim was to attract students' attention by giving an example of an endangered bird. Before the main activity, Robert reminded the students of how to find the area of a square, rectangle, triangle, and parallelogram because they would use the area of a square, rectangle, triangle, and parallelogram while building the birdhouse. Therefore, the properties and area relationships of these shapes were repeated. To move on to the main activity, Robert showed a video about the birdhouse and moved on to the problem in the main activity. In this problem, the students were expected to design a birdhouse using spaghetti and play dough brought by the teacher. For the birdhouse design, the students worked in groups and were expected to use at least two geometric shapes they have learned before. Then, they chose the materials for the birdhouses they have designed. They were expected to make this choice according to the criteria given on the activity sheet. At the end of the lesson, each group presented their birdhouse design and material selection. Finally, the best, most environmentally friendly, and most cost-effective design was selected.

Mathematics objective used in Robert's STEM lesson plan:

M.6.3.2.5. Students should be able to solve problems about area.

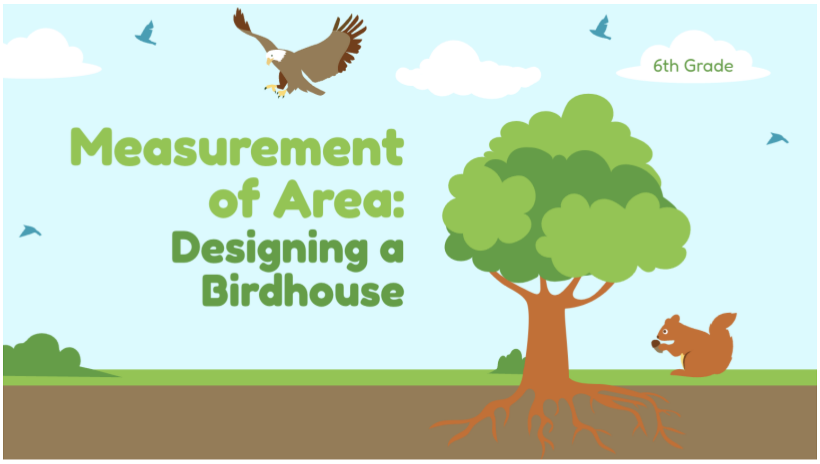


Figure 4.1. Robert's introduction slide: Measuring the Area: Designing a Birdhouse

4.1.2.2 Focus on Real-World Problems

Robert's second lesson plan started by talking about birds. He asked the students if they kept birds and what they thought about the living conditions of birds outside. To increase students' attention to the lesson, Robert showed videos about birdhouse. Robert chose to start the lesson with an interesting story.

In the middle part of his lesson plan, he told a story named 'The Story of Robert and Kirli', and there was a problem in this story:

> 'Every day after coming home from school, Robert played games with his beloved bird Kirli, listened to her singing, and loved her. On his way home from school that day, Robert noticed that the weather was getting colder with the arrival of winter, and he remembered the science lesson they had taught at school that day. As we try to keep the heat in the house, it gets colder outside. "When it is so cold, we are in our cozy house with Kirli, but the birds outside are getting wet, shivering, they must be very cold, maybe the birds are dying." He started to feel sad thinking out loud. When his father came home in the evening, he shared this thought with his father and told him that he wanted to build a birdhouse, how he would provide thermal insulation while building the birdhouse, and that he wanted to do the thermal insulation in the least cost and in the best way. His father supported Robert and said, "You can make it by thinking the shapes you see at school. You also learned how to find the areas of these shapes and you can use these area connections when calculating the cost." Also, there are many endangered birds in our country. You can make the birdhouse we built for one of those birds. Robert asked his father the name of one of these birds. His father said that the name of this bird was shearwater bird. Can you help Robert to build a birdhouse for the shearwater bird?'

Figure 4.2. Robert's 'story time' slide: The Story of Robert and Kirli

Robert wrote the story in a PowerPoint slide with catchy figures. In this way, the students could read the story. Also, in microteaching, one of the pre-service teachers in the class read the story. Therefore, a more interactive learning environment was created. As seen, Robert used the story about birds and there was a real-world problem that needed an engineering design. The problem was appropriate for all students because it did not contain stereotypes. Also, before this problem, showing video and talking about birds caught students' attention. Moreover, the problem has two criteria which are 'in the least cost' and 'the best way'. By looking at these criteria required in the problem, we can say that there is not a single solution to the problem and that the students were supported to find different solutions. There can be multiple birdhouse designs.

To summarize, Robert's second lesson plan consisted of a real-world problem that encouraged all students and had multiple solutions.

4.1.2.3 Engagement in Engineering Design

In the main activity, the students were expected to design a birdhouse. However, there were some criteria for this designing process. The birdhouse skeleton must contain at least two of the shapes they learned in the previous lesson which are square, rectangle, triangle, and parallelogram. The birdhouse must be environmentally friendly, cost-effective, and aesthetic. The students were expected to take these criteria into account when presenting their design. Thus, the students must consider the cost, function and aesthetics while designing their birdhouse which is an engineering level of thinking process. Also, the students can use sticks and playdough for design model; that is, they can create a design, analyze it and redesign. Robert's lesson plan consisted of an engineering design. With this real-world problem and engineering design, students are expected to develop STEM skills.

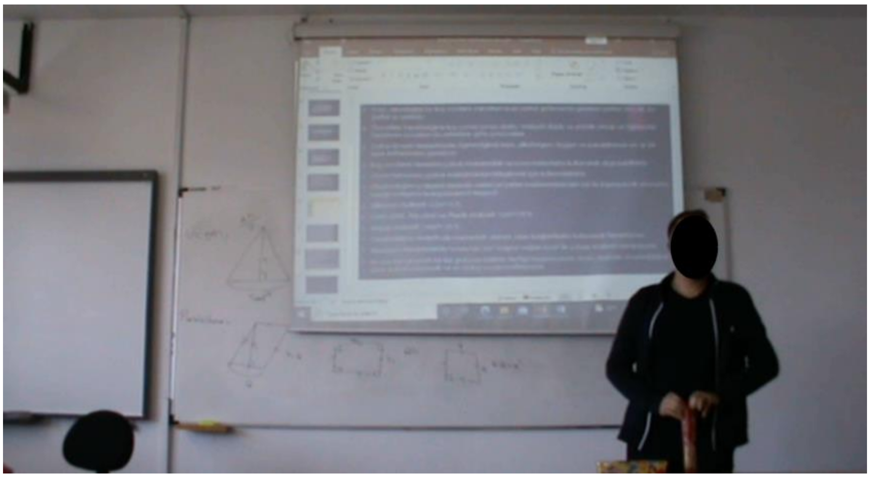


Figure 4.3. Robert gives his fellow pre-service teachers the materials (spaghetti pasta and playdough) they need to create an engineering design (birdhouse design).

Robert stated that he had difficulty in choosing the materials for engineering design. He asked for feedback on whether spaghetti pasta was the right decision. A straw was suggested by the pre-service teachers, but since they would also need to use scissors for the straw, it was decided that it was riskier to do an activity with scissors for the 6th grade students. For the connection points of the spaghetti pasta, Robert thought of playdough. Instead of using play dough, Styrofoam was suggested as a material. One of the participants in the class suggested Styrofoam and wooden sticks. She stated that this duo is more suitable as it is both fragile and easy to penetrate the foam. However, the possibility of students hurting each other due to the pointed ends of the wooden sticks was discussed. They thought that it might be difficult to hold the spaghetti pasta with play dough. Meanwhile, the cost of Styrofoam and where it is sold was discussed and it was decided that although it is easy to use for the lesson, Styrofoam is a difficult material to obtain. Also, marshmallow was suggested, however, his option was eliminated due to the possibility of students eating the marshmallow. At the end of the discussion about materials used in the activity, it was decided that wooden sticks and play dough were appropriate if the ends of each wooden stick needed to be cut before the lesson. As it can be seen, in the microteaching, Robert and the other participants had a discussion about what the best material for the STEM lesson plan was.

Robert received very positive feedback about the second lesson plan. Oscar (one of the pre-service teachers in the class) said:

> ‘I like the context, the introduction part, and the real-world problem. The only question I have is the design part. Whether students will have difficulties during the engineering design or not is questionable.’

On the other hand, the majority stated that if solid and correct material is used, students can do the birdhouse design without difficulty.

At the end of the microteaching, one group presented their birdhouse design. The presentation is shown in Figure 4.4.

> ‘We thought of the birdhouse as a pyramid. Since the area of the triangle would be less than the square, we wanted to reduce the cost by cutting the area. So, we made the side parts triangular and the base square.’

When we look at the group's birdhouse design, it is seen that they used two geometric shapes. Therefore, it was decided in the class discussion that it would be difficult to use all geometric shapes students have learned and therefore it was decided to limit the engineering design criterion to use at least two geometric shapes.

Figure 4.4. One of the groups present their birdhouse design made with spaghetti pasta and playdough.

The group presented their design and defended their material choose.

> 'When choosing materials, we first looked at whether they were harmful to the environment and eliminated plastic. We eliminated wood for the exterior because of the risk of burning. We were undecided between silicone wool and rock wool, but we decided that silicone wool was better since it costs the least. If we were going to choose thermal insulation material for the exterior. We thought that by making the inside wooden and outside silicone, we could provide two-sided insulation and eliminate the risk of burning.'

Sarah said they considered the risk of fire and the low cost. She also explained that they concluded that it is better to have a bilateral bedding.

Moreover, in the first interview Robert did not mention any challenges about engineering integration. While preparing the lesson plan, when asked, "Which of the four disciplines was the most challenging to integrate into the lesson plan?" Robert identified engineering as the most difficult discipline to incorporate. According to him, choosing the materials and organize the children in the lesson are the challenging parts.

> ‘I think it is a bit difficult to do engineering with children and integrate it into the lesson plan. I will do something, but how will I do it, what material will I use, will it be suitable for children or not? For example, my material was pasta. Will children eat pasta or not, it breaks quickly, which one is more elegant, which one is easier, which one is more difficult, which one is more instructive. These are engineering fields. There are some difficulties in the field of engineering.’

In summary, although Robert successfully integrated engineering design into his lesson plan, he stated that he had the most difficulties in this area while preparing his lesson plan. Moreover, looking at the lesson plan, we can say that Robert applied the engineering design criterion in the lesson plan.

4.1.2.4 Scientific Inquiry

In an STEM lesson, students should think like a real-life scientist. They should ask questions, create a hypothesis, and test this hypothesis. In Robert’s lesson plan, the students designed a model; however, it is questionable that they used scientific inquiry since students did not create the hypothesis and collect data. On the other hand, the main reason for designing birdhouse was thermal isolation. Robert initiated the lesson by introducing a topic that students had previously covered in their science class, which was thermal insulation. By incorporating a subject from science into the mathematics class, he encouraged students to consider the interconnections between different disciplines. In that context, Robert prepared a lesson plan in which science and mathematics were clearly integrated.

Science objectives used in Robert's STEM lesson plan are as follows:

F.6.4.3.2. Students should be able to determine the selection criteria of thermal insulation materials used in buildings.

F.6.4.3.3. Students should be able to develop alternative thermal insulation materials.

F.6.4.3.4. Students should be able to discuss the importance of thermal insulation in buildings in terms of family and national economy and effective use of resources.

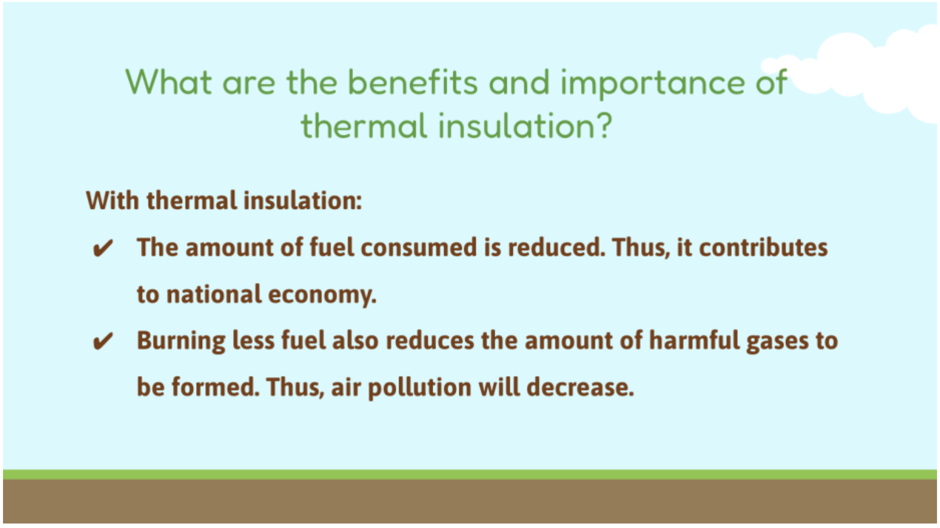


Figure 4.5. The slide Robert used in the lesson about thermal insulation.

Figure 4.6. Robert talking about thermal insulation during microteaching.

Robert informed his classmates about thermal insulation. He asked where we use thermal insulation in daily life, what is the importance of thermal insulation, and what are the benefits of thermal insulation. He asked them to think a little before answering. Robert thought that since the 6th grade students worked on this topic in the science course, they would not have any problems in answering. The answers were thermos, windows in houses, and sheathing system in buildings. Robert gave positive feedback to these answers. It was explained that in a house with thermal insulation, there would be no extra costs for heating: ‘Thermal insulation prevents energy loss, when we consider the heating in houses, the prices paid are reduced thanks to thermal insulation.’ The dialog that took place during microteaching is given below:

> Robert: Where do we encounter thermal insulation in daily life?
>
> Oscar: It is used in double glazing. For example, if it is cold outside, it does not let this cold in.
>
> Emma: Thermos

> Sarah: Thermal insulation prevents energy and cost loss. If there is sheathing on the outside of the house, the cost spent for heating decreases because it traps the heat inside.

In addition, in the main activity, students were expected to design a birdhouse for a bird. For the choice of bird, Robert suggested that it would be nice to choose an endangered bird species and at the same time give information about endangered animals. The participants liked this idea and Robert choose shearwater bird. This also drew attention to the topic that students learnt in the 5th grade science course.

Science objectives used in the Robert's STEM lesson plan are as follows:

F.5.6.1.1. Students should be able to question the importance of biodiversity for natural life. Students should be able to give examples of plants and animals that are extinct or in danger of extinction in our country and in the world.

Moreover, according to the Robert's answers in the interview, in the preparation process, at first, he did some research and find the context. Robert did not mention any difficulties about science. For him, science and mathematics can be considered together.

> 'It is easier to integrate science into the lesson plan than other disciplines because mathematics and science are intertwined. There can be no science without mathematics. Therefore, it is easy to integrate those two fields.'

According to Robert, since mathematics and science are intertwined, it is easier to integrate science into the STEM lesson plan than other disciplines.

In summary, Robert thought that it was easy to establish the relationship between science and mathematics and he successfully integrated science into his STEM lesson plan. However, the lesson plan lacked the elements of generating hypotheses, collecting, and analyzing data. This can be seen as a deficiency in the scientific inquiry criterion.

4.1.2.5 Technology Use in STEM Lessons

By using technology as a tool in the STEM lesson plan, students should be taught that technology is a facilitating tool in real life. In addition, the teacher should give students the chance to develop technological literacy. In this part, the answer to the question of how Robert uses technology in his STEM lesson plan is explained in detail.

In Robert's lesson plan, technology was used as a tool. For example, he used smart board to show PowerPoint slides and videos about birds to catch students' attention. For a more detailed explanation, Robert started the lesson by showing two interesting videos. He used the smart board to watch the videos.

Figure 4.7. The slide Robert used in the lesson to introduce videos.

Figure 4.8. The birdhouse construction video that Robert showed during microteaching as an introduction to the lesson.

In addition, Robert continued the lesson with a PowerPoint presentation on the smart board in which he organized the flow of the lesson and prepared a presentation suitable for the students. For these applications, he actively used technology in the preparation process of the lesson plan. Robert's use of a pre-prepared presentation rather than a traditional whiteboard demonstrates the ease of incorporating technology into teaching mathematics. However, it's worth noting that while technology was used as a teaching tool, it didn't necessarily engage students in active learning or encourage them to use technology in their own learning processes. Since the students did not use technological tools themselves and saw that Robert did not make much use of technological materials during the lesson, it can be concluded that the lesson plan was not sufficient to develop technological literacy. Moreover, feedback was given during microteaching on this topic. After Robert finished lecturing in class, he was given the idea that engineering design would be much better done in a technological environment rather than by hand. However, this idea could not be realized as there were no computer rooms in the school to provide a computer for each student. Therefore, the lack of technology in the school affected the integration of technology in Robert's lesson plan.

Moreover, according to Robert, technology integration is a must in a mathematics lesson plan. He stated that he knows the importance of GeoGebra activities in mathematics lessons since he took 'Exploring Geometry with Dynamic Geometry Applications' course. Robert said, 'Technology should be used not only in STEM lesson plans but also in regular lesson plans.' In the first interview, it is evident that Robert is knowledgeable about using GeoGebra in mathematics lessons, as he mentions that he would use GeoGebra when asked about preparing a STEM lesson plan. This highlights his familiarity with incorporating technology into teaching mathematics.

It can be said that technology integration was not sufficient in Robert's lesson plan although he said that technology integration is essential and necessary.

4.1.2.6 Mathematical Thinking

In STEM education, students need to be able to see where mathematics will appear in their daily life. Robert started his lesson with an objective students learned in science course. During the lesson, students were presented with a problem statement that deviated from classic mathematics questions they were accustomed to. Instead, the problem required mathematical thinking to solve real-world problems related to science, such as designing a birdhouse using shapes they had previously learned, including rectangles, squares, triangles, and parallelograms. This approach encouraged students to apply mathematical concepts in a practical context.

Before the problem-solving process, Robert reminded the students of the area of rectangle, square, triangle and parallelogram shown in Figure 4.9. He asked how the areas of rectangle, square, triangle and parallelogram are found and the properties of these geometric shapes.

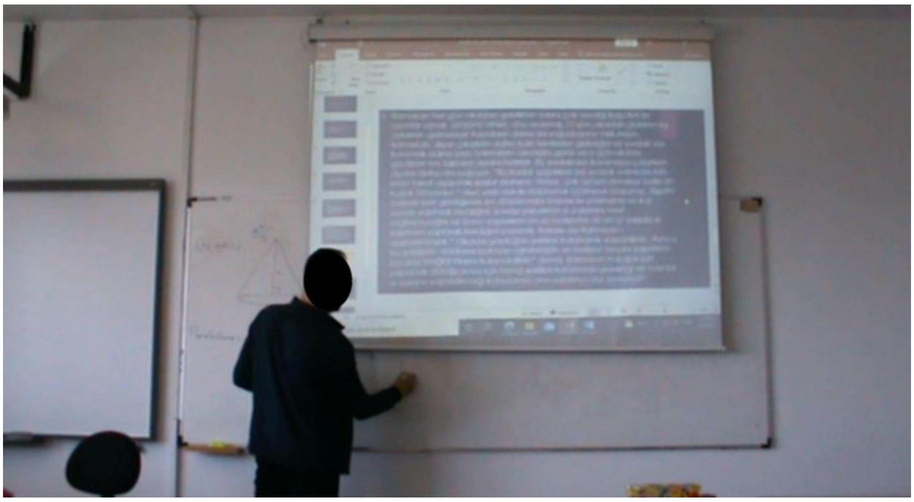


Figure 4.9. Robert reminding the area of geometric shapes students learned.

Moreover, the birdhouse needed to have a low cost. To calculate the cost, the students needed to find the area of the birdhouse they designed. Students could use the rulers to calculate the area of the exterior of the skeleton they designed. After calculating the areas, students needed to calculate the cost of the insulation material they have chosen, using the prices given per cm^2.

Figure 4.10. The slide used by Robert to explain the criteria.

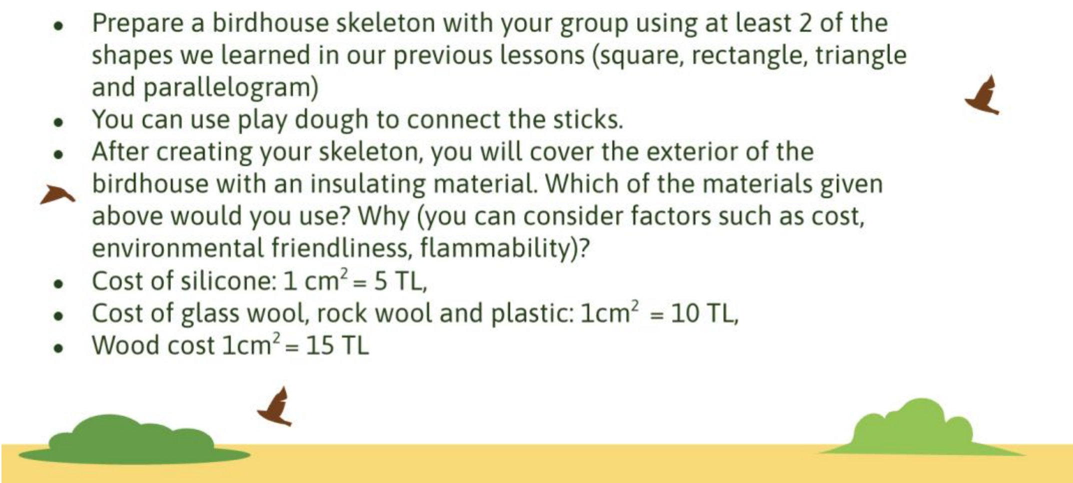


Figure 4.11. The slide used by Robert to explain the criteria.

During microteaching, the suggestion was made to Robert to prepare an activity sheet so that the students could see the criteria in the PowerPoint better and not have to look at the board all the time. The feedback about using activity sheet is given below.

> ‘How the students develop mathematical thinking from the beginning to the end of the lesson should be on the activity sheet. In other words, the paths to follow in the main activity in the lesson and the process used to create the design should all be on the activity sheet. The use of activity sheets is necessary so that both the student and the teacher can see what the student is doing in the lesson. Students learn to note his/her own progress and at the end of the lesson, the students should be left with what they have done in the lesson.’

Based on this feedback, Robert prepared an activity sheet while teaching at the internship school. The activity sheet contained the information in Figure 4.11 and Figure 4.12. There was also space for students to write their solutions. Thus, the students had the information they needed for the activity and did not have to look at the smart board all the time.

Furthermore, during his microteaching session, Robert did not specify a particular type of bird in the problem statement. This led to a discussion about whether students should design a birdhouse for a single large bird species or for multiple birds. Such variability in the problem statement made it challenging to determine which birdhouse design would be more optimal and meet the given criteria in the final presentation. Based on feedback received, it was suggested that specifying a single bird species for the birdhouse design would make the problem more manageable and allow for easier evaluation of designs. Consequently, Robert decided to focus on the endangered shearwater bird for his lesson plan. This decision aimed to simplify the problem and facilitate meaningful discussions during the lesson.

The students were expected to calculate the area of the exterior of the skeleton designed using a ruler. They measured the side lengths of the exterior of the birdhouse they designed with a ruler and calculated the area of the shapes they used with the values they found. After calculating their areas, they were expected to calculate the cost of the insulation material they have chosen, using the prices given per $1cm^2$. Cost of silicone: $1cm^2$=5 TL, Glass wool, Rock wool and Plastic cost: $1cm^2$=10 TL, Wood cost: $1cm^2$= 15 TL. The students made mathematical area calculations with the measurements of their own designs and calculated the cost. This was an appropriate activity for the objective Robert chose. In Robert's lesson plan, he presented a problem situation that required students to calculate the area. Since the answers would vary based on students' unique designs, they would encounter multiple instances of area calculation. This problem complexity necessitated a clear application of mathematics. In alignment with the lesson's objectives, students engaged in problem-solving that specifically involved finding areas. Robert's approach illustrates his commitment to integrating mathematics concretely into his lessons, fostering an environment where students start to question the presence of mathematics in other disciplines.

Moreover, Robert's thoughts on the integration of mathematics into STEM education changed during the data collection process. In the first interview, according to Robert, the easiest discipline to integrate STEM education was mathematics. He stated that integration of mathematics was not difficult because his field of study is mathematics, and he prepared lesson plans according to mathematics objectives. Additionally, for Robert, incorporating mathematics into a science context is straightforward because science and mathematics are inherently interconnected. He expressed, "You are already doing it based on mathematics, so it is easy to integrate mathematics." This perspective highlights the seamless integration of mathematics into science, emphasizing their natural synergy. On the other hand, in the second interview, Robert stated that it might be difficult to see mathematics in all disciplines and therefore it was not easy to integrate mathematics to the STEM lesson plans. Also, according to Robert, while giving place to other disciplines, it might be challenging to give enough space to mathematics. However, after implementing the lesson plan with the students, he thought that using mathematics was not particularly challenging. According to Robert, when presenting a STEM lesson plan, he often focused on activities related to topics that students are already familiar with.

> 'Since I did the activity after the lesson, it felt a bit like a repetition. It was easier when I explained the lesson and did the activity. I also think that we touched on mathematics enough, both of my teachers said that I touched on it enough, and it is a little difficult to integrate mathematics in STEM education.'

Since Robert did not teach a new mathematical objective from scratch, for him, integrating mathematics was not difficult and he satisfactorily integrated mathematics into the lesson plan.

4.1.2.7 Content Integration

All disciplines should be clearly visible in the STEM lesson plan and the link between disciplines should be clear. When we examined the four disciplines one by one in Robert' lesson plan, although technology integration was weak; science, mathematics and engineering were clearly presented to students. Also, the connection between these three disciplines was handled smoothly. In the lesson, students tried to solve a science problem using mathematics and engineering design. This enabled students to see these three disciplines separately and at the same time to use them all together.

To conclude, it can be said that Robert was successful in the integration of three disciplines other than technology.

4.1.2.8 Twenty-first Century Skills and STEM Careers

The problem in STEM lesson plan must have multiple entry points and solutions. Students feel free to solve the problem. The teacher can guide students but do not tell them how to solve the problem.

In Robert's lesson plan, the problem -designing a birdhouse which is environmentally friendly, cost-effective, and aesthetic- had more than one solution. The students were given the table below in Figure 4.11. Thus, they could choose one of the options in the table considering their reasoning. At the end of the lesson, the students were required to present their birdhouse designs and material choices along with the reasons for their choices. During this presentation they were required to defend their solutions, which would enable them to develop their multidimensional thinking in the face of problems in their future professions. This criterion was successfully fulfilled when students based their design presentations on evidence.

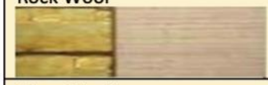
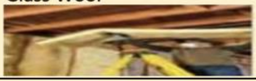
Insulation Material	Cost	Environmental Friendliness	Flammability	Cost
Plastic Foam 	low	harmful	burns easily	10 TL
Wood 	medium	harmless	burns easily	15 TL
Rock Wool 	low	harmless	fireproof	10 TL
Glass Wool 	low	harmless	hard to burn	10 TL
Silicone Wool 	very low	harmless	hard to burn	5 TL

Figure 4.12. Birdhouse Material Table in Robert's second lesson plan: insulation material, cost, environmental friendliness, combustion characteristics.

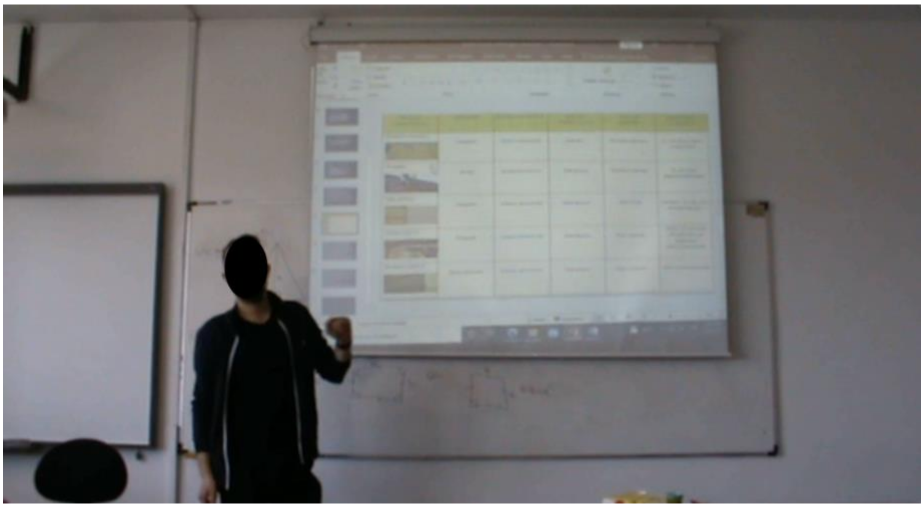


Figure 4.13. During microteaching Robert stated that he chose the insulation materials in the table according to the 6th grade science curriculum.

Therefore, when the 6th grade students see this table in the mathematics lesson, they will be reviewing what they have learned in science class, and they will see that the two disciplines are intertwined.

Furthermore, STEM lesson plan must be prepared to develop students' 21st century skills such as collaboration, critical thinking, creativity, analysis, and assessment. To achieve this improvement, STEM lesson plan should include small group work. Robert preferred group work in the lesson plan. In Robert's lesson plan, group work was written as follows:

> 'The teacher will divide the students into four groups and distribute sticks and play dough. Then the students will be asked to create a skeleton of a birdhouse, considering the criteria. The students will be given five minutes to think about the birdhouse skeleton and if they wish, they can take out paper and draw their design. They will be given twenty minutes to make their designs, calculate the areas of the shapes they use and their costs. While the students are making their designs, the teacher can walk around and answer the students' questions and give them the missing materials if the groups are missing them. NOTE: The design of the birdhouse is left to the students and the teacher should not direct the students' designs.'

Robert's second lesson plan was very different from the first one and the improvement in the second lesson plan was very clear.

Moreover, the STEM lesson plan should include a specific occupational group for students to learn about STEM careers. However, Robert did not include a specific STEM occupation in his lesson plan. A specific occupational group could have been mentioned during the problem-solving process and the students could have been informed about that occupation as one of the STEM careers.

4.2 Participant 2: Claire

In this section, the findings obtained from Claire, one of the six participants of the study, are presented under two main headings. Claire stated that she was happy to participate in this study and felt lucky to have the opportunity to prepare and implement a lesson plan for STEM education before graduating. Claire's experience on STEM education and challenges in the STEM lesson planning are examined under two main headings: Views on STEM Education and STEM Plan.

4.2.1 Views on STEM Education

In this section, Claire's answers to the questions, "What is STEM education? What is the purpose of STEM education? Do you think STEM education is important for your field? What are the stages you enjoy in your STEM activities? What are the stages you do not like or have difficulty in STEM activities?" are presented.

Claire is a participant who has heard of STEM education as a concept but has no knowledge of its content. In the beginning of this study, she did not know what STEM education stands for but thought that it is an education technique related to technology. The participant did not know the integration of engineering and science in STEM education. On the other hand, in the last interview at the end of the study, she correctly explained STEM education:

> "STEM education is an educational approach explained by the combination of science, technology, engineering, and mathematics. Teachers teach the lessons with this method. It is a system that is expected to teach children not only mathematics with the language of mathematics, but also with these disciplines. It is an interdisciplinary approach. "

While Claire never mentioned different disciplines in the first interview, at the end of the study she stated that STEM education is an interdisciplinary educational approach.

Claire stated that she did not have much knowledge, but that she thought STEM education is important for mathematics education, especially in the technology era. She emphasized that having knowledge of STEM education, especially in private schools, is considered a desirable trait among teachers, and she acknowledges that teachers show interest in this field.

In the second interview, Claire was asked about what she liked and disliked in STEM education activities. She stated that she enjoyed the intervention and realized the necessity of STEM education. According to Claire, even a student who does not like mathematics can be interested in the lesson thanks to STEM education. Since more than one discipline is intertwined, there will be at least one discipline that attracts students' attention. Claire made a point here that deserves attention. She stated that the transition between disciplines is very important. For example, the teacher should be able to move from a connection related to geography to mathematics.

In the first and the third interview, Claire was asked about the importance of STEM education. In the first interview, Claire did not know much about STEM education, and she thought it is an approach related to technology and technology integration to the mathematics lessons is important in this era.

On the other hand, after the implementation and preparing STEM lesson plan, Claire stated in the last interview that thanks to STEM education, teachers can attract students' attention and help them enjoy mathematics. In her reflection after preparing the STEM lesson plan, Claire stated that:

> ‘Every student has skills in different areas. She suggests that integrating lesson plans with various disciplines beyond just mathematics can make lessons much more interesting for each child. For example, for a child who loves and is successful in science lessons, the use of such experiments in

> mathematics lessons can be interesting, while for a student who is interested in engineering, the information about the principle of swimming a ship can be interesting. As a result of this situation, which I observed during the lesson, many more students than usual participated in the lesson. This reminded me once again how much every child needs to be explored.'

Claire observed that even students who do not like mathematics can participate in the lesson by using their interest in other disciplines and STEM education increases students' engagement in the lesson. However, according to Claire, STEM education applications are difficult in the public schools. It is not realistic for a teacher working in a public school to practice STEM education too often due to the lack of facilities in the public school, the high number of students and the curriculum that must be kept up. Claire stated that she intends to practice STEM education if she works in a private school or a school with a small number of students in the future.

In addition, Claire's responses to the questions 'What challenges did you face while implementing a STEM lesson plan? How did you expect the lesson to go? How was the lesson? Was it the way you expected?' were analyzed below.

In the first interview, Claire stated that although such different activities attract the attention of the students, it can be difficult to control the class. According to Claire, classroom management can be challenging. She stated that the implementation of STEM education can be difficult especially in public schools.

> 'In the internship, we prepared a lesson plan with GeoGebra. Although it attracted the attention of the children, after a while they lost their focus on the lesson. Although this and similar techniques have beneficial aspects, I think that if it shifts to a game a little bit, it will be difficult to focus on the subject. The implementation can be challenging because in public schools, teachers can spend fifteen minutes to make students sit again.'

In addition, Claire stated that the most important point to be considered while preparing a STEM lesson plan is the ease of application. This shows that for Claire, the difficulty of classroom management is a factor that should be considered in preparing a lesson plan.

Claire stated that if a class is doing STEM activity for the first time, it can be challenging to control the students. That is, an application that students are used to can be challenging. According to Claire, it would be easier to reinforce an application that has been made before. In the first interview, Claire mainly focused on the classroom management challenges. She stated three challenges: Staying connected to the subject in the classroom, keeping the focus on the subject, and time management. Students may lose their focus on the subject. Moreover, it can be difficult to use a method that students are not used to in a 40-minute class. Claire also talked about the importance of achievement levels of students. Depending on the success level of the class, the level of the activities may be higher for them and may not be effective no matter how good the activity is.

In the second interview held after Claire prepared the STEM lesson plan, she was asked how she expected the lesson to go in the classroom. Claire stated that she wanted the lesson to go well, and she was excited about it. She expressed her hope that STEM education, incorporating multiple disciplines, would capture the attention of all students and engage them effectively. She talked about time management among the challenges that can be experienced and the fact that students are not used to this system. Students may find STEM education different, since the lessons are normally in the form of lectures, topics being written on the board. Making a new application can be challenging. In addition, the activity she prepared may not fit in a class hour. She said she wanted time to catch up. In general, before she teaches, Claire expects the lesson to go well and the students to enjoy the lesson.

In the third interview after the lecture, Claire was asked how the lesson went. She stated that starting the lesson with an experiment video caught the attention of the students, and even the students who were not normally interested in the lesson watched the interesting experiment carefully. Therefore, Claire managed to attract the attention of the students at the beginning of the lesson. She noted that one challenge she encountered was that the questions appeared to be difficult for the students. Claire spent a lot of time helping the groups because they had difficulty in understanding the questions. Therefore, she emphasized the importance of better establishment of groups, especially when a group needs a lot of support. She stated that the lesson would have been better if she had had more time. However, at the end of the lesson, according to Claire, the students understood the subject and the lesson was successful.

4.2.2 Claire's STEM Lesson Plan

In this section, Claire's answers to the question " Would you have had any difficulties in preparing STEM Lesson Plan? Please explain your reasoning." are presented in connection with the STEM education framework. The second lesson plan that Claire prepared, the microteaching and individual interviews conducted during the lesson planning process were analyzed according to the conceptual framework of integrated STEM education (Kelley & Knowles, 2016; Roehrig et al., 2021). The challenges observed in this study were explained according to the data obtained from the interviews. To examine the difficulties Claire experienced in lesson planning, Claire's responses to the question 'What challenges did you face while preparing and implementing a STEM lesson plan?' were analyzed considering each discipline.

4.2.2.1 Description of the STEM Lesson Plan

At the beginning of the lesson, the teacher shared an experiment video on the smart board to motivate the students. In the experiment, an orange was dropped in water with and without a peel. After watching the video, the teacher summarized the factors affecting the experiment. In addition, the teacher verbally shared the scientific definition of density and the factors affecting density. Based on this discussion process at the beginning of the lesson and the results of the experiment, the teacher moved on to the middle part of the lesson by asking the students to brainstorm about "why ships do not sink and how they float in water". After listening to a few answers given by the students, the teacher shared the following information about the swimming principle of ships with the students.

After this information, the video named "Why Ships are Painted Red Below the Water Line" was shown. Then, the teacher stated the factors affecting the density and the relationship between the weight in the ship and the density of the ship. "One of the factors that affect density is mass. When we are talking about the floating principles of ships, we said that ships have less weight compared to their volume, so their density stays below 1 and they do not sink. From this point of view, if we load the ship more than the maximum weight it can carry, the ship will sink in the water as its density increases." Then, a news article on the subject was shared with the students. The article was about a ship that sank six minutes after its departure. According to the news, the factor that caused the ship to sink was "loading more than the maximum capacity of the ship".

Before starting the activity, the students were divided into groups of four. Before the groups started the activity, the teacher summarized what was expected from the groups during the activity by reading the "instructions to the captain" section. In the activity, the students were assumed to be the captain of a ship. They must solve questions about how much cargo should be loaded so that the ship does not sink. The groups were given 15-20 minutes to work together. At the end of the lesson, the groups presented their results.

The mathematics objective used in Claire' STEM lesson plan is as follows:

M.7.1.5.1. Students should be able to determine the value corresponding to a specified percentage of a quantity. Students should also be capable of calculating the total magnitude when provided with a particular percentage.

4.2.2.2 Focus on Real-World Problems

Claire's lesson plan was about the maximum amount of cargo that should be loaded on a ship. If it exceeds the maximum amount of cargo, the ship will sink. Claire’s main activity started by giving the students a real-life problem. The students were given the information that they are a ship captain working in the port and that there are four ships to be loaded to depart from the port. In line with this information, students needed to make the appropriate calculations and give the correct information about the ships to the port so that there is no sinking event. Before the main activity, Claire gave students a news article about a sinking ship.

> ‘The ship named Hayat sank six minutes after its departure from Bandırma Port. The ship, which was carrying 73 trucks and two cars, 28 crew members and more than 150 passengers, is said to have sunk due to overloading. After the accident, it was reported that about 30 people were missing and many injured. The passengers who jumped off the ship and struggled in the water were first helped by port officials and fishing boats. Many passengers swam to shore with their own efforts. Search and rescue operations that started at night are continuing at this hour. The ship was overloaded, no records were kept. One of the passengers who survived the accident said that the ship was on its side at during the loading, that the ship was overloaded to avoid the cost of transportation by road, and that records were not kept. Another passenger claimed that the ship operators overloaded the ship beyond ship’s carrying capacity for more money.’

After reading the news article, the students were informed in the main activity that they are captains at the Bandırma Port, where the accident in the news article took place and that they should take the necessary precautions to prevent other accidents like this one:

> ‘Imagine that you are a captain in this port. you are given some information about four ships that will be loaded to depart from the port in the next four

weeks. Based on this information, you need to make the necessary calculations and analysis and report all the information about these four ships to the port. Now, make the necessary calculations and do the calculations carefully to avoid any accidents ever happening again. Please review the Figure 4.14 and Figure 4.15 to complete the table.'

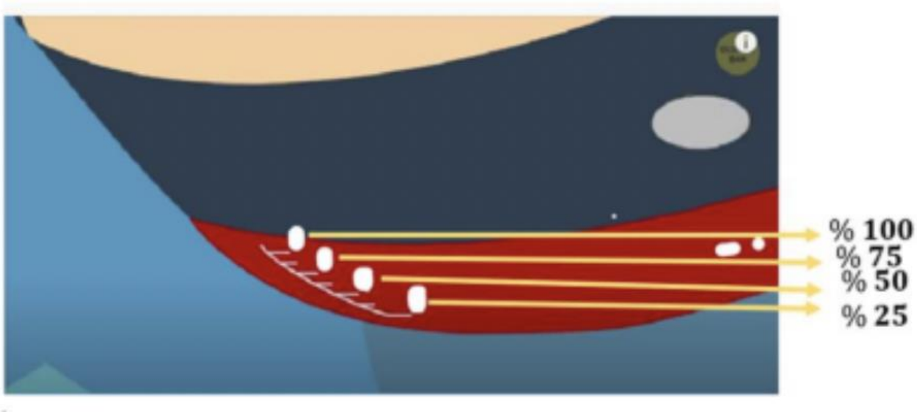


Figure 4.14. Sinking value of the ship according to the limit line and tons loaded.

800-900 Barrels	700-800 Barrels	600-700 Barrels
Low environmental sensitivity	**Medium** environmental sensitivity	**High** environmental sensitivity

Figure 4.15. Environmental sensitivity based on the ship's total fuel consumption.

Thus, Claire used a mathematics problem that required calculations to address a real-life issue, thereby preventing its recurrence. Claire's STEM lesson plan consisted of a real-world problem that encouraged all students and had multiple entry points.

4.2.2.3 Engagement in Engineering Design

In Claire's lesson plan, there was no problem situation that required students to create a design. Students were expected to fill in the table according to the data and determine the environmental sensitivity of the ship according to this table. The problem situation in the main activity did not require students to create a model. They did not need to test the design and redesign it, which is an engineering level of thinking process. Thus, Claire’s lesson plan did not meet this criterion.

To examine the difficulties Claire experienced in the field of science while preparing a STEM lesson plan, her responses to the question ‘What challenges did you face while preparing and implementing a STEM lesson plan?’ were analyzed in the field of engineering.

According to Claire, engineering is the most difficult discipline to integrate into a STEM lesson plan. Claire stated that she is a little more familiar with the science discipline because it has a lot of daily life connection. Since they took GeoGebra course, she could establish technology integration. However, for her, it was difficult to integrate engineering because she had no knowledge about engineering. Claire stated that the engineering terms were at a high level for her, and she had no interest in engineering.

4.2.2.4 Scientific Inquiry

In a STEM lessons, students should think like a real-life scientist. They should ask questions, create a hypothesis, and test this hypothesis. In Claire’s lesson plan, it is questionable whether the students used scientific inquiry since they did not create hypotheses and collect data. On the other hand, Claire’s lesson plan began with a clear science connection as she wanted to attract the attention of students with an interest in science. Claire initiated the lesson with a topic that students had previously encountered in their 6th-grade science class, with the intention of integrating mathematics into the discussion. The topic in question was density, which the students had previously studied in their science class.

The science objectives used in Claire's STEM lesson plan are as follows:

F.6.4.2.1. Students should be able to define density.

F.6.4.2.2. Students should be able to calculate the densities of various substances.

Students were required to calculate density by applying the ratio of mass to volume, which is a mathematical operation. This illustrates how mathematics is integrated into their science curriculum, where they learned about topics like density. Consequently, introducing a science topic in a mathematics class encourages students to explore the interconnections between these two disciplines. In that context Claire prepared a lesson plan in which science and mathematics were clearly integrated.

Figure 4.16. Video of an experiment showing that oranges do not sink with the peel but sink without the peel.

Claire had the idea of doing the orange experiment shown in Figure 4.16 in the classroom, but there was a risk of spilling the water and making a mess. During microteaching, she received feedback that she did not need to do the experiment herself but could show it in a video. Given that this experiment is relatable and can be easily visualized by students, it was determined that simply watching the video would be sufficient. After showing the experiment and asking students to provide explanations, Claire went on to clarify the experiment and reinforced the concept of density they learned in their science class. She explained, "Since there is more air in the peel, its density is less. In other words, the peeled orange stays on the surface because its volume is larger compared to its mass." This approach effectively connected the experiment to the scientific concept of density and helped students understand the relationship between science and mathematics in real-world scenarios.

After this experiment, Claire talked about why ships do not sink and created discussion environment in the class. To transition into the main activity, Claire introduced the concept of the red line under the ships and explained how it relates to density. This approach encouraged students to consider the factors that affect density and set the stage for the upcoming activity: "Since the weight of ships is light compared to their volume, their density is below 1. In this way, they do not sink. There is a line under the ships that shows the maximum point where they can enter the water. Even after this limit, some ships are painted in different colors. It is very important that the part entering the water does not cross that line."

In addition, in Figure 4.15, there is a table about the environmental sensitivity of the ship depending on the total fuel oil consumption. After calculating the total fuel oil requirement of four types of ships, the students were expected to classify their environmental sensitivity according to Figure 4.15. There is a topic in science curriculum about human and environment and this table makes students think about the environment like they did in the 5th grade science course. For example, if the total fuel oil requirement of the ship is 650 barrels, the environmental sensitivity of this ship due to fuel oil consumption is high.

The science objectives used in Claire's STEM lesson plan are as follows:

F.5.6.2.1. Students should be able to express the importance of the interaction between human and environment. The negative effects of environmental pollution on people's health are mentioned.

F.5.6.2.2. Students should be able to offer suggestions for solving an environmental problem in his/her immediate environment or in our country.

F.5.6.2.3. Students should be able to make inferences about environmental problems that may occur in the future as a result of human activities.

F.5.6.2.4. Students should be able to discuss benefit and harm situations in human-environment interaction on examples.

Moreover, Claire stated that she had a hard time preparing the lesson plan. She said that at one point she thought she could not handle it alone. For example, for science integration, Claire had to learn the difference between the mass and weight. She emphasized that in order not to give incorrect information to students about other disciplines, teachers should have sufficient knowledge about other disciplines. According to Claire, teachers should be competent enough to provide students with accurate information not only about their own field but also about other disciplines that are used in the STEM lesson plan and that this is a difficult process. She said that the feedback she received during microteaching in the classroom was very helpful in finalizing the lesson plan. Therefore, according to Claire, it would be more efficient and easier for more than one teacher to prepare a STEM lesson plan.

4.2.2.5 Technology Use in STEM Lessons

By using technology as a tool in the STEM lesson plan, students should be taught that technology is a facilitating tool in real life. Moreover, the teacher should give students the chance to develop technological literacy. In this part, the answer to the question of how Claire uses technology in her STEM lesson plan is explained in detail.

In Claire's lesson plan, technology was used as a tool as she used smart board to show PowerPoint slides and videos about an experiment about density and the news article about a sinking ship to catch students' attention. For a more detailed explanation, Claire started the lesson by showing an interesting video and news article. She used the smart board for showing these visuals.

Figure 4.17. Video of the second largest shipwreck in history that Claire showed during microteaching as an introduction to the lesson.

After watching the video in Figure 4.17, it was argued that the real cause of the ship's sinking was the impact it received. The relationship between mass and density was not at the forefront of this news. It was suggested that it sank faster because it was loaded with more cargo. In this way, the excess mass on the ship could be emphasized. It was then said that there was no need for such a big impact news, that there are many sinking ships in our country, especially in the Black Sea region. Claire could only use boats that sank due to excess cargo. These shipwrecks can easily be found on local news websites. If the goal is just a sinking ship, a more localized news story can also be found. In the light of this feedback, Claire used the news about a ship that sank within six minutes after setting off due to overload in the final version of the lesson plan. Therefore, she started the lesson with a news article that more clearly showed the relationship between mass and density.

Figure 4.18. Claire showing the video ‘Why Are Ships Painted Red Below the Waterline?’ during the microteaching (Explaining the relationship of the numbers below the waterline to the weight on the ship)

The video shown in Figure 4.18 explains why there are lines under ships. As the load on the ship increases, the lines go under the water to the same degree. By checking these lines, the amount of load on the ship can be calculated. The limit lines in this video are important for understanding the problem situation in the main activity.

Only video was used in the lesson plan for technology integration. Therefore, during microteaching, it was suggested to add a simulation of ships sinking as they are loaded in the lesson plan. While researching ship simulations, mainly games related to ship simulations were found. However, Claire did not include such a simulation in her lesson plan.

Moreover, Claire did not mention the discipline of technology among the difficulties she experienced while preparing a STEM lesson plan. She stated she took a GeoGebra course for technology integration and had some knowledge about it. Also, she stated that technological connections could be made by researching. However, although Claire used technology as a tool in the lesson plan during the lecture, the students did not encounter a situation that required the use of technology. Therefore, the students were not given the chance to develop technological literacy.

4.2.2.6 Mathematical Thinking

The aim of Claire’s lesson plan was to express the relationship between two multiplicities by examining real-life situations, calculate the quantity corresponding to a given percentage of a given multiplicity, and calculate the whole multiplicity of given quantity. The activity required students to calculate the percentage of the given quantities. However, Claire had concerns about the choice of topic during the preparation process. In the microteaching, Claire stated that she thought the percentage topic would be too simple in this lesson plan, so she wondered if there could be another mathematics objective. She was concerned about insufficient mathematics integration to the STEM lesson plan. However, her fellow pre-service teachers in the class stated that this topic was not actually simple, that finding percentages of given quantity was very simple for them as a mathematics teacher, but that it was a very difficult topic for a 7th grader. Therefore, Claire chose the mathematics connection.

In Figure 4.14, it can be observed that if the ship sinks up to 100% below the limit line, it is carrying the maximum weight it can handle and will sink if loaded any further. Conversely, if the ship is submerged below the limit line up to 50%, it means it is carrying only half of its maximum weight capacity. When the ship's submersion reaches 100%, it indicates that the ship has reached its maximum carrying capacity, and any additional weight will cause it to sink according to the limit line.

SHIP SELECTION CRITERIA	SHIP 1	SHIP 2	SHIP 3	SHIP 4
The Maximum Carrying Capacity of The Ship	....	....	....	....
The Amount of Sinking Depending on Tons	For every 9000 tons, 25% of the ship sinks	There are 36000 tons of cargo on board while 40% of the ship is unsinkable	With 39000 tons of cargo on board, 75% of the ship sank.	When loaded at two-fifths of the carrying capacity, the ship has 16000 tons of cargo and 60% of the ship is unsinkable

Figure 4.19. Table of the maximum carrying capacity of the ship and the amount of sinking depending on tons.

Figure 4.19 is one part of the main activity. The students were expected to find the total carrying capacity of the ship according to the sinking percentage of the ship. For example, in the second ship scenario, if 40% of the ship is still above water and it's carrying 36,000 tons of cargo, it means that 60% of the ship has already sunk with that cargo load. Here, the students needed to find the relationship between the sinking percentage and the amount of cargo on board and find the total carrying capacity of the ship. In the first ship scenario, with every 9,000 tons of cargo, if 25% of the ship sinks, the maximum carrying capacity of the first ship is 36,000 tons. This part of the table focuses on finding the total capacity of the ship when a specific percentage of it sinks, which is the main mathematical objective of the lesson plan.

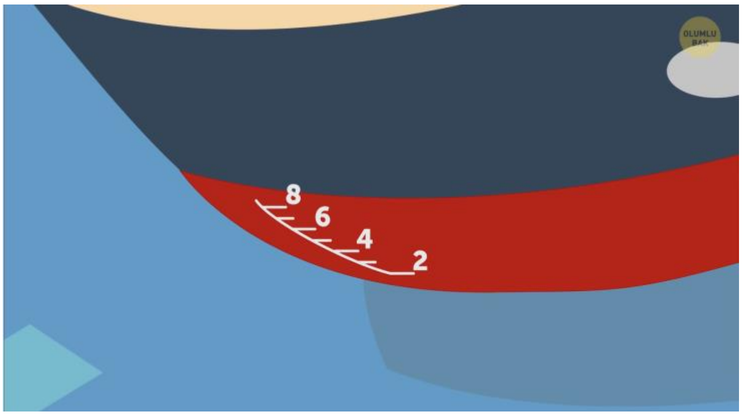


Figure 4.20. An image from the video 'Why Are Ships Painted Red Below the Waterline?' (The relationship of the numbers below the waterline to the weight on the ship)

Claire used Figure 4.14 in her activity sheet. In the original version of this image (Figure 4.20), the limit lines are numbered with 2,4,6 and 8. Claire preferred to use the concept of percentages instead of these numbers since percentages are the subject matter. That is, when the ship is loaded, if the limit line of 25% is sunk, the ship carries a weight of 25% of the maximum amount of cargo that can be loaded. The ship can still be loaded up to 75% of its maximum capacity. However, Claire was concerned that the term 100% sinking used in the activity could be confused with the sinking of the entire ship. She defined 100% as when the ship reaches the top of the limit lines at the bottom of the ship. In order to avoid this confusion for the students, she explained the term 100% used in the activity at the beginning of the activity and during group work.

Claire believed that although the activity was aligned with the learning objective, it may have been too challenging for the academic level of the students. She stated that if the students' mathematics achievement was better, the activity would proceed more easily. She suggested that it would be better to update the lesson plan with easier questions.

Claire stated that when she started the lesson with science, she was afraid that the students would be surprised and react as if this is not a mathematics course.

Therefore, she had to make the connection between disciplines very clearly. Claire emphasized that making the connection between mathematics and other disciplines is crucial, as it enables students to discover that mathematics is intertwined with various fields. For Claire, the mathematics connection in the STEM lesson plan needs to be clear. She stated that it is very important for students to see the mathematics in the lesson since this activity is done within the mathematics course, and that she had difficulty in making this connection. Especially during the lesson plan preparation process and microteaching, Claire stated that she made the science connection but could not make the transition from there to mathematics. For Claire, the process of preparing a STEM lesson plan starts by first selecting a science discipline and designing an engaging experiment. She liked this content and thought about which mathematics objective she could connect it to and decided on percentages. However, she stated that making the mathematics connection is very challenging for her and that the feedback given during microteaching was very helpful.

Although Claire had a hard time making mathematics connections in her lesson plan, the STEM lesson plan actually includes mathematics problems that align with the objectives. The main activity of the lesson is all about percentage problems. Therefore, Claire successfully integrated mathematics into the STEM lesson plan.

4.2.2.7 Content Integration

All disciplines should be clearly visible in the STEM lesson plan and the link between disciplines should be clear. When we examine the four disciplines one by one in Claire's lesson plan, although technology integration was weak; science and mathematics were clearly presented to students. On the other hand, there was no engineering design in Claire's STEM lesson plan. Considering only mathematics and science disciplines, the connection between these two disciplines was handled smoothly. In the lesson, the students tried to solve a problem situation which involved science by using mathematics. This enabled students to see these two disciplines separately and at the same time to use them all together.

To conclude, it can be said that Claire is successful in the integration of two disciplines other than technology and engineering.

4.2.2.8 Twenty-first Century Skills and STEM Careers

The problem in STEM lesson plan must have multiple entry points and solutions. Students should feel free to solve the problem. The teacher can guide students but does not tell them how to solve the problem. In Claire's STEM lesson plan, the students could fill in the table in the main activity in any order they wanted. There was no order for this. Furthermore, the mathematics questions in the activity did not have a single solution. The students could solve them by thinking as a ratio, as a fraction, or as a percentage.

Furthermore, an STEM lesson plan must be prepared to develop students' 21st century skills, including collaboration, critical thinking, creativity, analysis, and assessment. To achieve this improvement, an STEM lesson plan should include small group work. Claire included group work in her STEM lesson plan. In the main activity, the students worked in groups of four. Claire stated that she constantly observed the groups during the lesson. However, some of the groups did not understand the questions and the activity, which Claire described as challenging. In this case, Claire gave guidance to the groups without giving the exact answers. She also supported these students by having each group work as a team, encouraging students who had found the solution to explain it to their peers who were still struggling. In this way, the importance of teamwork was emphasized. To prevent this kind of problem in the future, according to Claire, the groups should be formed by the teacher in advance, considering that the success level of each group is equal. In this way, group work can be effective for all students.

An STEM lesson plan should include a specific occupational group for students to learn about STEM careers. In her STEM lesson plan, Claire asked the students to imagine that they were a ship captain and to solve the problem by thinking like a ship captain. As a ship captain, the students needed to make appropriate calculations in order to avoid any sinking accidents. There were also issues of fuel consumption and environmental awareness that they needed to think about as captains. In this way, it was ensured that the students learned about a professional group and solved the problems that they may encounter in this profession utilizing their STEM skills. Claire's STEM lesson plan effectively cultivates problem-solving and decision-making skills, exemplified by the role of the ship captain. Therefore, it can be said that her lesson plan successfully fulfills this criterion.

4.3 Participant 3: Sarah

In this section, the findings obtained from Sarah, one of the six participants of the study, are presented under two main headings. Sarah participated in the study because she was interested in innovative approaches in mathematics education. She was excited and enthusiastic to learn more about STEM education. Sarah’s experience in STEM education and challenges in the STEM lesson planning are examined under two main headings: Views on STEM Education and STEM Plan.

4.3.1 Views on STEM Education

In this section, Sarah’s responses to the questions, "What is STEM education? What is the purpose of STEM education? Do you think STEM education is important for your field? What are the stages you enjoy in your STEM activities? What are the stages you do not like or have difficulty in STEM activities?" are presented.

Sarah is a participant who has heard of STEM education before and knows what it stands for. She stated that STEM education is an educational approach in which different disciplines are taught together. Sarah preferred to use the term STEAM which stands for science, technology, engineering, art, and mathematics. Different from the other participants, Sarah added art as the fifth discipline.

Sarah was asked about the importance of STEM education for mathematics education. Sarah mentioned the mathematical modelling course she took before and her experience in that course. She stated that she encountered a mathematical problem based on the refraction of light, which is the subject of the science lesson, and was impressed by it. Sarah highlighted the significance of integrating different courses within STEM education, emphasizing how this approach directly addresses the question of where mathematics is applied in various contexts. Consequently, STEM education can provide students with a clear understanding of the real-world situations where mathematics is encountered in their daily lives.

In the last interview, Sarah gave a similar response:

> 'I think STEM education is important for mathematics education. In the future, students will become engineers and will deal with mathematics in a different way. They will get into situations where they have to use mathematics in the future. I do not think that memorizing direct rules has much effect on children. Life does not require memorization of rules. We need to solve real-life problems in mathematics. I also think that if we are going to prepare students for real life, we should ask real-life problems. That is why, STEM education is important.'

Sarah argued that mathematics lessons incorporating real-life problems are more impactful on students compared to traditional mathematics education. She emphasized that students would encounter mathematics in nearly every aspect of their lives, and teachers have a responsibility to prepare them for this reality.

In the first interview, Sarah said that the purpose of STEM education is to provide combined information from different disciplines. On the other hand, in the third interview, Sarah stated that STEM education is important not only for mathematics education, but also for raising people with the necessary skills for society.

> 'STEM education is an approach that today's society and technology need. Due to the lack of skills among engineers entering the workforce, there's a growing need to develop these skills in students, especially in a society and technology landscape that is constantly evolving. Education must adapt to meet these changing needs.'

Sarah stated that STEM education is more than just an educational technique used in schools. In order to adapt to developing technology, it is necessary to provide students with skills appropriate for society and STEM education helps to achieve this.

Sarah argued that among the enjoyable aspects of STEM education is learning new things. A teacher should have knowledge about other disciplines when preparing a STEM lesson plan and it can be enjoyable for the teacher to learn more about other disciplines. From a student perspective, students enjoy group work and discovering new knowledge. Sarah stated that from what she observed in the internship, there is generally direct teaching in schools and STEM education can be different and fun for students.

After implementing the STEM lesson plan in the internship class, Sarah was asked how the lesson went. Sarah stated that she was generally satisfied with the lesson, but she had some difficulties. She stated that the students did not understand the problem situation in the activity because they did not read it, so she wasted time in that part. Therefore, Sarah had time management problems in the lesson. She also stated that it was not an effective group work because the students were not used to group work. On the other hand, Sarah had no difficulty in controlling the groups since she had support from her fellow pre-service teachers during the lesson.

For Sarah, for an effective group work in the class, group work should be explained to the students. What group work is, what is expected from the students and what needs to be done for an effective group work should be clearly explained to the students. Sarah could have formed the groups better if she knew the students in the class well enough. When Sarah randomly formed groups, she found it challenging to keep students who were close friends within the same group focused on the task. In addition, the students had difficulty in making calculations and therefore had difficulty in moving on to the main objective. Sarah stated that she would have let the students to use a calculator. However, their teacher did not allow the students to use a calculator in class. According to Sarah, while fluency in mathematical operations is important, using a calculator for tasks like finding the perimeter of a circle is acceptable, especially when students are encountering this type of activity for the first time. She believes that STEM education would be more effective if students were more familiar with it.

Sarah also stated that STEM education provides students with different skills. She stated that it is very effective for students to learn to work together. During Sarah's STEM lesson, one student helped the other friends in the group, so they learned from each other, and peer learning was effective. According to Sarah, STEM education can also increase the participation of students who do not normally participate in mathematics lessons. A student who is prejudiced against mathematics may be interested in science integration or art integration in the STEM lessons. Their interest in mathematics lessons can be increased by using their interest in different disciplines. Sarah explained this by giving an example from her experience:

> 'A student in the class who normally never participated in the lesson participated in the lesson because he is good at science. He felt confident and participated in the mathematics lesson. So, STEM education is a good exercise when we want to involve all the students in the class. Some children

can draw pictures, but they have no interest in mathematics. We can integrate art to the mathematics lessons to gain their interests.'

According to Sarah, STEM education is a way to overcome the prejudices of students who struggle with mathematics. Students' success in different disciplines can be used and they can realize that mathematics is actually within the disciplines they love.

4.3.2 Sarah's STEM Lesson Plan

In this section, Sarah's response to the question, "Would you have had any difficulties in preparing a STEM Lesson Plan? Please explain your reasoning." is presented in connection with the STEM education framework. The second lesson plan Sarah prepared, the microteaching and individual interviews conducted during the lesson planning process were analyzed according to the conceptual framework of integrated STEM education (Kelley & Knowles, 2016; Roehrig et al., 2021). The challenges observed in this study are explained according to the data obtained from the interviews. To examine the difficulties Sarah experienced in lesson planning, Sarah's responses to the question 'What challenges did you face while preparing and implementing a STEM lesson plan?' are analyzed considering each discipline.

4.3.2.1 Description of the STEM Lesson Plan

The lesson plan aimed to give students a problem situation about the perimeter of the circle. At the beginning of the lesson, the teacher asked who is riding a bike to attract students' attention and prepare them for the activity. Then, the video called 'The Working Principle of The Bicycle' was shown. In this video, the effect of gear on pedaling and the gear system on the bicycle are explained. The Working Principle of The Bicycle is also explained in the activity sheet distributed to the students. After watching the video and making sure that the students understood the working principle of the bicycle, the main activity was started. In the activity, students worked as a group. The students were told that they are engineers who work in a bicycle company, and they needed to produce a new bicycle model. They were asked to design a new bicycle model to travel long distances with little cost and little effort. The students were expected to design the bicycle (wheel and gear system) by using the table given in the activity sheet and choose the ideal one for their criteria. After the students created the bicycle design, they answered some related questions. They needed to find the distance based on the wheel diameter and gear ratio. They calculated the distance that the bicycle they designed would take. At the end of the lesson, each group shared their design according to the given criteria with their classmates.

The mathematics objective used in Sarah's STEM lesson plan is as follows:

M.6.3.3.3. Students should be able to solve problems that require calculating the perimeter of a circle given the diameter or radius.

4.3.2.2 Focus on Real-World Problems

Sarah's lesson plan began by explaining the working principle of the bicycle. The students needed to understand the gear system of the bicycle in order to find the distance traveled by the bicycle and make the gear selection.

> 'When bicycles were first produced, they worked directly on human power. In other words, when we pedaled once, we could only travel as far as the perimeter of the wheel. Simple machines (pulley, gear, etc.) that we use to reduce human effort and make our lives easier appear as gears in the working mechanism of bicycles. With this gear system, we are now able to travel more for perimeter the wheel when pedaling once. The diameter ratios of the cogwheel in the gear system and the ratio of the number teeth on the cogwheel

> of on them are equal. The ratio of pedaling speed and number of gears directly affects the speed of the bicycle, the energy expended, and the distance traveled. Depending on the slope of the road, the effort spent by the person while pedaling may increase or decrease. The driver can reduce the gear ratio to reduce the effort. The large gear ratio makes it challenging for the driver when going uphill.'

After explaining the working principle of the bicycle and the formula to be used in the problem, Sarah moved on to the real-life problem situation in the activity.

> 'A famous bicycle company brings young engineers together with a competition for a new bicycle model to be produced. The company asks engineers to design the bicycle's gear system and wheel structure in accordance with their criteria. The new bicycle they produce must be low in cost and can travel long distances with little effort. It is expected that the bicycle, which has only one gear for an easy use by everyone, will be a product for teenagers and adults. Using the given information shown in Figure 4.21 and Figure 4.22, you are expected to answer the following questions. By answering these questions, you will calculate and decide on the wheel diameter and gear ratio of the bike. Please consider the criteria the company asks of you and show your work clearly. You must defend your choice.

As seen, Sarah's lesson plan included a math problem about bicycle design and the working principle of the bicycle. Sarah's STEM lesson plan consisted of a real-world problem that encouraged all students and had multiple entry points.

4.3.2.3 Engagement in Engineering Design

Sarah's STEM lesson plan required the students to design new bicycle. The students were given two tables shown in Figure 4.21 and Figure 2.22. They were expected to consider these tables in their decision-making process. Also, the problem required some criteria. The new bicycle must be low in cost and travel long distances with little effort. The students were expected to take these criteria into account when presenting their design. They had to consider the cost and the gear ratio while choosing their bicycle design, which is an engineering level of thinking process. Sarah's lesson plan consisted of an engineering design. With this real-world problem and engineering design, the students were expected to develop STEM skills.

Wheel Diameter (cm)	Estimated Production Cost
61 cm	2.140 TL
66 cm	2.560 TL
70 cm	4.370 TL
71 cm	5.130 TL
74 cm	6.260 TL

Figure 4.21. Wheel diameter of bicycles produced and the estimated production cost.

Gear Ratio (Front/Back)
4,82
4,08
3,79
2,65
2,30
1,71
1,47

Figure 4.22. Gear Ratios table Sarah used in the activity sheet.

In Sarah's STEM lesson plan for microteaching, she expected from her fellow pre-service teachers to design and draw bicycles for the wheel diameter of their choice. However, since it would be difficult for 6th graders to draw a bicycle in one class hour, Sarah did not include a bicycle drawing task in the final version of the lesson plan. Through feedback in microteaching, it was decided that a bicycle drawing could be added to this lesson plan if it was to be implemented in long duration. The bicycle drawing would allow the students to show their designs concretely and add art discipline to the lesson plan.

In the microteaching, Henry's group presented the first group's bicycle design. They choose the wheel diameter of 61 cm, which is the most appropriate when considering the economic conditions. Also, Henry mentioned that the price increases a lot when the wheel diameter increases. For example, when the wheel diameter increased by 10 cm, the price tripled. For this reason, 61 cm was the cheapest. In addition, Henry stated that they chose the middle one in the gear ratio (2.65). He stated that as the gear ratio increases, the force the rider consumed increases. Therefore, they did not choose the one with the largest gear ratio. A bicycle with the 4.82 gear ratio would be difficult to use. That is why, Henry's group chose 2.65 to be an average value. Their bicycle design is shown in Figure 4.23.

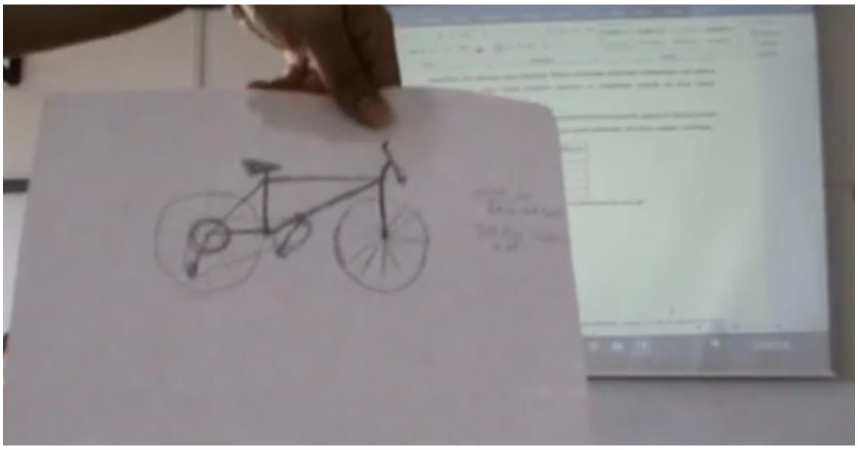


Figure 4.23. The first group's bicycle design.

Oscar presented the second group's bicycle design. They chose a wheel diameter of 66 cm because there is a 5 cm increase from 61 cm to 66 cm and the price has only increased by 420 TL. On the other hand, when the wheel diameter is 70 cm, the price almost doubles. According to Oscar, when they considered the ratio, they thought that 66 cm is the most suitable. Oscar stated that they chose the wheel ratio of 2.65 in order not to have difficulty when climbing. He also stated that the ratio of 4.82 would be better for long distance, but they wanted to choose a model for daily use. Their bicycle design is shown in Figure 4.24. They have also designed a windbreak in front of the bicycle.

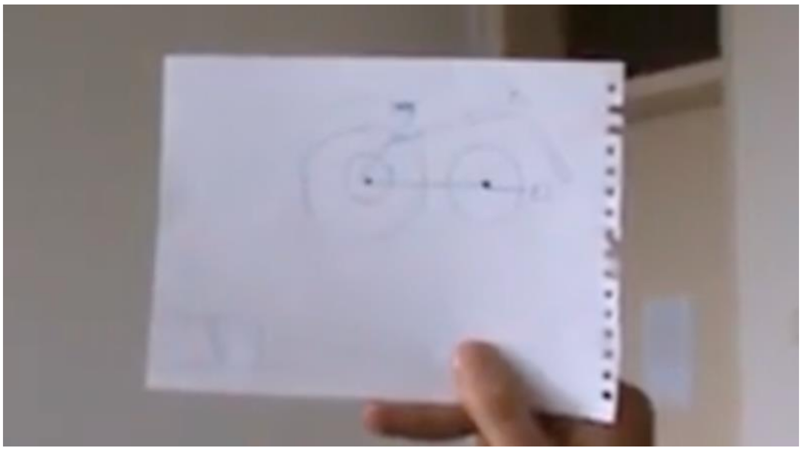


Figure 4.24. The second group's bicycle design.

Gina presented the third group's bicycle design. Gina stated that her group chose wheel diameter of 66 cm, similar to the second group, because there was not much difference between 66 cm and 61 cm in terms of cost. They thought it was more appropriate to choose 66 cm. Moreover, they chose a gear ratio of 2.30. Gina stated that since they increased the wheel diameter by 5 cm, they could choose the gear ratio smaller. Their bicycle design is shown in Figure 4.25.

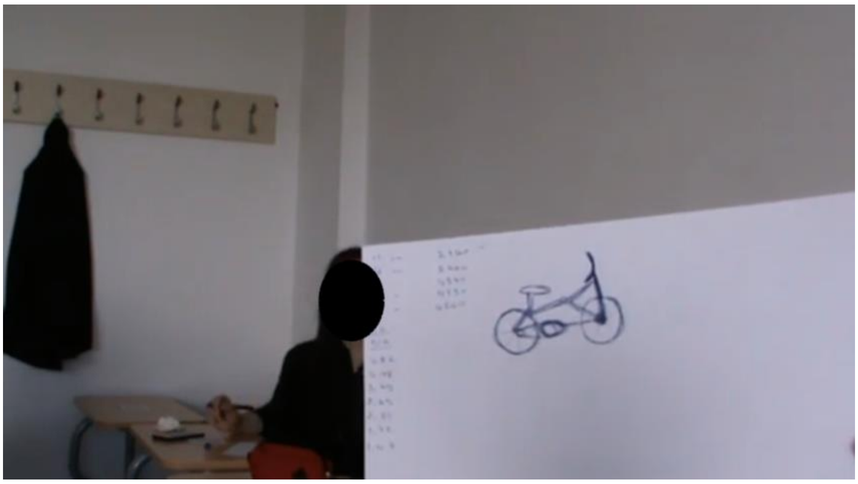


Figure 4.25. The third group's bicycle design.

Sarah stated that while lesson planning, she enjoyed thinking about different disciplines together, however it was challenging for her to reduce the activity to the students' level. Sarah prepared an activity to develop critical thinking skills at engineering level. The students were expected to prepare a bicycle model according to the given criteria. This shows that Sarah applied the engineering design criterion in her STEM lesson plan.

4.3.2.4 Scientific Inquiry

In a STEM lesson, students should think like a real-life scientist. They should ask questions, create a hypothesis, and test this hypothesis. In Sarah's lesson plan, it is questionable whether they made a scientific inquiry since students did not create any hypotheses and collect data. On the other hand, Sarah's lesson plan began with a clear science connection. Sarah started the lesson with the working principle of a bicycle and showed a video about it. This video was actually about gear wheels. It explained gear wheels with a bicycle example. Cogwheels are the subject of 8th grade science lesson. Sarah showed the bicycle mechanism that is relevant to her lesson instead of watching the whole cogwheels because students will see simple machines and cogwheels in detail in 8^{th} grade science course.

The science objectives used in Sarah's STEM lesson plan are as follows:

F.8.5.1.1. Students should be able to explain the advantages of simple machines through examples.

a. From simple machines, the focus is on the fixed pulley, the movable pulley, the pulley, the lever, the inclined plane, and the spinning wheel.

b. It is indicated by visuals that gear wheels, screws and pulleys are also simple machines.

c. It is emphasized that there is no gain from work in simple machines.

F.8.5.1.2. Students should be able to design a mechanism that will provide ease of work in daily life by utilizing simple machines.

Sarah thought that this content was appropriate for 6^{th} graders because students encounter simple machines in daily life. In her reflection in the lesson plan, she noted that almost all the students used bicycles and that this topic was of interest to them.

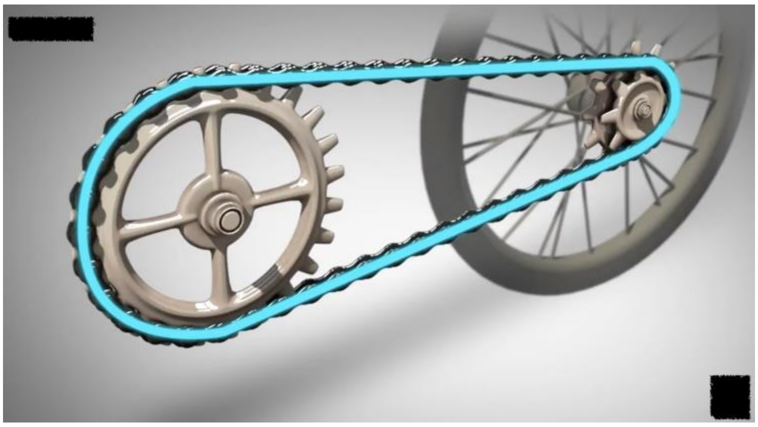


Figure 4.26. An image from the gear wheels video.

Mathematics is used in the working principle of the bicycle and the distance the bicycle travels. To find the traveled distance a bicycle takes, students need to use the circumference of the circle they learned in mathematics lesson. Thanks to the explanation at the beginning of Sarah's STEM lesson and the information written on the activity sheet, the students could clearly see mathematics in the science discipline.

In addition, the aim was to help students discover mathematical formulas through the guiding questions given to the students, which were explained in detail in the mathematical thinking section. The students needed to examine the relationship between variables like a real-life scientist.

When Sarah was asked about the lesson planning process in the second interview, she said that it was easy to prepare a context. Sarah did the science integration first and then made the mathematical connection. She also stated that the discipline she integrated most easily into the STEM lesson plan was science.

4.3.2.5 Technology Use in STEM Lessons

By using technology as a tool in the STEM lesson plan, students should be taught that technology is a facilitating tool in real life. Also, the teacher should give students the chance to develop technological literacy. In this part, the answer to the question of how Sarah uses technology in her STEM lesson plan is explained in detail.

In Sarah's lesson plan, technology was used as a tool such as she used smart board to show PowerPoint slides and the video about the working principle of a bicycle to catch students' attention and to give information about the activity. For more detailed explanation, Sarah started the lesson by showing an interesting video. She used the smart board to show the visuals.

There was no video component in Sarah’s draft lesson plan. She planned to explain the working principle of the bicycle verbally. However, during the microteaching she received feedback that the working principle of the bicycle should be understood by the student because it forms the basis of the activity. Therefore, it was thought that the visual effect of this presentation could be enhanced. During the lesson, Sarah’s fellow pre-service teachers searched for an appropriate video. It was decided that the video was necessary and sufficient to understand the subject. Based on this feedback, Sarah added the video shown in Figure 4.27 to the lesson plan.

Figure 4.27. The working principle of a bicycle video that Sarah showed during microteaching.

Except for the video Sarah used at the beginning of the lesson, she did not integrate technology into the STEM lesson plan. She did not use technology sufficiently during the lesson. As the students themselves did not use technology, they did not witness teacher's use of technology adequately. Therefore, it can be said that there was no technology integration in Sarah's lesson plan.

4.3.2.6 Mathematical Thinking

Sarah started the lesson with the working principle of bicycle. In this section, students needed to understand the effect of the gear diameter ratio and the number of pedaling cycles on the rotation of the wheel because they were expected to design a bicycle based on these variables. Sarah also aimed to help students discover that the distance traveled on a bicycle is related to the perimeter of a circle. She explained this in the activity sheet as follows: ‘At this point, we can express the distance traveled as the number of rotations of the wheel times the perimeter of the wheel.’

Sarah's activity sheet included the number of turns of the wheel:

> ‘The number of rotations of the wheel depends on the number of pedal turns and the ratio of the diameter of the front and rear gears. This means that when we turn the pedal one time, the rear gear and therefore our rear wheel will rotate by this ratio. We can express this with a formula:
>
> $\frac{diameter\ of\ the\ front\ gear}{diameter\ of\ the\ rear\ gear}$ x the number of pedaling = the number of rotations of the wheel
>
> Depending on the slope of the road, the effort spent by the person while pedaling may increase or decrease. The driver can change the gear ratio by downshifting to reduce the effort. A large gear ratio makes it difficult for the driver when going uphill.’

The students were expected to solve the question given in activity sheet with this information. The number of rotations of the wheel is an equation and the students should think about how changes to the variables may affect the equation. This part is important for understanding the variables and the equation. By giving these formulas, Sarah encouraged students to think critically.

In the first version of Sarah's lesson plan, there was a mathematical connection problem. That is, students were expected to design a bicycle that met the given criteria. Therefore, during microteaching, Sarah was asked what the planned objective was. Sarah's chosen objective was the perimeter of a circle in 6^{th} grade, but there was no activity related to the perimeter of a circle in the lesson plan. It was then concluded that Sarah needed to make the mathematics connection in the lesson plan more clearly.

For example, the first question in the activity sheet was as follows: 'What does an increase in wheel diameter mean?'. The expected answer to this question is that as the wheel diameter increases, the traveled distance by the wheel increases depending on the diameter. As the wheel diameter increases, the distance traveled by the bicycle increases. Based on the circumference formula ($\pi R = \pi$ x diameter $= 2\pi r$), the distance traveled depends on the diameter of the bicycle. Since the distance traveled depends on the diameter/radius of the bicycle, as the wheel increases, the distance traveled by the bicycle also increases. This question aims to help students for better understand the perimeter of circle and establish the relationship between diameter and circumference. Therefore, Sarah reinforced the target objective with this question.

The second question in the activity sheet was as follows: 'What does an increase in the gear ratio mean?'. The expected answer to this question is the greater the gear ratio, the greater the distance the bicycle travels in one pedal rotation. Therefore, when the gear ratio increases, the number of rotations of the wheel increases. Increasing the gear ratio increases the number of rotations of the wheel. The aim of this question was to interpret the number wheel rotation given above and to make the students explore the relationship between the gear ratio and the distance traveled.

Then, on the activity sheet, there was a question about the traveled distance: 'How many pedaling cycles it takes for your bicycle to cover a distance of 500 meter?' With this question, the students were expected to apply the circumference relation they have discovered. Also, each student solved this question for the bicycle of his/her own design. This allowed the students to see more than one solution to a single question and see the features of the bicycle they designed. First, the students needed to calculate the distance the wheel travels in one pedal stroke. They needed to do this by finding the circumference of the wheel and the number of rotations the wheel makes in one pedal stroke. The distance the wheel travels in one pedaling cycle is equal to the gear ratio. Multiplying the gear ratio by the circumference of the wheel (πR, R is the wheel diameter) gives the distance the wheel travels in one pedal stroke. Similarly, students calculate how many meters the bicycle they designed will travel in 200 pedaling cycles.

Sarah established the integration of mathematics in the STEM lesson plan more clearly with the questions she added after the bicycle design. Therefore, Sarah has successfully fulfilled this criterion in her STEM lesson plan.

4.3.2.7 Content Integration

All disciplines should be clearly visible in the STEM lesson plan and the link between disciplines should be clear. When we examine the four disciplines one by one in Sarah' STEM lesson plan, it can be stated that although technology integration was weak; science, mathematics and engineering were clearly presented to the students. Also, the connection between these three disciplines was handled smoothly. Moreover, in the first version of Sarah's STEM lesson plan, there was a drawing of a bicycle, which Sarah also thought of as an art integration.

To conclude, it can be said that Sarah was successful in the integration of three disciplines other than technology. Sarah successfully integrated multiple disciplines into her STEM lesson plan.

4.3.2.8 Twenty-first Century Skills and STEM Careers

In a STEM lesson plan, it's important for the problem to have multiple entry points and solutions so that students can approach it freely. While the teacher can provide guidance, they should refrain from simply telling students how to solve the problem. This encourages students to think critically and problem-solve independently. In Sarah's STEM lesson plan, there was a part for designing a bicycle. The students were expected to design a bicycle, using Figure 4.21 and Figure 4.22. The students could choose one of the options in the table considering their reasoning. In microteaching, three group chose three different designs. Therefore, this part of the activity had more than one solution. At the end of the lesson, the students were required to present their designs with the reasons for their choices. During this presentation, they were required to defend their solutions, which would enable them to develop their multidimensional thinking in the face of problems in their future professions. This criterion is successfully fulfilled if students base their design presentations on evidence.

Furthermore, STEM lesson plan must be prepared to develop students' 21st century skills such as collaboration, critical thinking, creativity, analysis, and assessment. To achieve this improvement, STEM lesson plan should include small group work. Sarah included group work in her STEM lesson plan. In the main activity, the students worked in groups of four. Sarah stated that since some students were in the same group with their closest friends, it was challenging to control them. If she knew the students better, she formed a group by taking this situation into account. Sarah mentioned that she encouraged teamwork among her students by assigning them to work in groups. In this collaborative setting, she also encouraged students who had successfully reached a solution to explain it to their peers who were still working on it. This approach emphasized the importance of teamwork.

The STEM lesson plan should include a specific occupational group for students to learn about STEM careers. In her STEM lesson plan, Sarah asked the students to imagine that they were an engineer and to solve the problem by thinking like an engineer. As an engineer, students needed to make appropriate calculations. In addition, the activity showed that being an engineer is not gender specific. Both male and female students can become an engineer. Thus, Sarah's STEM lesson plan met this criterion.

CHAPTER 5

DISCUSSION

The results of the present study, which aimed to examine pre-service mathematics teachers' experience in STEM education and challenges in the lesson planning process, are discussed in this section, based on the previous studies in the literature. Then, implications for educational practices and recommendations for further research are presented.

5.1 Discussion

Within the scope of the research question, the findings related to the experiences of the three pre-service mathematics teachers in STEM education and the challenges they faced in lesson planning were determined within the characteristics of the conceptual framework of integrated STEM education (Kelley & Knowles, 2016; Roehrig et al., 2021). These findings will be discussed in relation to each characteristic, including a focus on real-world problems, engagement in engineering design, scientific inquiry, technological literacy, mathematical thinking, content integration, twenty-first-century skills, and STEM careers. This discussion will involve comparisons between the participants and related studies in the literature.

5.1.1 Views on STEM Education

As a result of the study, it was determined that all three participants had positive opinions about STEM education and thought that STEM education is important for mathematics education. Parallel findings were reported by Rifandi et al. (2020). A great majority of the participants in Rifandi et al. (2020) study argued that STEM education is necessary for learning. Similar to the study by Özbilen (2018), in this study, the participants stated that STEM education is important for their field. All three participants believed that it would be beneficial for them to graduate by learning STEM education. This finding resonates with the conclusions drawn by Pimthong and Williams (2021), Wijaya et al. (2022), and Zhang and Zhu (2023), emphasizing the inclusion of STEM education activities in teacher education programs. Furthermore, participants in the study expressed satisfaction with creating a STEM lesson plan at the end of the study, which is consistent with the statements of Lewis et al. (2021) and Sian Hoon et al. (2022) that STEM education activities strengthen pre-service teachers' self-confidence.

The participants' knowledge about STEM education differed at the beginning of the study. Claire had heard of STEM education by name but had no knowledge about its meaning. She thought that STEM education was only a technology-supported education approach. Robert had heard of STEM education before and knew what it stands for. Sarah, on the other hand, knew what STEM education stands for and that it is an interdisciplinary educational approach. This result in the current study is in parallel with the study conducted by Yıldırım (2017) with pre-service science teachers.

Macit and Aslaner (2019) stated that teachers also had negative opinions on group work in the classroom. Similarly, in this study, it was concluded that the participants had concerns about time management in STEM lessons. All three participants reported having difficulty in controlling time during the lesson. While Robert and Claire did not have time management problems, Sarah stated that she could not perform the last part of the activity. In addition, in this study, the participants stated that it is not realistic to implement STEM education for every subject. These results support the study of Kurtuluş et al. (2017).

In the present study, participants conveyed that their STEM knowledge and awareness exhibited notable improvement following the STEM activity intervention. This outcome aligns with the findings of Berisha and Vula (2021), who contended that the STEM workshop had a beneficial impact on enhancing the STEM knowledge of pre-service teachers. Consequently, the findings of the current study align closely with those of Berisha and Vula (2021).

5.1.2 STEM Lesson Plans

The participants were asked to prepare two STEM lesson plans within the course. The lesson plans prepared by all three participants after the STEM education practices were different from the first lesson plan they prepared. While their first lesson plans did not have an interdisciplinary approach, their second lesson plans had at least two disciplines integrated. They also included group work in their second lesson plans. Since the participants' first lesson plans were not applicable for STEM education, their second lesson plans are analyzed in detail in the previous chapter. As a result, all the participants developed their lesson plans in a period of four months. Their STEM lesson plans are discussed in light of the findings reported in the previous chapter.

5.1.2.1 Science, Technology, Engineering and Mathematics

In this study, the data obtained from the participants are examined from three distinct dimensions: views, design, and implementation.

All three participants in this study added real-world problems to their STEM lesson plans. In addition, all three participants stated that STEM education is a good way to integrate real-life problems into the mathematics lesson so that there is a direct answer to the question of where mathematics is encountered in daily life. Supporting the study of Çorlu et al. (2014), the current study also concluded that STEM education offers opportunities for daily life applications. Furthermore, as Ceylan and Karahan (2021) point out, the real-world problems used by the participants in their STEM lesson plans involve more than one discipline.

Two of the participants (Robert and Sarah) successfully integrated engineering design into their lesson plans. Robert included a model design activity with the use of materials in his lesson plan. Students had the opportunity to test the robustness of their designs. They were also expected to design according to the given criteria. Robert's lesson plan supports the statement of Özdemir (2016) that the letter E in STEM education also stands for designing. Similarly, Sarah expected the students to design according to the criteria. Unlike Robert, Sarah did not have a concrete design in her lesson plan. Claire, on the other hand, did not include engineering design in her lesson plan. When the three participants are compared, Robert seems to be the most successful in engineering design. Consistent with the findings of Maiorca and Mohr-Schroeder (2020), who scrutinized STEM lesson plans crafted by pre-service teachers, two out of three participants in the present study effectively incorporated engineering concepts into their lesson plans. Despite the participants' collective view that integrating engineering was a challenging endeavor, their performance in designing and executing the lesson plans demonstrated their proficiency in this aspect.

In terms of the challenges experienced, all three participants indicated that engineering was the most difficult discipline to integrate into STEM education. This aligns with the observations made by Chai et al. (2020), as pre-service teachers in this study likewise encountered considerable difficulty when attempting to incorporate engineering into their STEM lesson plans. Particularly, Claire explicitly acknowledged her struggle to integrate engineering, citing her limited knowledge in the field of engineering as the primary obstacle, a sentiment that echoes the findings of Chai et al. (2020).

All three participants in the study started their STEM lesson plans with science integration. They integrated the topics the students have learned or will learn in the science course into their lesson plans. When the challenges experienced were evaluated, two of the participants stated that the integration of science was the easiest. They stated that it was easy to connect science and mathematics because the science course uses mathematics. On the other hand, Claire stated that she had difficulty in science integration. According to Claire, her lack of expertise in the field of science could lead to misconceptions, and she feels the need to have a solid understanding of science before attempting integration. The challenges experienced by Claire support the statement of Nadelson et al. (2012). In addition, Claire's proposal supports Lawson et al.'s (2021) statement that different disciplines should plan STEM education together.

Different from the study of Özdemir (2016), the participants only thought of science course as science integration into STEM lesson plans. According to Özdemir (2016), the letter S in STEM education also covers other sciences such as social sciences, literature, and music. However, in this study, the participants only integrated the science course and answered the science integration questions by thinking about the science course.

At the beginning of the study, the participants argued that technology integration is very important for mathematics education and that the use of technology is necessary in our age. However, it was observed that technology integration was weak in all three lesson plans. As for the use of technology, the participants added videos and presentations on the smart board to their lessons. However, according to McCulloch et al. (2018) and Baki (2023), the use of smart boards is not sufficient for technology integration in mathematics courses and teacher should have knowledge about integrating technology into their lessons. Since the participants did their internship in a public school, they prepared their lesson plans in accordance with the school conditions. For example, Robert wanted to have the students design in a digital environment instead of using sticks and play dough. However, there was no computer room in the public school. Claire and Sarah stated that the students were not used to technology integrated lessons. This result supports the study of Tondeur et al. (2013).

There were similarities as well as differences between the current study and the study by Şahin and Kabasakal (2018). Before preparing the STEM lesson plan, the participants stated that GeoGebra could be used in the STEM lesson plan. They mentioned the benefits of concretizing abstract concepts, visualizing them and increasing student interest by giving GeoGebra as an example of technology integration. This result is in parallel with the results of the study by Şahin and Kabasakal (2018). On the other hand, none of the participants used GeoGebra in their STEM lesson plans, and their technology integration was weak. Despite recognizing GeoGebra as a valuable STEM resource, much like Şahin and Kabasakal (2018), they did not incorporate it into their lesson plans. Instead, they relied on internet sources as their primary form of technology integration, echoing the observations made by Jocius et al. (2021). In harmony with the findings of Chai et al. (2020), this study's participants exhibited shortcomings in technology integration, underscoring the inadequacy of pre-service teachers in seamlessly incorporating technology into their lesson plans due to their limited technological proficiency.

Furthermore, the participants' weak technology integration aligns with Jocius et al.'s (2021) argument that pre-service teachers should bolster their technological skills. Interestingly, although the participants expressed favorable opinions about the potential of GeoGebra in mathematics lessons, they failed to incorporate it into their lesson plan designs. They attributed this omission to the perceived challenges of implementing GeoGebra in public schools, suggesting that the underlying reasons for the technology integration deficit warrant further exploration. Among these factors, the participants' limited GeoGebra skills may be a contributing factor. Additionally, during the initial interview, the participants concentrated solely on technology in their STEM lesson plan designs. However, they experienced a shift in perspective following the intervention, recognizing the significance of science and engineering disciplines. This shift may have overshadowed the importance of technology integration, with participants focusing more on science and engineering in their STEM education designs. Consequently, the reasons underlying the lack of technology usage in STEM lesson plans may be attributed to either a dearth of technological knowledge or a greater emphasis on other STEM disciplines.

In the current study, the participants successfully integrated mathematics into their STEM lesson plans. They stated that they had difficulties in making mathematics visible in other disciplines during the preparation process. In Sarah's draft STEM lesson plan, mathematics integration was weak. She strengthened the mathematics integration in her lesson plan according to the feedback she received in microteaching. Robert and Claire stated that the transition from other disciplines to mathematics should be set clearly and explicitly. Claire expressed her concern about potential student reactions, fearing that they might perceive the lesson as something other than mathematics. This underscores the significance of establishing robust interdisciplinary connections, a concern that resonates with findings from the study conducted by Sian Hoon et al. (2022). Despite the limited exposure to STEM activities, all three participants exhibited remarkable dedication to enhancing their proficiency in STEM education.

According to the participants in this study, thanks to STEM education, students go beyond the usual mathematics education and thus their thinking about mathematics can be positively affected. This result can be considered an example of making mathematics enjoyable, as noted by Tatar et al. (2013), and Sümen and Çalisici (2016). Furthermore, in alignment with the assertions of Anderson et al. (2020) and Bartels et al. (2019), the participants contended that STEM education proves to be an effective mode of learning.

5.1.2.2 Context Integration and the 21st Century Skills

The participants in the study prepared a lesson plan integrating at least two disciplines. Each of them made the connection between mathematics and science. Robert and Sarah integrated engineering as well as mathematics and science. Sarah wanted to include art in her lesson plan as well; however, she did not do this due to potential time constraints. Claire integrated science and mathematics and did not include other disciplines. Although the participants stated that technology integration was very important, they did not integrate it into their STEM lesson plans.

In this study, a result supporting the studies of Aykan and Yıldırım (2021), Altan and Ucuncuoglu (2019), Lawson et al. (2021), and Durmuş and Alpkaya (2019) was obtained. Claire stated that she had a lot of difficulty in preparing STEM lesson plans and that she had difficulty in making interdisciplinary connections. According to Claire, the feedback she received during microteaching facilitated her lesson plan preparation significantly. She also suggested that it might be better to get support from teachers of different disciplines. Thus, in the current study, it was concluded that it was more effective for the teachers to prepare their lesson plans together.

All of the participants emphasized the importance of students developing new skills while preparing STEM lesson plans and included group work in their STEM lesson plans. In addition, Sarah and Robert expected the groups to present their designs and defend their answers at the end of the lesson which aimed to develop 21st century skills. This result supports the studies by Aydeniz (2017), Wijaya et al. (2022), and Zhang and Zhu (2023).

Two participants included a professional group in their STEM lesson plans. Claire asked the students to imagine that they were a ship captain and Sarah asked the students to imagine that they were engineers. Sahin (2020) also argues that STEM education should offer students the opportunity to recognize professional groups.

5.2 Implications of Educational Practices

In this section, implications based on the findings are presented, aligning with the research's goal of exploring pre-service mathematics teachers' views, experiences, challenges, and recommendations concerning STEM education and lesson planning.

Since STEM education practices are still considered new in our country and open to development, educational stakeholders need to be informed about the integration processes of such activities. The current study has some implications for teachers, school managements, the MoNE, and teacher educators.

The study's findings indicated that the pre-service teachers who took part in the research felt a sense of fulfillment in creating STEM lesson plans. This satisfaction contributed to their growing sense of competence as they approached graduation. Furthermore, their experiences suggested a reduction in students' biases against mathematics lessons and an increase in student engagement. Thus, it has been observed that the motivation of pre-service mathematics teachers and their willingness to discover and apply innovations in mathematics education have increased. In this respect, including elective or must courses related to STEM education in teacher education programs can help teachers become educators who are open to innovation and development. Considering the results of this study, it is recommended to increase the number of studies that provide opportunities for teachers and pre-service teachers to practice STEM education.

The study highlighted the challenges the participants faced when creating STEM lesson plans, and it emphasized the value of the feedback they received during microteaching. Therefore, it is recommended to incorporate activities that foster the development of a teacher's vision for STEM education, allowing teacher candidates to learn from their own experiences in pre-service teacher education programs. These experiences can enhance their preparedness for teaching in STEM-focused classrooms.

In this study, it was concluded that three pre-service mathematics teachers' perspectives and knowledge of STEM education improved even with only four STEM education applications. If awareness about STEM education can be raised even in such a short time, providing opportunities for teachers to actively participate in STEM education activities and organizing STEM education practices will also be beneficial for the development of prospective mathematics teachers. Moreover, all participants stated that they had difficulties because they were not used to interactive lessons. In the research, it was concluded that STEM education practices may be more effective and easier if students regularly encounter STEM education applications.

STEM education is inherently interdisciplinary, and teachers must possess knowledge in the disciplines they plan to integrate into their lessons. This study has revealed that the participants faced challenges when attempting to effectively integrate other disciplines into their STEM lesson plans. In this respect, it would be beneficial to cooperate with other departments in the school. With the cooperation of all branch teachers in schools, joint training can be given to raise the awareness of interdisciplinary approach. In line with these results, teachers should be encouraged to carry out their activities by creating a collaborative working environment and receiving financial and moral support from school management at the school level and the MoNE at the national level.

The participants were inadequate in technology integration due to the inadequacy in public schools. In addition, crowded and small classes were determined as compelling factors for the participants. Therefore, improving the physical characteristics of public schools and providing students with opportunities to improve their technological literacy may be facilitating factors for STEM education practices. The MoNE and researchers can develop strategies to overcome the lack of equipment needed to implement STEM activities and teachers' lack of knowledge about STEM education for better mathematics education.

5.3 Recommendations for Further Studies

The present study focused on the pre-service mathematics teachers' experiences in STEM education and challenges they faced in planning STEM lessons. In this part, in line with the research results, suggestions for future research are presented.

Since the current study was conducted with a limited number of pre-service mathematics teachers, similar studies aiming to investigate teachers' experiences in STEM education can be done by increasing the number of participants. Future research could also focus on STEM education experiences of teachers with different years of experience and use action research as a possible design.

This study focused on the challenges the pre-service teachers faced in STEM lesson planning. By conducting in-depth research on the STEM lesson practices of teachers or pre-service teachers in the classroom, information on the problems in practice can be obtained.

An important point of consideration for future research is the need for more in-depth exploration of the specific challenges pre-service teachers face in each discipline when preparing STEM lesson plans. While participants in this study mentioned the disciplines they found most and least challenging, a more comprehensive analysis could yield richer insights. To address this, future studies could employ more detailed questioning or provide specific examples to gather more nuanced data regarding the difficulties encountered in each discipline. Moreover, data collection tools can be developed in future studies. The data collection tool of the current study was semi-structured interviews. It may be recommended to conduct similar studies using the mixed design, including qualitative and quantitative data collection tools to obtain richer data.

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APPENDICES

A. Semi-structured Interview Questions

The First Interview Questions

1. Have you heard of the STEM education before?

2. What is STEM education?

3. Do you think STEM activities are important for your field, why?

4. Have you participated in STEM activities before? If so, tell us about your experiences?

5. What are the stages you enjoy in your STEM activities?

6. What are the stages you do not like or have difficulty in STEM activities?

7. What challenges can be encountered while preparing a STEM related lesson plan, why?

8. Which discipline do you give priority to when preparing a STEM activity, why?

The Second Interview Questions

1. Do you think STEM activities are important for your field, why?

3. What are the stages you enjoy in your STEM activities?

4. What are the stages you do not like or have difficulty in STEM activities?

5. What challenges did you face while preparing a STEM related lesson plan, why?

6. Which discipline do you give priority to when preparing a STEM activity, why?

7. which discipline was easy to integrate to the STEM lesson plan, which discipline was difficult to integrate in the STEM lesson plan, why?

8. How do you expect the lesson to go?

9. What difficulties might you encounter during the lesson?

The Third Interview Questions

1. What is STEM education?

2. Do you think STEM activities are important for your field, why?

3. Did the lesson go as you expected?

4. What difficulties did you face during the lesson?

5. How did you handle the difficulties you faced in the lesson?

6. Are there any areas in the lesson plan you prepared that you would like to change or improve, what are they?

7. When you start teaching after graduation, would you use it in STEM education your classes, why?

B. METU HUMAN SUBJECTS ETHICS COMMITTEE APPROVAL

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
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14 OCAK 2022

Konu : Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi : İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Doç.Dr. Didem AKYÜZ

Danışmanlığını yürüttüğünüz Büşragül Çelik KAYA'nın "İlköğretim Matematik Öğretmen Adaylarının STEM Eğitimine Yönelik Görüşlerinin ve Ders Planlama Sürecinde Yaşadıkları Zorlukların İncelenmesi" başlıklı araştırmanız İnsan Araştırmaları Etik Kurulu tarafından uygun görülmüş ve **0018-ODTUİAEK-2022** protokol numarası ile onaylanmıştır.

Saygılarımızla bilgilerinize sunarız.

Prof.Dr. Mine MISIRLISOY
İAEK Başkan

C. CONSENT FORM

ARAŞTIRMAYA GÖNÜLLÜ KATILIM FORMU

Bu araştırma, ODTÜ Matematik ve Fen Bilimleri Eğitimi Bölümü Yüksek Lisans öğrencisi Büşragül Çelik Kaya tarafından Prof. Dr. Didem Akyüz danışmanlığındaki yüksek lisans tezi kapsamında yürütülmektedir. Bu form sizi araştırma koşulları hakkında bilgilendirmek için hazırlanmıştır.

Çalışmanın Amacı Nedir?

Araştırmanın amacı, ilköğretim matematik öğretmen adaylarının STEM eğitimine yönelik görüşlerinin ve ders planlama - uygulama sürecinde yaşadıkları zorlukların incelenmesidir.

Bize Nasıl Yardımcı Olmanızı İsteyeceğiz?

Araştırmaya katılmayı kabul ederseniz sizlerden STEM eğitimine yönelik ders planı hazırlamanız beklenecektir. Ders planı hazırlanma sürecinin öncesinde, sonrasında ve ders planı uygulamasının ardından sizlere düşünceleriniz ve deneyimlediğiniz zorluklarınız sorulacaktır. Bu görüşmeler çevrimiçi ortamda (Zoom Meeting Application) yapılacaktır. İçerik analizi ile değerlendirilmek üzere ses kaydı alınacak ve görüşmeler çevrimiçi ortamda kayıt altına alınacaktır.

Sizden Topladığımız Bilgileri Nasıl Kullanacağız?

Araştırmaya katılımınız tamamen gönüllülük temelinde olmalıdır. Çalışmada sizden kimlik veya kurum belirleyici hiçbir bilgi istenmemektedir. Cevaplarınız tamamıyla gizli tutulacak ve sadece araştırmacılar tarafından değerlendirilecektir. Katılımcılardan elde edilecek bilgiler toplu halde değerlendirilecek ve bilimsel yayımlarda kullanılacaktır.

Katılımınızla ilgili bilmeniz gerekenler:

Çalışma, genel olarak kişisel rahatsızlık verecek sorular veya uygulamalar içermemektedir. Ancak, katılım sırasında sorulardan ya da herhangi başka bir nedenden ötürü kendinizi rahatsız hissederseniz çalışmayı yarıda bırakıp çıkmakta serbestsiniz. Böyle bir durumda çalışmayı uygulayan kişiye çalışmadan çıkmak istediğinizi söylemek yeterli olacaktır.

Araştırmayla ilgili daha fazla bilgi almak isterseniz:

Çalışma sonunda, bu çalışmayla ilgili sorularınız cevaplanacaktır. Bu çalışmaya katıldığınız için şimdiden teşekkür ederiz. Çalışma hakkında daha fazla bilgi almak için Matematik ve Fen Bilimleri Eğitimi Bölümü öğretim üyelerinden Prof. Dr. Didem Akyüz (E-posta: dakyüz@metu.edu.tr) ya da yüksek lisans öğrencisi Büşragül Çelik Kaya (E-posta: busragul.celik@metu.edu.tr) ile iletişim kurabilirsiniz.

Yukarıdaki bilgileri okudum ve bu çalışmaya tamamen gönüllü olarak katılıyorum.

Ad- Soy Ad | Tarih | İmza