T.C.
BAHCESEHIR UNIVERSITY
GRADUATE SCHOOL
EDUCATIONAL DESIGN AND EVALUATION HEAD OF THE DEPARTMENT

ANALYSIS OF IN-SERVICE TEACHERS' LESSON PLANS: RESULTS FROM A LONG-TERM INTEGRATED STEM PROFESSIONAL DEVELOPMENT PROGRAM

MASTER’S THESIS

SABİHA ELVAN GÜLER

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ABSTRACT

ANALYSIS OF IN-SERVICE TEACHERS' LESSON PLANS: RESULTS FROM A LONG-TERM INTEGRATED STEM PROFESSIONAL DEVELOPMENT PROGRAM

Sabiha Elvan Güler

Master's Program in Educational Design and Evaluation

Supervisor: Associate Professor Nilay Öztürk

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With the evolution of technology and societal perceptions, reforms in the field of education have become inevitable. It has become important for students to receive an education that is integrated with the real world to prepare them for professional life. Integrated STEM education, which is highly valued in the 21st century, aims to educate students in the fields of science, technology, engineering, and mathematics. There are professional development programs available aiming to ensure that teachers possess the necessary knowledge and skills for effective integrated STEM education. This study aims to examine in-service teachers' lesson plans after participating in a long-term STEM Leader Teacher Professional Development Program. The data was two sets of lesson plans developed by 57 teachers who participated in this program during the 2022-2023 academic year. The lesson plans were analysed using the STEM Lesson Plan Evaluation Rubric revised in the present study. Analyses that were conducted using SPSS 25 statistical software program showed that there was a significant improvement when the first and fourth lesson plans designed by teachers during the program were compared. However, no significant difference was found in the average scores of the first and fourth lesson plans in terms of teachers' discipline areas. It is concluded that the STEM Leader Teacher Professional Development Program has improved teachers' lesson planning regardless of the discipline taught.

Keywords: Stem Education, Professional Development, Lesson Plan, Lesson Plan Rubric

ÖZ

HİZMET İÇİ ÖĞRETMENLERİN DERS PLANLARININ İNCELENMESİ: STEM MESLEKİ GELİŞİM PROGRAMINDAN ELDE EDİLEN SONUÇLAR

Sabiha Elvan Güler
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Teknolojinin ve toplumsal algıların evrimleşmesiyle birlikte eğitim alanında reformlar kaçınılmaz hale gelmiştir. Öğrencilerin mesleki yaşama hazırlanmaları için gerçek dünyaya entegre bir eğitim almaları önem kazanmıştır. 21. yüzyılın büyük önem atfettiği entegre STEM eğitimi, öğrencileri bilim, teknoloji, mühendislik ve matematik alanlarında yetiştirmeyi amaçlamaktadır. Bu eğitimi verecek öğretmenlerin, gereken bilgi ve becerilere sahip olabilmelerini sağlayacak mesleki gelişim programları mevcuttur. Bu çalışma, STEM Lider Öğretmen Mesleki Gelişim Programı'na katılan öğretmenlerin ders planlamalarındaki değişimi incelemektedir. Veriler, 2022-2023 akademik yılında bu programa katılan 57 öğretmen tarafından geliştirilen iki set ders planından oluşmaktadır. Ders planları, bu çalışmada revize edilen STEM Ders Planı Değerlendirme Ölçeği kullanılarak analiz edilmiştir. SPSS 25 istatistik yazılım programı kullanılarak yapılan analizler, öğretmenlerin program süresince tasarladıkları ilk ve dördüncü ders planları arasında önemli bir iyileşme olduğunu göstermiştir. Ancak, öğretmenlerin disiplin alanları açısından ilk ve dördüncü ders planlarının ortalama puanlarında anlamlı bir fark bulunamamıştır. Araştırma, STEM Lider Öğretmen Mesleki Gelişim Programının, disiplin alanından bağımsız olarak öğretmenlerin ders planlama becerilerini geliştirdiği sonucuna ulaşmıştır.

Anahtar Kelimeler: STEM Eğitimi, Mesleki Gelişim, Ders Planı, Ders Planı Rubriği

Dedicating to my *family*

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Chapter 1

Introduction

1.1 Statement of the Problem

The tremendous developments in science and technology in the last century have prompted countries to revise their educational systems and teaching programs. Integrated Science, Technology, Engineering, and Mathematics (STEM) education was first emerged with the motivation to create a curriculum that reflects the interconnected nature of STEM disciplines as seen in real-world scenarios (Moore et al., 2020; Vasquez, 2014). At the same time, STEM education focuses on developing critical skills such as problem solving, critical thinking, creativity, and collaboration, which are crucial in the 21st century workforce (Guzey et al., 2016). The integration of STEM education into course subjects reflects the interdisciplinary nature of professional work in these fields, where complex problems often involve more than one area of expertise (Breiner et al., 2012).

The importance of integrated STEM education in the development of 21st century skills is highly emphasized by the studies. The studies carried out in this field lead to an increase in the demand for STEM competence and education (Kennedy & Odell, 2014). STEM education is defined as interdisciplinary teaching and learning in the fields of science, technology, engineering, and mathematics in a study published by the US Department of Education (Lemoine, 2013). After the publication of The National Science Education Standards program, integrated STEM gained significant attention in the United States during the 2000s, highlighting the need to prepare students for the workforce (Moore, 2020; NRC, 2009). According to the STEM Task Force Report (2014), integrated STEM education reflects the real-world work of engineers and scientists.

It is underlined that STEM education not only develops students' critical thinking and problem-solving skills, but also improves their attitudes, interest, and motivation (Sanders et al., 2019). The key aspect of education lies in students encountering real-world problems and applications within the classroom setting, thereby rendering the learning process more meaningful and motivational (Berland & Steingut, 2016; Lou et al., 2011). Furthermore, STEM disciplines are closely linked to specific vocational skills, and academics highlight the significance of integrated STEM activities in cultivating these skills (Bybee, 2013; Guzey et al., 2016). Such activities foster the development of teamwork, communication skills, and the ability to solve complex problems, with a strong encouragement for students to acquire these competencies (Meyrick, 2011; Shaughnessy, 2013). The transition towards STEM education mirrors a broader shift in educational priorities, acknowledging the necessity to prepare students for a world continually reshaped by technological advancements (Johnson, 2013; Wang & Knobloch, 2018). This paradigm shift is aimed at equipping students with the essential knowledge and skills to thrive in the future. Lastly, the integration of STEM allows students to engage in interdisciplinary practices and develop new skills (Brown & Bogiages, 2019). This integration enhances students' conceptual understanding and their capacity for problem-solving, enabling them to effectively tackle complex challenges (Karahan et al., 2015; Lou et al., 2011).

With the increased interest in developing integrated STEM education both in the US and other countries such as Australia and Turkey, it has become critical to develop instructional strategies and curriculum materials to develop and sustain the integrated STEM education model (Han et al., 2023). Because of the reason that teachers are the key factors of implementing a recent change in curriculum programs (Cherng & Davis, 2019), it is very crucial to provide teachers with effective professional development (PD) programs related to integrated STEM education pedagogies (Shernoff et al., 2017).

The deficiency of teachers in STEM education and the necessity for high-quality STEM teacher training has been highlighted in the report Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future (America, 2007). To make unified STEM education a reality, PD needs to be specifically designed with educators' specific needs in mind. PD must be designed to support teachers' capacity to comprehend educational approaches, integrate disciplines, and make the connection between 21st-century skills and practical application (Kurup et al., 2019).

In the rapidly evolving landscape of education, the prominence of STEM disciplines in shaping future generations is indisputable. Despite the potential advantages of integrated STEM education for student learning, it is emphasized that there are still many aspects open to research in the STEM field (Hiğde et al., 2020). Despite its acknowledged importance, there remains a paucity of research particularly in the realm of pedagogical strategies employed by teachers in integrated STEM education (Kelley & Knowles, 2016). This gap signifies a critical area of exploration, as the efficacy of STEM education is intrinsically linked to the quality of instruction and the resources available to educators. The lack of resources and limited time needed for teacher training, the use of real-world context with the subjects in the curriculum, and the planning and evaluation process of applied STEM courses continue to be challenging for STEM education (NAE & NRC, 2014; Thibaut et al., 2018). One of the studies advocates the importance of teacher training to increase the quality of STEM teaching (Altan et al., 2018).

Despite the recognized importance of STEM, challenges persist in the availability and quality of teaching materials. Despite the growing body of STEM teaching resources, it has been noted that these often address STEM subjects separately rather than in an integrated manner (Honey et al., 2012). This deficiency can lead to a disjointed educational experience, underscoring the need for cohesive and comprehensive STEM teaching materials that align with the interconnected nature of STEM disciplines. In accordance with this, the biggest deficiency in this field is the scarcity of studies emphasizing the importance of teachers' development in STEM course content planning (Guzey et al., 2016). In teacher PD programs, a significant emphasis should be placed on the methodologies teachers employ in lesson planning. This focus includes an exploration of how educators integrate various disciplines within their lesson plans and the specific elements they incorporate when structuring their lessons around integrated STEM approaches (Charalambous & Hill, 2012; NAE & NRC, 2014; Wallace & Priestley, 2017). For teachers, lesson plans are a guide they use for lesson preparation and work that they learn to develop during the implementation process (Brown & Melear, 2006). When we look at the research in the literature, examining the lesson plans prepared by teachers is a necessity to increase development in the implementation process (Huong & Linh, 2017). In addition, research on the examination of lesson plans provides the basis for examining the designs of incorporating professional knowledge into lesson plans (Zaragoza et al., 2023). In this study, we mainly aim to examine in-service teachers' lesson plans that they develop over the course of a long-term integrated STEM PD program.

1.2 Purpose of the Study

The main purpose of the study is to examine the development of teachers' lesson planning and how they incorporate integrated STEM elements into their lesson plans over the course of a long-term STEM teacher PD program. This study also examines whether the change (if any) in teachers' lesson plan scores across the timeline of the integrated STEM PD program differs for teachers' discipline areas.

1.3 Research Questions

1. Is there any statistically significant increase in in-service teachers' lesson plan scores after completing a long-term integrated STEM PD program?
2. How in-service teachers incorporated integrated STEM aspects into their lesson plans before and after a long-term integrated STEM PD program?
3. Is there any statistically significant difference in lesson plan scores in terms of teachers' discipline area?

1.4 Limitations

The participants in this study are a group of in-service teachers who completed a long-term teacher PD program carried out during 2022-2023 academic year. The findings are not generalizable to large groups as the study group consist of integrated STEM PD program only. So, the findings should be interpreted in the context of this PD program. Second limitation is related to the content of the PD program and how the program was implemented. The participating teachers took different online courses over the course of two semesters and engaged in different activities such as interdisciplinary meetings at schools. The content of the PD covers the topics of STEM definition and applications, STEM lesson plan preparation, STEM rubric introduction, and providing detailed feedback. It was not the focus of the present study to investigated specifically which part contributed to the development in teachers' integrated STEM lesson planning. Moreover, the teachers took the courses asynchronously. So, the findings obtained in the present study should be interpreted within the context of the PD program and the readers should be cautious that implementing the PD synchronously might have resulted different findings.

1.5 Significance of Study

There are mainly three reasons to conduct the present study:

1. Despite the potential contributions of integrated STEM education to student learning, there are still limited number of studies investigating teacher pedagogies in designing and implementing integrated STEM education. This gap is evident in studies by Thibaut et al. (2018) and Kelley and Knowles (2016), who both highlight the scarcity of research in this vital area. For effective STEM education, advancing teacher competencies and understanding in tandem with curriculum development is crucial. Additionally, as Yıldırım and Altun (2018) emphasize, there is a critical link between the quality of STEM education and the level of teacher training. This study will analyse in-service teachers' lesson plans after a long-term PD program that focuses on integrated STEM education. The focal point is evaluating the content planning within these lesson plans and assessing how teachers align them with 21st-century skills. Addressing this gap is crucial for advancing professional teacher development (Guzey et al., 2016) and enhancing teacher preparedness in STEM, thereby positively influencing student outcomes and equipping them with essential 21st-century skills. It will also provide insights into in-service teachers' perceptions and instructional design skills, addressing a literature gap in understanding teachers' views on the challenges and facilitators of STEM integration in curricula and pedagogy (Demircan, 2021). Ultimately, the study promises to make a significant contribution to the literature by revealing the impact of long-term PD programs on in-service teachers' capabilities to design and implement effective integrated STEM lesson plans.

2. This study provides an analytical tool (i.e., the scoring rubric) to analyse integrated STEM lesson plans. There is a limited number of tools to test and analyse teacher lesson plans in the context of integrated STEM education in K-12. This study introduces a revised version of an innovative analytical tool, the STEM Lesson Plan Rubric, designed to analyse integrated STEM lesson plans in K-12 classrooms, where currently such tools are limited. Developed initially for the Integrated STEM Leader PD Program by Asik et al. (2017), the rubric aims to improve teachers' lesson planning skills and contribute positively to the evaluation process of these plans. This development is vital, considering the gaps in the integrated STEM literature and lesson plan evaluation highlighted who stress the importance of assessment in STEM education research and curriculum development (Knowles et al., 2017; Sungur-Gul & Tasar, 2023). In summary, this study, through the rubric, addresses a significant gap in the field by providing a robust tool for evaluating the effectiveness, quality, and impact of integrated STEM lesson plans, as underscored by the existing literature.
3. The data in the present study was collected from a diverse group of participants in terms of gender, discipline, and grade level. Therefore, while the scoring of the lesson plans reveals findings about how the implemented PD affected teacher pedagogies (i.e., lesson planning), it will also give some insights into how the scores might show variability among different teachers who have different discipline expertise across different grade levels. While existing research highlights the positive influence of participant diversity on educators' practices and student outcomes (Lee et al., 2008; Schniedewind, 2001), there is less clarity on how these effects manifest across different disciplines and grade levels. This study aims to bridge this gap by exploring the variability in PD outcomes due to differences in teacher backgrounds. The findings are expected to contribute to a more nuanced understanding of PD's role in enhancing teaching strategies and lesson planning, tailored to diverse educational contexts.

Chapter 2

Literature Review

This chapter provides an overview of the related literature on integrated STEM education, supporting teachers with PD programs on integrated STEM education and how PD programs supported teachers' lesson planning regarding K-12 integrated STEM education.

2.1 Integrated STEM Education

In the past quarter century, with the advancement of research in STEM education, educators and researchers have shifted towards an interdisciplinary approach beyond individual disciplines. In this context, integrated STEM education unifies the teaching of STEM disciplines through scientific research, technological and engineering design, mathematical analysis, and the incorporation of interdisciplinary themes and skills of the 21st century (Moore et al., 2014). This integrated approach helps students develop various 21st century skills such as critical and analytical thinking, problem-solving, and communication (Guzey & Aranda, 2017). It is noted that the changes occurring in the world have triggered reforms in education and have made the role of integrated STEM education even more significant. In this regard, the necessity to review the curriculum, assessment, teaching practices, and teacher education to enhance the quality of integrated STEM education has been highlighted (English, 2017).

Moreover, integrated STEM was recognized as an effective method to prepare students for solving global social and environmental challenges (Hallström & Ankiewicz, 2023). STEM education emerges as a product of students' and teachers' interests and life experiences. This educational approach involves the process of integrating unique knowledge and skills from one STEM discipline with at least one other STEM field. This integration aims to create an interdisciplinary learning environment and thus enables students to develop their ability to combine and apply knowledge from different fields (Corlu et al., 2014). The main goals of integrated STEM education are not only to equip students with the necessary skills and knowledge for a rapidly evolving world but also to foster critical thinking and problem-solving, a core aspect highlighted by Bybee (2013) in his framework for STEM education. Integrated STEM education transcends learning individual subjects; it's about understanding their intersection and application in real-world situations (Sanders, 2009). This approach also fosters essential collaboration and communication skills, preparing students for the modern workforce's demands (NAE and NRC, 2014).

Moreover, it addresses the growing need for technical proficiency in our technology-driven society, as echoed by the National Science Foundation. By preparing students for future careers and instilling a lifelong love of learning, integrated STEM education doesn't just enhance academic achievement; it equips young minds with the tools necessary for navigating an increasingly complex world (Morrison, 2006). A testament to this is the impact of programs like the FIRST Robotics Competition, where students' participation has been shown to significantly increase their interest in STEM careers and improve their problem-solving skills (Melchior et al., 2005). Finally, STEM aimed to increase their motivation and develop their twenty-first-century skills (Johnson, 2013). Integrated STEM education enabled students to connect with the real world and gain experience in the interconnected nature of their disciplines (Breiner et al., 2012; Han et al., 2023; STEM Task Force Report, 2014).

STEM education has been defined by different researchers and organizations so far. Of these, English (2016) and Vasquez et al. (2013) examined STEM under 4 main headings: disciplinary, multidisciplinary, interdisciplinary, and transdisciplinary. They argued that STEM integration will be more advanced as these four disciplines constantly follow each other and are intertwined (Lo, 2021). This innovative educational framework allows the four disciplines to interact with each other, resulting in a product that keeps its real-world functions similar (Tsoukala, 2021).

NRC's integrated STEM education framework attempts to thoroughly document its influence on students' identity and perseverance development. Enhancing student learning, cognitive functions, and engagement helps achieve this. It also aims to develop precise theories about the underlying mechanisms, with an emphasis on the associated processes (Lambert et al., 2018; NRC, 2014; Scherer et al., 2019). With the latest technological and educational reforms, integrated STEM is progressing increasingly (English, 2016). One of the forerunners of these has been the establishment of the Next Generation Science Standards (NGSS) in the United States. These standards encourage deeper connections between STEM disciplines and emphasize the importance of integration in K-12 STEM subjects in engineering design and practice (NGSS Lead States, 2013).

Regarding Turkish context and implementation of integrated STEM education in Turkey, it could be argued that the differences between STEM approaches in the United States and STEM-FeTeMM education in Turkey are striking. These differences might be existent because of the reasons that Turkish society does not have a generally negative attitude towards science, and the difficulties in implementing programs that are designed by using integrated approaches (Corlu & Calli, 2017). The centralized structure of the Turkish curriculum also demonstrates the need to develop the workforce to support Turkey's transformation into an information society and innovation. To ensure that everyone has access to advanced scientific and math education, a change is required. Instructors need to have the abilities to design curricula and assessments that are relevant to their particular contexts. These teaching methods ought to be updated frequently and should depart from centralized frameworks. Given Turkey's particular circumstances, this shift calls for a more localized and integrated approach to STEM education (Corlu et al., 2014).

In one of the studies supporting these innovations, they stated that integrated STEM education provides an ideal environment for situated learning in engineering design because it provides a context that is unique within a problem and connected to science and engineering applications. (Kelley et al., 2020). In addition, STEM education, apart from its four disciplines, enabled students to realize creative and different solutions that lead them to think integratively and solve complex problems (Hwang & Taylor, 2016).

A meta-analysis by Tenti and colleagues (2021) investigated the impact of STEM education on students' learning outcomes and provided additional evidence for the effectiveness of integrated STEM education. This study supports the view that integrated STEM education improves student learning outcomes. Therefore, for STEM to be implemented in K-12, it requires an effective and efficient teaching system and application (Wei & Chen, 2020).

Maiorca and Mohr-Schroeder (2020) stated the importance of designs that include research-based, original learning activities to increase the effectiveness of integrated STEM education. This situation demonstrates the need for conscious teaching and learning methods in the field of integrated STEM education. It is also important to develop and maintain quality programs focusing on STEM education, which is of critical importance for educators (Guzey et al., 2016).

To summarize, integrated STEM education is an interdisciplinary approach focused on solving real-world problems using the disciplines of science, technology, engineering, and mathematics in an integrated manner. This approach aims to increase students' interest and success in STEM fields. Research supports that integrated STEM education is effective in improving students' learning and problem-solving skills and is compatible with the main purposes of this approach.

2.2 Teacher Professional Development on Integrated STEM Education

Integrated STEM approach embodies the main principles of problem-based and project-based learning approaches. Project-based learning (PBL) incorporates real-world, contextual experiences that enable collaborative learning, critical thinking, and self-directed learning while facilitating the development of comprehensive concepts across disciplines. It incorporates strict academic requirements, develops higher-order thinking abilities in kids, and presents them with challenging tasks to solve (Capraro & Slough, 2013). Designing impactful experiential learning activities for STEM education demands a team of skilled teachers capable of creating experiences that fully realize student potential (Garet, 2001). Thus, to be effective in STEM, educators need to engage in high-quality professional development programs that equip them with the tools to craft superior experiential learning opportunities (Morgan et al., 2012).

Teacher PD programs are an important way to improve teachers' teaching practices and students' learning processes in a global process where constantly changing and innovative technologies emerge (Garet et al., 2001). These programs provide ongoing learning and training opportunities for in-service teachers to develop their knowledge, skills, and teaching methods. Although there are numerous definitions of PD for teachers in the literature, it is more important to understand the basic components of an effective PD program. For meaningful teacher development, PD is a part of the teacher's continuous learning journey.

Research has shown that a common conceptual framework is important to ensure that PD programs are of a certain quality (Desimone, 2009). Desmione (2009) proposes this framework in five categories: (1) focus on content; (2) active learning; (3) collective participation; (4) consistency; and (5) duration. This created framework aims to shape teachers' teaching and learning opportunities while also improving students' learning processes. With PD programs, 21st-century skills can also be recognized as increasing the quality of student outcomes (Bandara, 2018; Lin, 2020). It is stated in the literature that PD programs are effective for the development of in-service teachers (Jin et al., 2019). In one of the studies, the PD programs that teachers need most are curriculum improvements, project-based learning, and 21st century teaching pedagogies and it is stated as the subject content (Tshering, 2023). In addition, it has revealed the importance of PD programs to observe the satisfaction, subject mastery, following innovations, and attitude changes of teachers within the profession (Guskey, 2002; Frechtling et al., 1995). Research on PD programs has revealed that well-designed programs can increase teachers' knowledge and skills (Garet et al., 2001). In addition, PD programs have an important denominator in the development of teachers' competencies (Budiwati et al., 2019). Ubit (2022) showed that PD programs have a positive effect on teachers if they are continuous and expanded rather than single-session and short. Among the results of these studies, PD programs can provide improvements in teachers' classroom practice and have a positive impact on students' success.

Teacher PD programs are crucial for successfully adopting new educational approaches like STEM in classrooms. Research highlights the need for ongoing, high-quality PD to enhance learning outcomes and integrate innovative teaching methods. For instance, studies demonstrate that well-designed STEM PD programs positively influence student achievement (Desmino 2009; Yoon et al., 2007). These programs notably enhance teachers' understanding of both the subject matter and teaching methods, while also improving their ability to link different disciplines and apply real-world STEM concepts in teaching. A specific study showed that PD, combined with a problem-based curriculum, significantly improved gifted students' science skills, understanding, and knowledge (Robinson et al., 2014). However, it's important to view PD programs as more than just vehicles for subject knowledge and teaching techniques. Research indicates that these programs also bolster teachers' collaborative skills and collective expertise (Fullan & Hargreaves, 2012; Jacobs et al., 2016). Successful PD programs should, therefore, emphasize collaboration, creating opportunities for teachers to develop cross-curricular links and engaging, inquiry-based learning experiences.

In a sustainable world where 21st-century competencies gain importance; the importance of STEM PD is understood. STEM PD programs are an important structure that aims to increase and develop the capacity of teachers to understand multiple disciplines and integrate practices. This training prioritizes the course preparation and development process to improve real-world problem-solving skills (Shernoff et al., 2017). In this context, an effective STEM PD program should prioritize the enhancement of content knowledge in STEM while also emphasizing the improvement of its integration across the curriculum, as highlighted by Margot and Kettler (2019) and Thibaut et al. (2018).

In addition, research has shown that STEM PD programs increase the competence and self-confidence of teachers (Borko, 2004). These programs are very important for the advancement and development of STEM education by understanding the professional identities of STEM teachers (Jiang et al., 2021). In addition, the importance of equipping teachers with the necessary knowledge and 21st-century skills through PD programs and that STEM education increases students' interest in disciplines and success has been emphasized (Thibaut et al., 2018). The study reported that although the program's effectiveness yielded positive results, there were limitations in applying newly gained knowledge about STEM in the classroom, which underlined potential obstacles in practice (Rivera & Manning, 2013). Another potential challenge is reflected in research as adapting to new integration reforms (Polgampala et al., 2017). The STEM PD program is a comprehensive approach that includes several important elements such as content knowledge, identity development, emotional dimensions, and sustainable PD techniques. To adapt to new integration reforms in the classroom, the importance of high-quality STEM education programs for teachers is increasing, a need also emphasized by Polgampala and collagues (2017).

In-service teachers and teacher candidates who participate in effective STEM PD programs should receive training on 21st-century competencies, technological developments, and subject knowledge. An effective STEM PD program should not only be a knowledge-based education but also an active program that leads to critical thinking (Banilower et al., 2007). In addition, these programs should update teachers' perceptions of their disciplines and show and shape how they can integrate them with their fields (Çopur-Gençtürk et al., 2014; Gardner et al., 2019; Heba et al., 2017). Moreover, the rapid advancement of technology presents challenges in PD programs, especially in keeping educators up-to-date. A major hurdle in STEM PD is familiarizing teachers with recent technologies. A study by Polgampala et al. (2017) found that teachers often struggle to integrate innovative technologies into their classrooms. This underscores the impact of effective STEM PD programs on enhancing teachers' technological competencies.

A review of the existing literature reveals a need for more research evaluating the outcomes of effective STEM PD programs. In addition, studies have shown that measuring the effectiveness of PD programs is insufficient. Desmino (2009) found that the level of time and resources allocated to the evaluations of the programs was insufficient. Also, this research stated that there are few opportunities to measure the adequacy of teachers' application of the knowledge they have learned in their programs. Additionally, there is a serious lack of research in measuring the lasting impact on schools and teachers after the end of PD programs (Yamagata-Lynch, 2003). Accepting that it is only the beginning, it is imperative to use sound evaluation methods (Guskey, 2002). It is important to eliminate the deficiencies seen in the programs in research on evaluating STEM PD programs.

2.3 Teacher Lesson Planning in the Context of Integrated STEM Education

Effective lesson plan development factors were examined to identify and measure teachers' lesson planning skills. Research show that teachers' lesson-planning skills affect students' learning outcomes and teacher development. At the same time, lesson planning skills are accepted as a process for the teacher development, which should be continuous, and it has been demonstrated that a long-term application is required (Fitriati et al., 2023).

Teachers' process of designing lesson plans begins during the higher education process. Taylan (2016) presented in his study that there is a positive relationship between teacher candidates' ability to analyze the content and practices of lessons and their ability to create effective lesson plans. In addition, it has been emphasized that it contributes to the development of teacher identity and increases the PD of teacher candidates before practicing their profession (Khoiriyah et al., 2022). In one of the studies, it was emphasized that increasing lesson planning skills, which are prominent in science education, is important in other branches and it was recommended that teaching programs should be changed in this direction (Yacap, 2022).

Also, a study by Zaragoza et al. (2023) on how prospective teachers integrate professional knowledge into their lesson plans revealed that there is a significant relationship between professional knowledge and lesson plans. In a study conducted with prospective physics teachers, it was revealed that there is a relationship between their professional knowledge, reflection skills, and planning skills (Vogelsang et al., 2022). These studies have revealed the importance of improving teachers' lesson-planning skills and teaching through PD programs.

Lasica et al.'s (2020) teacher development program focuses on improving teachers' technological and instructional skills, especially in integrating augmented reality into classrooms. This program demonstrates a direct link between improved technological competencies and better lesson-planning capabilities. In addition, in many studies, there is a very effective and critical link between in-service teachers' lesson planning skills and teacher PD programs (e.g. Fitriati et al., 2023; Yacap, 2022). PD programs are designed to help teachers improve their teaching strategies, support pedagogical knowledge, and ensure general professional competence.

In addition to the PD programs designed for teachers, measuring the effectiveness of lesson plans developed during these PD programs is another critical aspect highlighted in the literature. Research indicates that evaluating teachers' competencies in this area encompasses a range of methods. In one of the studies, a combination of qualitative and quantitative methods was used to measure the lesson-planning skills of teacher candidates by focusing on the student's way of thinking (Taylan, 2016). Similarly, Vogelsang et al. (2022) used a multifaceted approach to evaluate the lesson-planning skills of physics teacher candidates in their study.

In addition, it has been revealed that when evaluating teachers' lesson planning skills, only written work should not be considered, but an evaluation should be made for the holistic process. Because teachers' lesson plans were more than written work, the teacher's preparation process for the lesson; was visualization, resource scanning and planning, etc. It has been revealed that all activities carried out affect lesson planning skills (Sabetra et al., 2021). Moreover, the importance of using special evaluation rubrics for formative and summative evaluation of lesson plans in a teacher PD program has been emphasized (Jacobs et al., 2008).

Also, Kersting et al.'s (2009) study examined the reliability and validity of an objective rubric used to analyze teachers' classroom videos for its effects on teacher knowledge and student learning. This study reveals the effectiveness of the tools used in evaluating teaching practices. With a similar approach, in a study conducted by Adıguzel and colleagues in 2023, a special scoring table designed to be used in the processes of examining lesson plans and developing these plans through collaborative work was used. This study highlights the role of scoring tables as a valuable evaluation and development tool that contributes to the PD of teachers. These two studies made significant contributions to the evaluation of teacher competencies and teaching practices in the field of education.

As a result, the use of evaluation rubrics provides a systematic and structured approach to the evaluation of lesson plans. These rubrics allow for a comprehensive assessment of the quality of teaching, its compliance with educational standards, and the integration of specific teaching methods.

STEM lesson plans are an important component that is compatible with multiple disciplines, compatible with 21st-century competencies and aims to bring different disciplines closer together. When looking at the literature, the aim of lesson plans prepared for integrated STEM education emphasizes increasing students' motivation and improving learning outcomes (Thibaut et al., 2018). Margot and Kettler's (2019) study noted that teachers' views on STEM education and integration are hindered by the frequent scheduling and separation of subjects of interdisciplinary STEM courses. On the other hand, it has been shown that effective STEM lesson plans integrate engineering challenges with fields such as mathematics and science, such as biology, physics, or geology (Guzey et al., 2016).

In the field of integrated STEM education, it's essential to highlight the vital role of PD programs in enhancing teachers' abilities to create and execute effective lesson plans (Qablan, 2021). A study investigating the lesson plans designed by teachers involved in the Early STEM Leader Teacher PD Program supports this thesis (Yabas & Abanoz, 2023). The research included 33 educators and focused on the evolution of their lesson planning skills during the program. It involved the evaluation of teachers' lesson plans using a specific rubric, and a paired sample t-test was applied to analyze the data. This analysis showed a statistically significant improvement in the quality of the lesson plans. This finding underlines the impact of PD programs in advancing teachers' skills in STEM education (Yabas & Abanoz, 2023).

Implementing STEM education process stated by Willoughby (2022) refers to an approach to solving problems by following systematic steps. The first step involves asking questions to accurately define the problem. This phase is followed by a brainstorming process to explore various solutions. Then, planning is done to choose the most suitable one among these solutions. The chosen solution needs to be turned into a concrete design. Refinement the designed solution to evaluate its effectiveness is the next step in this process. Finally, developing the solution is one of the most important stages of this process and requires constant improvement. These steps offer an effective methodology for solving problems encountered in STEM education. Similarly, Anderson and Li's studies (2020) demonstrated the potential of the design and implementation of integrated STEM curricula to encourage and inspire students to pursue STEM disciplines.

Yabas and Corlu (2021) discuss the importance of certain principles in the design of lesson plans within the framework of the STEM integrated Teaching Framework. These principles are known as depth in the field, relevance, interdisciplinarity, and equality. They are also referred to as Integrated Teaching Principles (Figure 1). The importance of building lesson plans in line with and in balance with these principles is emphasized.

Figure 1. STEM Integrated Teaching Framework (Corlu, 2017)

The STEM Integrated Teaching Framework sets four main goals. These goals are to contribute to the knowledge society, create a professional learning community, contribute to the unity of theory and practice, and create a flexible curriculum that dynamically changes (Corlu, 2017). Teachers need to pay attention to the principles of equality, relevance, interdisciplinarity, and rigor emphasized in this framework. These principles are divided into two groups: equality-relevance and interdisciplinarity-rigor. These principles are further detailed in the 2021 study by Yabas and Corlu.

Equality-Relevance: The principle of equality emphasizes that applications should be accessible to all students, and that planning should be done while being aware of the differences that students have. The relevance principle states the importance of teachers being sensitive to the problems and developments of the age and being open to development.

Interdisciplinarity-Rigor: These principles emphasize the importance of teachers internalizing disciplines outside of their field, and not ignoring the special equipment belonging to other disciplines in their planning.

The STEM Integrated Teaching Framework, as described in Corlu's (2017) study, provides a roadmap for teachers. The purpose of this roadmap is to ensure the transformation of society into a 'Knowledge Society', to create a culture of acquiring new equipment in schools, to develop equipment with scientific research, and to bring a flexible and open curriculum innovation to schools. This approach is aimed to improve teachers' in-school performance and expand their PD.

Teacher development programs prepared for the development and advancement of STEM in Turkey enable teachers to develop the STEM lesson planning process. The "STEM Cycline" structure is mentioned, which will guide both the teachers who help implement STEM education in learning environments and the individuals who implement it (Corlu, 2017). Figure 2 explains the STEM Learning Circle in detail. STEM Cycline is examined in two parts. These are expressed as scientific processes and social products. It is understood that the cognitive process begins with the transfer of the concept of APoKS (Authentic Problems of Knowledge Society) and serves as a preparatory stage for the formation of the social product.

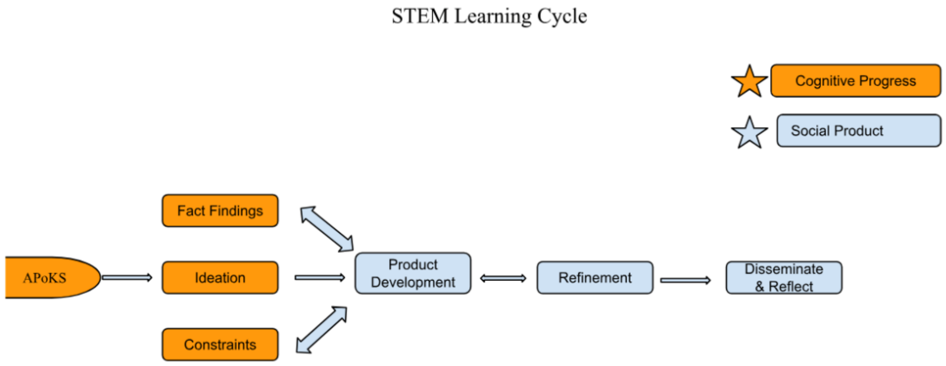

Figure 2. STEM Cycline Used in STEM Professional Development Program

There are six subsections in STEM lesson planning, which stand out as the "Course Content" section and provide the order and even ease of application in themselves. These subsections are:

- APoKS and Limitations
- Fact Finding
- Ideation
- Product Development
- Refinement
- Disseminate & Reflect

The concept of APoKS, which is a part of STEM education, is at the center of STEM lesson plans based on real-life problems of the 21st century in Corlu's (2017) study. APoKS presented to students is used to arouse their curiosity and enable them to understand the problem in depth. Students take time to digest and think about the

APoKS, then develop their product within the time, cost, and material limits set by the “Limitations” section.

In the "Fact Finding" phase, students learned APoKS and developed problem-solving designs. In this process, the aim was to deepen the problem further with the information they acquired. In the "Ideation" section, creative and innovative ideas are produced by combining APoKS and the acquired information. This stage was an important step that improved the quality of the design and created a draft of the social product in the minds of the students.

In the "Product Development" phase, students synthesize the information and ideas they have obtained through their research and in-group collaborations and turn them into concrete products. In this section, the transformation of ideas into a workable product takes place. In the "Refinement" section, the effectiveness of the created product is tested and evaluated. This phase is critical to determine whether the product is a suitable solution for APoKS.

Finally, in the "Disseminate & Reflect" section, all groups share and evaluate the implementation results and achievements with other groups. This final phase completes the learning process and provides participants with the opportunity to share their experiences. In the present study, we used this framework to examine in-service teachers’ integrated STEM lesson plans.

Chapter 3

Methodology

This chapter presents information about the research design and context, participants and sampling, data collection procedure, data analysis, and validity and reliability.

3.1 Research Design and Context

This study utilized repeated measures design – pre-post-test design which lacks a comparison group in which the data is collected from the same group of participants in different times (Drew et al., 2014). More specifically, in this study, lesson plans designed by the teachers at the outset of the STEM Leader Teacher PD Program and at the end of the PD were analysed to seek for any improvements after the PD (Figure 3).

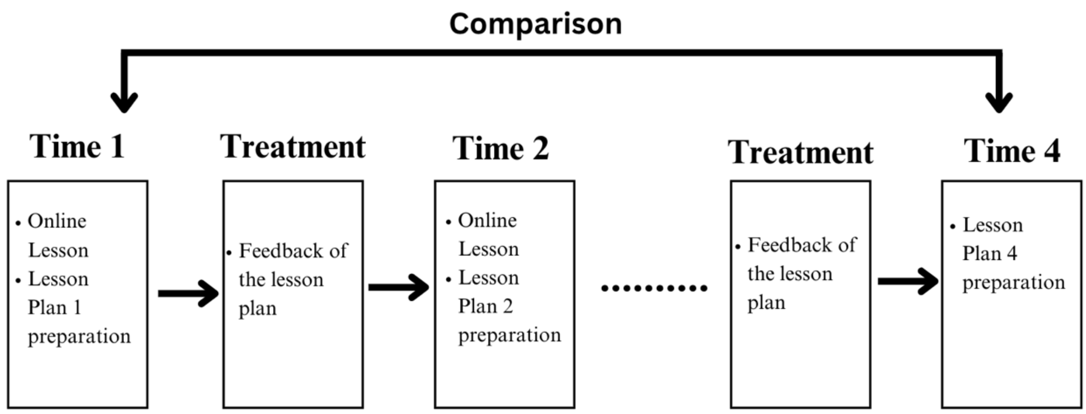

Figure 3. Comparison of Lesson Plans Over Time in the STEM Leader Teacher Professional Development Program

The integrated STEM PD program is a long-term (i.e., two semesters, eight months) asynchronous program for in-service teachers aiming to develop their integrated STEM pedagogies. The program takes eight months from start to finish. The program is split into four parts. The content of the program includes online training, in-class applications, activity evaluation, and exams. The actual PD takes place in an asynchronous online format. Integrated STEM PD program covers many elements that make PD effective, and the results and objectives of the program are as follows (Yabas & Corlu, 2021): Experience gained by watching online STEM videos, improving knowledge through interdisciplinary meetings and research, providing solutions to concrete problems experienced by the information society. To produce original ideas to find out, to integrate these experiences into the curriculum in harmony with theory and practice, to constantly update the curriculum based on the feedback received, to write an evaluation article on classroom teaching methods, and to promote collaboration between teachers as an active member of the PD community.

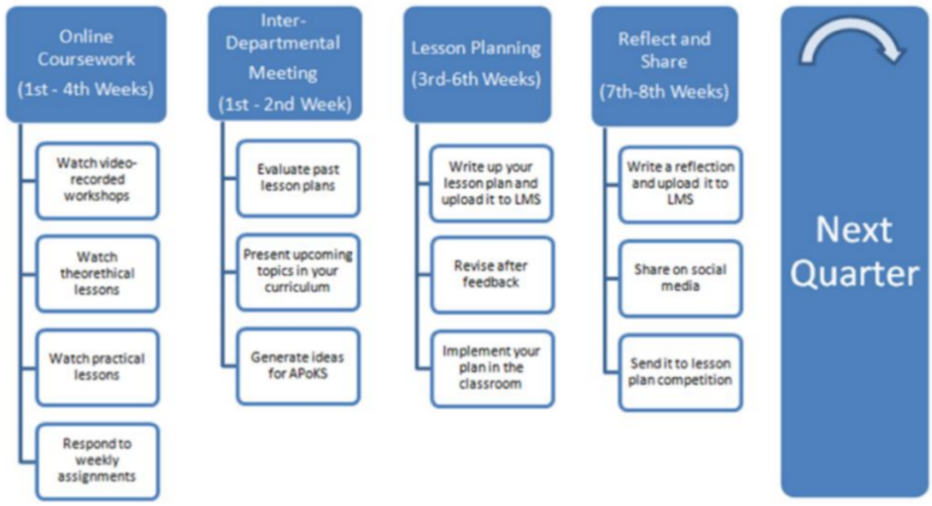

Figure 4. STEM Leader Teacher Professional Development Program Schedule Per Quarter

This training program provided participants with various materials throughout the course to provide information about the STEM cycle and integration principles. These include rubrics that evaluate cognitive processes in science and engineering, self-assessment forms, and interdisciplinary meeting forms. Participants were also given a rubric for their STEM lesson plan, which included items such as cognitive and social objectives, materials, and resources. The program also provided additional resources such as a booklet on the STEM cycle, APoKS resources, Bloom's Taxonomy-based goals and verb lists, school curriculums, and engineering-technology goals.

To successfully complete the program, a large portion of the educational videos must be watched, at least three STEM lesson plans must be written, and three lessons must be taught to real students. The first section of the program covers an introduction to the STEM lesson plan template, STEM workshop videos, the term APoKS, the political history of STEM, engineering principles, STEM circles, plagiarism rules, and graduation requirements. Teachers engage with these topics through 2.5 hours of video materials spread over five weeks. Each week, teachers are assigned homework based on the videos they have watched. They are also tasked with creating their initial lesson plans by the end of this section. Teachers' submissions for each assignment are individually assessed and feedback is provided via a word document through the teaching management system.

In the program's second section, teachers view approximately 1 hour of videos focusing on an in-depth analysis of the STEM cycle, scientific objectives, and how to implement lesson plans. Similar to the first section, teachers are expected to draft a second set of lesson plans based on their mid-term assignments. Following this section, a midterm exam is given, with written feedback on performance provided in word format, to enable teachers to progress in the program. The third section delves into mathematics STEM lesson plans, using Minecraft for educational purposes, and setting technology goals. Here, teachers watch around 2 hours of video content. As with previous sections, they are required to complete mid-term assignments and develop a third set of lesson plans. The final section of the program concentrates on mathematics projects, biology STEM lesson plans, and strategies for product development. Teachers are expected to engage with roughly 2 hours of video content, complete mid-term assignments, and prepare their final lesson plans.

In addition, this template was uploaded to all participating teachers so that they could use the same STEM lesson plan template (Appendix 1). Teachers designed lesson plans for every quarter using a STEM lesson plan template. During the program, they explained how this template works and looked at example lesson plans. This STEM lesson plan template consists of 5 main sections. It includes the achievements of the course under the first section. These achievements are reduced under three sub-sections: cognitive process gains, gains from other STEM disciplines and social product gains. The second and third sections are materials and resources to be used in the course. The fourth segment is delineated as "Authentic Problems of the Knowledge Society," wherein the discourse is subdivided into three distinct sections, APoKS problem, APoKS limitations, and Profession, and the

Duties and Responsibilities. The last part, the fifth section, teachers are expected to explain the course content and this section consists of five sub-sections: APoKS and Limitations, Fact Finding, Ideation, Product Development, Refinement, Disseminate &Reflect. Teachers use this template in every lesson plan they prepare. They upload the lesson plans they have prepared online, and they are evaluated by STEM Leaders. This evaluation is customized, and the lesson plans created by the teachers involved are assessed using the program's rubric. Detailed feedback is provided to the teachers in a word document, highlighting areas for improvement and specific sections within the lesson plan. Based on the extent and nature of the feedback, teachers are asked to submit a revised lesson plan. Following this revision process, teachers implement their prepared lesson plans in their classrooms and compile a report on this implementation.

3.2 Participants and Sampling

In this study, criterion sampling was employed (Frankel et al., 2009). The study group consists of 57 in-service teachers who completed the integrated STEM PD program between the years 2022-2023. The participant selection criteria were; participating in the 2022-2023 integrated STEM PD program, being a middle school and/or high school teacher, submitting the 4 lesson plans given as homework during the PD program, giving consent to share their lesson plans as data in this study (Figure 5). Among the entire teacher data, we identified teachers who were eligible to participate in this study. Also, participating teachers were requested to sign a research permission form (Appendix 2).

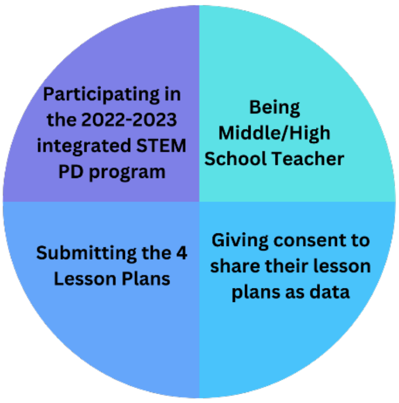

Figure 5. Criteria for Participant Selection

Table 1

Gender of Teachers Participating in the STEM Leader Teacher Professional Development

Characteristic	N	%
Female	48	84.2
Male	9	15.8

As displayed in Table 1, the gender distribution of the teachers participating in the program is 48 women and 9 men.

Table 2

Discipline of Teachers Participating in the STEM Leader Teacher Professional Development Program

Characteristic	N	%
Hs_Math	6	10.5
Ms_Math	13	22.8
Science	21	36.8
Computer	8	14.0
Chemistry	6	10.5
Biology	3	5.3

Note: Hs_Math: High school mathematics, Ms_Math: Middle school mathematics

The relevant disciplines in which teachers participated in the program were examined in 6 categories as shown in Table 2. 6 high school mathematics, 13 middle school mathematics, 21 science, 8 computer, 6 chemistry, and 3 biology teachers participated in the present study.

Table 3

Grade Level of Teachers Participating in the STEM Leader Teacher Professional Development Program

Characteristic	N	%
Middle School	41	71.9
High School	16	28.1

Also, as shown in Table 3, 41 of the teachers teach in middle schools and 16 in high schools.

Table 4

Number of Participating Teachers in the STEM Leader Teacher Professional Development Program by Provinces

City	N	%
N/A	1	1.8
Adana	1	1.8
Afyon	1	1.8
Ankara	4	7.0
Aydın	1	1.8
Balıkesir	3	5.3
Batman	1	1.8
Bodrum	1	1.8
Bursa	5	8.8
Çanakkale	1	1.8
Çankırı	2	3.5
Edirne	2	3.5
Gaziantep	1	1.8
İskenderun	1	1.8
İstanbul	11	19.3
İzmir	4	7.0
Kayseri	3	5.3
Kocaeli	1	1.8
Manisa	2	3.5
Mersin	3	5.3
Muş	1	1.8
Osmaniye	1	1.8
Rize	1	1.8
Samsun	2	3.5
Sinop	1	1.8
Yalova	2	3.5

Table 4 reveals that teachers from various provinces across Turkey participated in the program. Istanbul recorded the highest number of participants, totalling 11. Bursa followed as the second highest with 5 participants, while both Izmir and Ankara are tied for third place, each contributing 4 participants.

3.3 Data Collection Procedure

The data analysed in the present study is in-service teachers' lesson plans. Over the course of the integrated STEM PD program, teachers are required to design four different integrated STEM lesson plans. In the present study, we examine the first and the last (the fourth) lesson plans to be able to make comparisons. Since the PD program was conducted in an online environment, all data were collected digitally. Teachers who will be the participants of the present study will upload their lesson plan assignments to the Itslearning platform, which is an online learning platform which led the researcher group to put all the teaching materials such as videos and other course materials, share the assignments, and give feedback to the teachers.

To obtain the whole data, the researcher downloaded the lesson plans and recorded them in an Excel file. Participation to the study was based on voluntariness. All PD program teachers will be asked if they want to be volunteers to share their data by signing 1- the informed consent form (Appendix 3 and 4) and 2- a form that indicates their willingness to share their data. The second form will be signed by the participant teachers as part of integrated STEM PD. The project coordinator also provided documentation indicating which teachers had signed this form and their respective teaching fields. Also, the ethical committee permission was taken from Bahcesehir University (Appendix 5).

In this study, the first and fourth lesson plans of 57 teachers were evaluated based on a newly developed STEM lesson plan, which comprised 12 categories and was designed in accordance with the template of a STEM lesson plan. The resulting data from this evaluation were then transferred to an Excel format. For instance, the entries for the teachers were coded as LP1_1, LP1_2, LP1_3, etc., and LP4_1, LP4_2, LP4_3, etc. After scoring, the data was imported to SPSS 25 Statistical Program.

3.4 Data Analysis

As aforementioned, in this study, the data were the lesson plans designed by PD program teachers. The teachers were asked to prepare their lesson plans by using a common template which was provided to them at the beginning of the PD program (Appendix 1). The lesson plans were coded by using a scoring rubric which is consistent with the sections in the lesson plan template. Namely, the lesson plan template and the rubric involve the sections: 1-Cognitive objectives, Other disciplinary objectives, Social product objectives, Materials Used, Sources, APoKS, Constraints and Profession-Role-Responsibilities, Presentation of APoKS and Constraints, Fact Finding, Ideation, Product Development, Refinement, Disseminate & Reflect. In the following section details about the lesson plan scoring rubric are provided.

Quantitative analysis was conducted to answer the first and third research questions. IBM SPSS statistical software (Statistical Package for Social Sciences - Version 25) was used for data analysis. For the analysis of the first question, the quantitative data were examined descriptively and after the normality check was completed, a paired sample t-test was performed (Pallant, 2020). The purpose of conducting a paired sample t-test is to see whether there is a change over time between the first and fourth lesson plans of the participating teachers. To answer the third research question, the lesson plans prepared by the teachers participating in the program on different disciplines were examined by making interdisciplinary comparisons. These disciplines; high school mathematics, secondary school mathematics, science, computer, physics, chemistry, and biology. These disciplines are coded between one and seven in the SPSS program. Simultaneously, a comparison was conducted, considering the lesson plan scores of the participating teachers with respect to their discipline area. After the lesson plans prepared by the teachers were scored with the developed STEM Lesson Plan Rubric, the total and mean scores obtained by the lesson plans by each teacher were computed. Following this process, a one-way ANOVA test was performed in the SPPS 25 program (Pallant, 2000) to examine whether the changes in teachers' lesson plan scores vary for different demographics (i.e., discipline area). Regarding the second research question, a qualitative thematic analysis was conducted by coding the lesson plans.

The lesson plans were coded by two researchers, categories and patterns were determined (Saldaña, 2021).

3.4.1 Lesson plan scoring rubric. The scoring rubric was initially developed by Asik et al. (2017) almost ten years ago. In the present study, this scoring rubric was revised majorly to make sure each score in the rubric is described explicitly. Regarding lesson plan scoring rubrics, Korkut (2018) highlights three important questions:

"(1) Are the scoring categories well defined?

(2) Are the differences between scoring categories clear?

(3) Would two independent raters arrive at the same score for a given response based on the scoring rubric?" (Korkut, 2018, p. 5).

In the study conducted to revise the STEM lesson plan scoring rubric, three guiding questions (Korkut, 2018, p.5) were employed to facilitate the evaluation process. The researchers agreed that the response to the first question provided a comprehensive description of the categories within the lesson plan scoring rubric. However, upon examining the responses to the second question, it became evident that the lesson plan scoring rubric's categories lacked clear differentiation, leading to ambiguity during the scoring process. Regarding the third question, it was observed that the researchers assigned inconsistent scores to the same categories, resulting in a lack of consensus. This analysis shows the need for refinement in the rubric's design to ensure clarity, consistency, and reliability in evaluating STEM lesson plans. Based on the evaluations, the researcher and her advisor decided to revise the STEM Lesson Plan Rubric and revised a new STEM Lesson Plan Rubric. In the revision process of this rubric, determining whether the rubric measure what it is intended to measure (validity) and whether it provides consistency in scoring (reliability) were the two main concerns taken into consideration (Moskal & Leydens, 2000).

As a first step in the rubric revision process, researchers delineate the rubric's categories, establish the criteria, and define the learning outcomes or skills that the rubric is intended to assess (Mace & Pearl, 2019). During this step, the researchers undertook an extensive review of the relevant literature and conducted a detailed examination of the scoring rubric currently in use for the program. Additionally, the researchers used the STEM lesson plan template as a tool for further refinement. This comprehensive approach facilitated the development of categories and learning outcomes specifically tailored for the revised version of the scoring rubric. Consequently, this meticulous process culminated in the formulation of an initial draft of the scoring rubric, which is composed of 13 distinct categories.

As a second step, a panel was constituted with two STEM expert researchers to get expert opinion on the revisions of the scoring rubric. According to the feedback received here, the draft scale improvement process was initiated (Mace & Pearl, 2019). The third step is to pilot the prepared STEM Lesson Plan Rubric. This is an important step to see the rubric implemented in real-world settings to evaluate its practicality, effectiveness, and consistency in scoring (Mace & Pearl, 2019). In the pilot study, the researchers randomly selected five teachers who had participated in the 22-23 integrated STEM PD program. The randomly selected teachers had to meet specific criteria, which included adding all four lesson plans to the system and approving the research form.

Two researchers separately scored the first and fourth lesson plans prepared by five teachers (10 lesson plans) within the program, using the revised STEM Lesson Plan Rubric. They entered these evaluations into Excel and evaluated the different evaluations they gave, and revised the developed rubric again, and they decided to remove the 13th item, "Layout and Language Used", from the analysis section. Although it remains in the rubric, this item was not scored in this study. Also, the researchers made some further revisions in the descriptions of each scoring level (0-3) in the rubric. After scoring the 10 lesson plans independently, the researchers came together to discuss the discrepancies. The interrater reliability was computed as 0.93 but after the negotiations the researchers reached a full consensus on each of the sections in the rubric for each of the selected lesson plans. Furthermore, the analysis of intraclass correlation revealed values between 0.75 and 0.90 (Table 5), indicating good reliability, while values exceeding 0.90 are considered to reflect excellent reliability (Portney & Watkins, 2009). In this context, categories cognitive objectives and learning objectives exhibit good reliability, whereas the remaining categories are characterized by excellent reliability. This differentiation underscores the scale's overall reliability in measuring the constructs of interest, thereby supporting its validity and reliability.

Table 5

Intraclass Correlation of the Rubric Categories

Rubric category	Intraclass Correlation
Cognitive Objectives	.780
Other Disciplinary Objectives	.919
Social Product Objectives	.748
Materials Used	1
Sources	1
APoKS, Limitations and Profession-Role Responsibilities	.946
Presentation of APoKS and Limitations	.980
Fact Finding	.968
Ideation	1
Product Development	1
Refinement	.955
Disseminate & Reflect	1

After this step, the consistency and accuracy of the scoring of the new STEM Lesson Plan Rubric was completed and the validity and reliability of the rubric was ensured. The newly developed STEM Lesson Plan Rubric was created using a four-point scale (Table 6): Below acceptable level (0 points), Needs improvement (1 point), Acceptable: (2 Points), Goal achieved: (3 Points). In the updated rubric, the maximum score a teacher can achieve is 39 points, with the minimum possible score being 0 points.

Each category within the previously used rubric was meticulously examined. In the old rubric, scoring between items often led to multiple outcomes from a single criterion, resulting in some inconsistencies. Therefore, to enhance consistency and follow a specific pattern, each category was made more uniform. The items were structured in a cumulative manner, which highly clarified the rubric categories.

Table 6

Revised STEM Lesson Plan Scoring Rubric

Categories	Learning Objectives (LO) Cognitive objectives	Learning Objectives (LO) Other disciplinary objectives	Learning Objectives (LO) Social product objectives
Below acceptable level (0 point)	● The materials used are not specified.	●No LO was specified for any discipline other than the central discipline.	●Social product LOs are not specified.
Needs improvement (1 point)	● There are cognitive process LOs of the discipline in the center, but the objectives written are not written by choosing the ABC method and appropriate verbs or the objectives are not related to the course content, or they are weakly related.	● Cognitive process LO of at least one other STEM discipline was included, but the learning objectives were not written by selecting the ABC method and appropriate verbs, or the learning objectives were not related to the course content, or they were weakly related.	●There are social product LOs, but the objectives written are not written by selecting the ABC method and appropriate verbs, or there is no explanation in the course content on how to achieve these objectives.
Acceptable (2 point)	● The cognitive process LOs of the discipline in the center are written by selecting the ABC method and appropriate verbs, but the relationship of the learning objectives with the course content is not strong/moderate.	● The cognitive process LO of at least one other STEM discipline was included, and the learning objectives were written by selecting the ABC method and appropriate verbs, but the relationship of the learning objectives with the course content was not strong/moderate.	● Social product LOs are available, and the written objectives are written by choosing the ABC method and appropriate verbs, but there is an insufficient explanation on how to achieve these objectives.
Goal Achieved (3 point)	● The cognitive process LOs of the discipline in the center are written by selecting the ABC method and appropriate verbs, and the relationship of the learning objectives with the course content is strong.	●The cognitive process LO of at least one other STEM discipline was included, and the learning objectives were written by selecting the ABC method and appropriate verbs, and the relationship of the learning objectives with the course content is strong.	● Social product LOs are available, written by selecting the ABC method and appropriate verbs, and how to achieve these objectives is clearly stated in the course content.

Table 6 (cont.d)

Categories	Materials Used	Sources	APoKS, Limitations and Profession/Role/Responsibilitie s
Below acceptable level **(0 point)**	● The materials used are not specified.	● Source not specified.	● In the lesson plan, APoKS is not included, limitations and jobs are not included.
Needs improvement **(1 point)**	● The materials used are not sufficient and appropriate for the course content, unrelated to daily life or easily accessible.	● A limited number of sources have been used or sufficient information about the source has not been provided.	● APoKS is available, limitations and jobs are specified in accordance with the course content, but the selected APoKS is not one that can provide multiple solutions, there is no need for knowledge and skills from more than one STEM discipline for the solution of APoKS, and APoKS does not contain sociocultural dimensions (social, economic, political, etc. dimension in the selected context).
Acceptable **(2 point)**	● The materials used are sufficient and appropriate for the course content, related to daily life and easily accessible.	● In addition to textbooks, storybooks, scientific books, websites were also used and the links of the websites were specified completely.	● APoKS is available, the limitations and jobs suitable for the course content are specified in detail, the selected APoKS is one that can be more than one solution, the solution of APoKS requires knowledge and skills from more than one STEM discipline, but APoKS does not include sociocultural dimensions (social, economic, political, etc. dimension in the selected context).
Goal Achieved **(3 point)**	● The materials used are sufficient (amount specified) and appropriate for the course content, related to daily life and easily accessible, innovative technologies such as TI calculators, robotics, arduino etc. have been used.	● Textbooks, storybooks, scientific books and/or websites containing interactive applications were used in both Turkish and foreign languages, and the resources were presented in a complete way that could be accessed later and the purpose of use in the course was explained.	● APoKS is available, the limitations and jobs appropriate to the course content are specified in detail, a APoKS that can be multiple solutions is selected, knowledge and skills from more than one STEM discipline are needed for the solution of APoKS, and APoKS includes sociocultural dimensions (social, economic, political, etc. dimension in the selected context).

Table 6 (cont.d)

Categories	Presentation of APoKS and Limitations	Ideation
Below acceptable level (0 point)	● No engaging introduction is planned for the course.	● There is no detailed planning, only the use of notebooks is foreseen.
Needs improvement (1 point)	● APoKS presentation has no/weak relationship with learning objectives and course content.	● An undetailed activity has been planned for students to develop ideas in a systematic way (brainstorming, finding the most ridiculous idea, padlet, etc.) and there are no details on how to provide a democratic environment for ideation and idea sharing.
Acceptable (2 point)	● The link of the APoKS presentation with the learning objectives and course content is not strong/moderate.	● A detailed activity has been planned for students to develop ideas in a systematic way (brainstorming, finding the most ridiculous idea, padlet, etc.), but there are no details on how to provide a democratic environment for ideation and idea sharing.
Goal Achieved (3 point)	● APoKS presentation has a strong connection with learning objectives and course content, and APoKS's presentation is enriched with intriguing questions, materials, visuals and activities at different levels to attract each student's attention to the lesson.	● A detailed activity was planned for students to develop ideas in a systematic way (brainstorming, finding the most ridiculous idea, padlet, etc.), details were given on how to provide a democratic environment for ideation and idea sharing, and the necessary preparation was made for some interesting ideas that students could develop.

Table 6 (cont.d)

Categories	Fact Finding	Product Development
Below acceptable level (0 point)	● There is no detailed planning, only the use of notebooks is foreseen.	● There is no detailed planning, only the use of notebooks is foreseen.
Needs improvement (1 point)	● The research questions presented to the students are not open-ended and have little to do with APoKS, the answers to the questions are not included and it is not explained how the teacher will create an independent educational setting in the classroom.	● The necessary theoretical knowledge that coincides with the determined objectives has been processed in the classroom, but how to make draft drawings (for example, how to use isometric paper) has not been exemplified, and there is no need for knowledge and skills from more than one STEM discipline in order to develop the product.
Acceptable (2 point)	● The research questions presented to the students are open-ended and include answers to questions about APoKS, but it is not explained how the teacher will create an independent educational setting in the classroom.	● The necessary theoretical knowledge that coincides with the determined objectives is processed in the classroom, how to make draft drawings (for example, how to use isometric paper) is exemplified, and more than one STEM discipline knowledge and skills are needed to develop the product.
Goal Achieved (3 point)	● The research questions presented to the students are open-ended and related to APoKS, the answers to the questions are included, the questions of the students are also included in the education obtainment process, the planned activities are motivating and motivating independent work for the students, and the summarizing and explanatory role of the teacher is clear.	● The necessary theoretical knowledge, which coincides with the identified objectives, is processed in the classroom, how the draft drawings can be made (for example, how to use isometric paper) is exemplified, knowledge and skills from more than one STEM discipline are needed to develop the product, it is planned to use technology for draft drawings (e.g., ThinkerCad), and the role of the teacher as a guide is clear.

Table 6 (cont.d)

Categories	Refinement	Disseminate & Reflect
Below acceptaple level (0 points)	● There was no time for students to test their products.	● There is no detailed planning, only the use of notebooks is foreseen.
Needs improvement (1 point)	● There is a time for students to test their products, but in cases where the product does not work, an activity is not planned to revise (retest) the product by returning to the information and ideation stage.	●For the level-assessment, it was limited to question-answer or quiz-test-exam methods, and no sharing and reflection activity was planned.
Acceptable (2 point)	● Students were given a time to test their products, and an activity was planned to revise (retest) the product by returning to the stage of Fact Finding and developing ideas in cases where the product did not work.	● The level-assessment was made with questions-answers, quiz-test-exams and/or rubrics, an activity was planned in the classroom for only one of them without sharing and reflecting, and it was given as a reflection homework.
Goal Achieved (3 point)	●Students were given a time to test their products, and an activity was planned to revise (retest) the product by returning to the stage of Fact Finding and developing ideas when the product was not working, and during the refinement process, students were given the opportunity to explain how they used knowledge and skills from different disciplines.	● The level-assessment was made with both quiz-test-exams and rubrics, ready-made student rubrics were arranged by making them special for APoKS, an activity was planned in the classroom for both sharing and reflecting, and students were allowed to evaluate both their own products and the products of their peers.

3.5 Validity and Reliability

3.5.1 Internal validity and reliability for quantitative analysis. Internal validity in research studies can be compromised by several factors, such as participant characteristics, mortality rates, study location, measurement instruments, testing procedures, past events, participant maturity, attitudes, regression effects, and application techniques (Fraenkel & Wallen, 2006). In this study, participants were selected based on some characteristics. For this reason, subject characteristics were not considered a threat to this study. Mortality threat is one of the threats that may arise if participants drop out the study sample during the study process (Fraenkel & Wallen, 2006). In the present study, the teachers who attended almost the entire PD program were selected as the participants, so, mortality was not a threat. However, characteristics of the teachers participating in the study, such as their motivation for education or their teaching experience, were not controlled.

Throughout the data-gathering phase, the instrument used for collection remained unchanged, ensuring consistency. Furthermore, a single group of researchers was responsible for the analysis of all data, which guarantees uniformity in the evaluation process. The integrity of the research conditions was meticulously maintained by the data collection team, and the research's validity was not compromised as there were no unforeseen incidents or deviations from the planned methodology. Ultimately, prior to commencing the data collection process, the researcher ensured that participants were provided with clear explanations, including details on voluntary participation, among other considerations.

3.5.2 Trustworthiness of the qualitative analysis. Erlandson et al. (1993) suggested using various methods such as long-term participation, continuous observation, data collection from various sources (triangulation), referential adequacy, peer debriefing and participant approval to increase trustworthiness. In the present study, a second researcher was involved in the data analysis phase of the lesson plans to increase the reliability of the research. Peer debriefing, that is, review of the research process by external experts, stated by Lincoln and Guba (1985) were applied in this study. In addition, experts in STEM education evaluated both the qualitative and quantitative aspects of the study and made necessary corrections in response to their assessments. In the revision process of the STEM Lesson Plan Scoring Rubric, an expert panel was constituted to get expert opinion. Finally, throughout the data collection and analysis processes the two researchers made a concerted effort to come to ensure consistency and create a consensus on coding of the lesson plans.

Chapter 4

Findings

4.1 Findings Related to the First Research Question

A paired sample t-test was used in the statistical analysis to assess the differences between the two conditions, L1_TOTAL and L4_TOTAL. Assumption analyses were run to evaluate the data's distribution before the paired sample t-test (Field, 2013; George & Mallery, 2019). All categories are scored separately in the lesson plans. The total scores of the first and last STEM lesson plans designed by the teachers were obtained and their averages were taken. Descriptive statistics after taking the averages are given in Table 7 and 8.

Table 5

Mean and Standard Deviation of L1_TOTAL and L4_TOTAL

Group	**N**	**M**	**SD**
L1_TOTAL	57	20.667	6.52285
L4_TOTAL	57	22.333	7.34199

Table 6

Mean and Standard Deviation of L1_MEAN[a] and L4_MEAN[a]

Group	**N**	**M**	**SD**
L1_MEAN	57	1.722	.54357
L4_MEAN	57	1.8611	.61183

Note: a. L1_MEAN: Average score of STEM Lesson Plan 1
L4_MEAN: Average score of STEM Lesson Plan 4

As shown in Table 7 and 8, it is observed that the average scores and total scores of the last lesson plans designed by the teachers are above the average scores they received in the first lesson plans. It was decided to apply a paired sample t-test groups to determine whether the difference was significant or not. The assumptions of normality and homogeneity of variance were tested before applying the paired sample t-test (Pallant, 2020).

Table 7

Mean and Standard Deviation of L1_Objectives_MEAN and L4_ Objectives MEAN

Group	**N**	**M**	**SD**
L1_MEAN	57	2.1930	.75579
L4_MEAN	57	2.2807	.59691

As shown in Table 9, it is observed that the average scores of objectives of the last lesson plans designed by the teachers are above the average scores of objectives they received in the first lesson plans. Also, it is observed that the average scores of APOKS of the first lesson plans designed by the teachers are above the average scores of APOKS they received in the last lesson plans (Table 10).

Table 8

Mean and Standard Deviation of L1_ APOKS_MEAN and L4 APOKS_MEAN

Group	N	M	SD
L1_APOKS_MEAN	57	2.2456	.76836
L4_APOKS_MEAN	57	2.1579	.84069

When examining the average scores in the "Components of STEM Integration" section, as shown in Table 11, it is clear that the scores for the last lesson plans created by teachers are higher than those for their first lesson plans. This indicates an improvement in the lesson plans' quality across the five categories analysed.

Table 9

Mean and Standard Deviation of Components of STEM Integration

Group	N	M	SD
LP1_Fact_Finding	57	1.14	.875
LP4_Fact_Finding	57	1.44	.982
LP1_Ideation	57	1.12	.867
LP4_Ideation	57	1.35	.876

Table 11 (cont.d)

Mean and Standard Deviation of Components of STEM Integration

Group	N	M	SD
LP1_Product_Development	57	1.19	.934
LP4_Product_Development	57	1.35	1.044
LP1_Refinement	57	1.19	.875
LP4_Refinement	57	1.46	.983
LP1_Disseminate_Reflect	57	1.19	.875
LP4_Dissemimate_Reflect	57	1.54	1.103
LP1_Product_Development	57	1.19	.934
LP4_Product_Development	57	1.35	1.044

Table 10

L1_MEAN and L4_MEAN of Normality Test

	Kolmogorw-Smirnov [a]			**Shapiro-wilk**		
	Statistic	df	p	Statistic	df	p
L1_MEAN	.126	57	.025	.953	57	.027
L4_MEAN	.080	57	.200*	.967	57	.124

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Looking at the skewness and kurtosis values in Table 12, it can be assumed that the first and last lesson plan averages show a normal distribution since the skewness and kurtosis values are between -1.5 and +1.5 (Tabachnick et al., 2013). Since the normality assumption was met, a paired sample t-test was applied.

Table 11

L1_MEAN and L4_MEAN of Paired Samples Test

		Paired Differences							
					95% CI of Difference				
		M	SD	SEM	LL	UL	t	df	*p*
Pair 1	L1_MEAN-L4_MEAN	-.13889	.48216	.06386	-.26682	-.01096	-2.175	56	.034

Note: $p < .05$, two tailed.

As seen in Table 13, the t value found as a result of the paired sample t-test applied to the first and last lesson plan scores of the teachers participating in the integrated STEM PD program, t (degrees of freedom) = -2.175, p = .034, indicating that the results are statistically significant, which is below the traditional threshold of .05 (Pallant, 2020). Cohen's d coefficient calculated with this t value was calculated as 0.23. This value indicates a small effect (Cohen, 1988).

4.2 Findings Related to the Second Research Question

To answer the second research question, the first and fourth lesson plans of the teachers were qualitatively analyzed to have a deeper understanding of teachers' incorporation of integrated STEM components in their lesson plans. In accordance with the scoring rubric, the lesson plans were analyzed in terms of; 1- Learning objectives, 2- Authentic Problems of Knowledge Society (APoKS), and 3- Components of STEM Integration (Table 14).

Table 12

Lesson Plan Analysis Categories

Category	Sub-Category
Learning Objectives	Cognitive Objectives
	Other Discipline Objectives
	Social Product Objectives
Authentic Problems of Knowledge Society (APoKS)	APoKS Limitations
	APoKS Presentation
	Profession-Role-Responsibilities

Table 14 (cont.d)

Category	Sub-Category
Components of STEM Integration	Fact Finding
	Ideation
	Product Development
	Refinement
	Sharing and Reflection

4.1.1 Learning Objectives. The researchers of this study evaluated the learning objectives of the first and fourth lesson plans of 57 teachers, according to the following sub-categories:

1- Cognitive objectives: The objectives are present in the plan, the learning objectives written are in accordance with the ABC method and are related to the course content.

2- Other disciplinary objectives: At least one other STEM objective should be included, the objectives written should be in accordance with the ABC method and be related to the course content.

3- Social Product objectives: It should be present in the plan, the written objectives should be in accordance with the ABC method, and how the objectives will be achieved should be clearly expressed.

While evaluating the lesson plans, the entire lesson plans was examined, and it was checked whether each of the objectives were addressed in the lesson plans. It was observed that teachers generally took the objectives from the Ministry of Education curriculum writing guide. In the preparation of their lesson plans, teachers articulated the achievements aligned with the ABC method (The ABC Method of Objective Setting involves defining targets under specific conditions where students are expected to exhibit measurable and observable behaviors to acquire certain skills) and the curriculum provided by the MoNE. A review of these lesson plans revealed a consistent use of Bloom's Taxonomy verbs, indicating an enhancement in teachers' proficiency in formulating objectives throughout the program. Specifically, there was a notable advancement in the articulation of objectives related to social product acquisition. For instance, social product objectives have been notably refined for Teacher 57. Additionally, as the lesson plans were thoroughly examined, adjustments were made to the scores for cognitive and disciplinary outcomes. This comprehensive analysis included excerpts demonstrating the evolution of these outcomes from the initial lesson plan, as presented in Table 15.

Table 13

Exemplar Quotations of Three Learning Objectives Categories (Cognitive Objectives, Other Discipline Objectives, Social Product Objectives)

		Sub-Category		
		Cognitive Objectives	Other Discipline Objectives	Social Product Objectives
T57	LP1	Explains the contribution of recycling of polymer, paper, glass, and metal materials to the country's economy. (Score: 1)	Evaluates the causes and possible consequences of current environmental problems. (Score: 1)	Developing creative thinking, teamwork, problem solving and high-level thinking skills during the product development process. (Score: 1)
	LP4	Matches the names of elements that are frequently interacted with in daily life with their symbols. Matches the formulas of compounds with their names. (Score: 3)	Creates compositions with natural and artificial objects that have the effect of dots and lines, using the organizing principles of art. Uses measurement and proportion in pattern studies. (Score: 3)	Demonstrates patience in painting. Develops the ability to work collaboratively with friends. Acquires basic skills in the art of origami. Fulfill responsibilities within the group. Mentally develops matching constructs. Manual skills are improved. (Score: 2)

Table 15 (cont.d)

		Sub-Category		
		Cognitive Objectives	Other Discipline Objectives	Social Product Objectives
T41	LP1	Calculates the area of a rectangle, using square centimeters and square meters. a. The square is treated as a special case of the rectangle. b. Additionally, studies aimed at making sense of the concept of field are included. (Score: 2)	It offers suggestions for solving an environmental problem in its immediate surroundings or in our country. (Score: 3)	Teacher did not write any social product objectives. (Score: 0)
	LP4	Draws a circle and recognizes its center, radius, and diameter. (Score: 3)	Design the 3D object he dreams on the computer. (Score:3)	Students present the designed product to the class in a clear and understandable manner. (Score: 2)

4.1.2 Authentic problems of knowledge society (APoKS). The concept of APoKS serves as a foundational element in the application of STEM education and addresses a pivotal life problem of the 21st century. APoKS is designed to ignite students' curiosity by presenting them with a problem that not only is relevant and meaningful but also enhances the effectiveness of STEM applications. A judicious selection of APoKS is crucial as it not only stimulates students' curiosity but also ensures the efficiency of STEM applications. By integrating real-world problems that students find engaging and significant, educators can foster a more dynamic and impactful learning environment in STEM fields.

When preparing a lesson plan, teachers should begin by designing an appropriate APoKS. This step is crucial in the implementation of STEM education, as teachers initially introduce APoKS to their students. It is essential for the presentation and explanation of APoKS to be engaging and well-articulated during the lesson planning phase. This is because the lesson plan will subsequently delve deeper into the subject matter through research and exploration of the APoKS. By effectively setting the stage with a compelling APoKS, teachers can ensure a more immersive and investigative learning experience for students in STEM disciplines.

Another critical aspect to consider is the limitations of APoKS. Establishing clear constraints is vital to effectively address the problem at hand. These limitations help teachers maintain focus on the core subject matter of the lesson, thereby facilitating students' learning processes. Moreover, setting these boundaries ensures that the solutions developed are both realistic and feasible. By implementing such constraints, teachers can guide students towards practical and achievable outcomes, enhancing the educational value of the STEM learning experience. Also, incorporating a "Profession-Roles-Responsibilities" section into the lesson plan is crucial during STEM applications. It necessitates students working collaboratively in groups, with each group member being assigned specific responsibilities related to the problem at hand. This structured approach ensures that students are clear about the nature of the problem they are addressing and the characteristics of the solution they are tasked with developing. By delineating roles based on professional simulations, students gain an understanding of the collaborative and interdisciplinary nature of STEM fields, enhancing their ability to contribute effectively to the problem-solving process. This strategy not only fosters teamwork and accountability but also aligns students' efforts toward creating a solution that is well-defined and purposeful. While examining this category, the above criteria were taken into consideration and three sub-categories were created. These are APoKS Limitations, APoKS Presentation, Profession-Role-Responsibilities.

When looking at the two sub-categories (APoKS Limitations, Profession-Role-Responsibilities), the problem must have more than one solution, in addition to being in accordance with the learning objectives written for the course according to the revised lesson plan rubric, stating the professions and limitations in detail. For the APoKS presentation, which is another sub-category, it must be linked to the objectives and course content and supported by materials that will attract students' interest. Some excerpts from the lesson plans examined according to these criteria are shown in Table 16, 17, and 18.

Table 14

Exemplar APoKS Quotations - APoKS Presentation

		Sub-Category
		APoKS Presentation
T4	LP1	APoKS: (Score: 0) Dear students, nowadays energy saving and conscious consumption; It is necessary for a quality life and efficient use of resources. In this regard, you are expected to prepare a savings plan to optimally heat our school building during the winter months. Presentation: (Score: 0) The teacher explains the savings plan to his students as follows: ……It asks to calculate the arithmetic mean and span of the temperatures noted at the end of the day. ……It expects them to consider the measures that can be taken to minimize this difference in work areas where the difference in clearance is greatest.
	LP4	APoKS: (Score:2) ….. While their predecessors are considered "digital pioneers" who witnessed the explosion of technology and social media, Generation Z was born into a world where information is accessible immediately and from anywhere, ……. We stated that the project of the group that prepared the best content would be implemented. Presentation: (Score:2) ...... After this information was presented to the students, each group was asked to prepare its own social media content and was reminded that the most successful of these contents would be implemented within the scope of the project. Students are divided into groups of 3. ....they are told to decide what their duties and professions will be, and the groups and professions that can be chosen are written on the board. Each student in the group should choose a profession and care should be taken that no one has the same profession and task. ......
T6	LP1	APoKS (Score:1): Ahmet, a 6th grade student, lives in Bursa. ...... One day, while waiting for the subway, he stated at school that he felt cold and was blown around a bit by the wind caused by two subways passing at the same time. Thereupon, his teacher said that the force of the wind was effective in many areas and that it was benefited from. For example, have you ever seen wind roses among the mountains when you travel intercity? he asked. (He gets the answer from the students, "Yes, we saw it.") Then, he asks why they might have done this and asks them to investigate. The teacher examines the research conducted in the next lesson and asks: If you were engineers, what would you design that works with wind? he asks.

Table 16 (cont.d)

		Sub-Category
		APoKS Presentation
T6	LP1	Presentation (Score:1): At the beginning of the lesson, the teacher reads the story of teacher Ahmet to his students, then divides them into groups and shares the contents of the application.
	LP4	APoKS (Score:3): A car company produced in Turkey added a new train fleet to its team to transport its vehicles across the country as a result of increasing costs. They wanted to shorten the road by building a bridge over the river in order to reduce the length of the road made during the railway planning phase. The company official had a strong plan to maintain the train level so as not to damage the products carried by the train. contacted you to design a bridge model. As a team of engineers, we want to build a bridge to cross the river. Presentation (Score:2): Before presenting BTHP, a short video is shown at the beginning of the lesson to attract students' attention (teacher provides the link).

Table 15

Exemplar APoKS Quotations - APoKS Limitations

		Sub-Category
		APoKS Limitations
T4	LP1	In terms of location, the study areas will be the science laboratory, painting workshop, gym, 6th grade classrooms and 6th grade floor corridor. (Score: 0)
	LP4	The .... project that can explain its representations mathematically (income tables obtained from content) will be implemented. .... Project working time should not exceed 120 minutes. Support can be obtained from the teacher when using electronic devices. (Score:2)
T6	LP1	……, The cost of the materials used in the model to be created should be low; You must complete the study within 4 class hours; You should use environmentally friendly materials; The length of the train is between 60-100 cm; The length of the wind pole to be created will be less than 30 cm. (Score:1)
	LP4	The materials to be used should be at minimum price and maximum results (Recycled materials can be used); Bridge models will be determined by you. The width of the river should be 1 m long and the depth of the bridge should be at least 40 cm. The design product must be balanced and standing. (Score:3)

Table 16

Exemplar APoKS Quotations - Profession-Role-Responsibilities

		Sub-Category
		Profession-Role-Responsibilities
T4	LP1	Teachers responsible for access to study areas (Score:0)
	LP4	Scribe: Responsible for writing the decided information and texts in the notebooks given by the teacher. Your clerk must ensure that all books are in order and proceed with the flow. Measurement Expert: Undertakes the measurements that need to be taken during the experiment and decides with which tool and unit to measure. To access study areas, help is received from the teachers responsible for these areas. (Score: 2)
T6	LP1	Electrical electronics Engineering Command and Control &Railway Signaling …, Computer and software engineer (Score:1)
	LP4	Civil Engineer (Building inspection-installation), Architect (project drawing), Project manager, Environmental Engineering (Ground survey work) (Score:3)

APoKS, limitations and profession-role-responsibilities sections are scored together in the lesson plan scoring rubric. As seen in T4 teacher's first lesson plan, APoKS poses a specific problem but does not have multiple solutions, and it is not an effective introduction, but summarizes the general lesson plan in the presentation part. Also, it seems that the limitations and profession-role-responsibility section was written for teachers, not students. On the contrary, in the fourth lesson plan, the APOKS and presentation prepared by the teacher are more detailed and student supporting. Moreover, the limitations and profession-role-responsibilities section was written in detail for the students. This section was emphasized in the presentation part. Likewise, there appears to be a significant improvement in APoKS writing and presentation between T6, the first and fourth lesson plans. In the T6 limitations section, the limits for students' products are determined by making detailed explanations in the two lesson plans.

4.1.3 Components of STEM Integration. In this category, it was examined how the course content will be given in the teachers' lesson plans, how the activity will be designed, and how the students will be able to connect with the subject under five categories: Fact Finding, Ideation, Product Development, Refinement and Sharing and Reflection.

Teachers were expected to write open-ended research questions related to APoKS. Also, possible answers to these questions should be given to provide detailed and clear information. Additionally, possible questions that students will ask should be included and the summative and explanatory role of the teacher should be evident in the lesson plans. Table 19 below contains quotes related to this sub-category.

Table 17

Exemplar Quotations for Components of STEM Integration – Fact Finding

			Sub-Category
			Fact Finding
T12	LP1	Score: 0	APoKS is given to students. Students in the group brainstorm in line with APoKS and fill out the information notebook step by step. Meanwhile, there should be no interaction between groups.
	LP4	Score: 2	APoKS is given to students. (Video 1 is played.) The following questions are asked to help students create their own questions after watching the video. ….in the group are given time to brainstorm and fill out the information notebook step by step…By creating a mind map with different questions without criticism, students' motivation in individual studies is increased. Give examples of recycled materials? “Plastic bottles, Batteries, Newspaper paper and cardboard, Glass bottles, Metal waste, Electronic waste, etc.”…
T23	LP1	Score:2	….The open-ended questions asked by the teacher to the students are noted by the scribe. Answers are shared with the class through the spokesperson. “What sustainable energy sources can be used when designing a house? In which parts of the house can sustainable energy sources be used?...
	LP4	Score: 3	.... The open-ended questions asked by the teacher to the students are noted by the scribe…. Why do we avoid taking shelter under tall trees during a storm? (Students are expected to answer that there is a high probability of lightning hitting the trees.) Are thunder and lightning the same thing? (Students may confuse lightning with lightning. The answer is expected …. clouds, and the teacher makes an explanation on the subject.)….

When the Fact-finding sections in the T12 and T24 lesson plans are examined, in the first lesson plan of T12, there is no detailed explanation in this section, nor is the role of the students and the teacher mentioned. On the contrary, in the fourth plan, the teacher mentioned about the introduction to the lesson, talked about the roles of the students, and supported and developed this part of the plan by asking open-ended questions. When T24's plan is analysed, open-ended questions are answered in the fourth plan compared to the first plan. By articulating the role of the student in the lesson plans and further enriching the final lesson plan with potential responses from students, the teacher significantly enhances the clarity and developmental depth of the instructional design.

In the other sub-category, ideation, teachers were expected to present in-class activities in their plans that will enable students to develop their own independent ideas about the subject of the course. Teachers should provide detailed information as to how they support students to develop ideas and to provide the necessary democratic presentation environment. Table 20 contains exemplar quotes related to this sub-category.

Table 18

Exemplar Quotations for Components of STEM Integration – Ideation

			Sub-Category
			Ideation
T27	LP1	Score: 1	…Different ideas that could be a solution to the BTHP are presented by students by creating a fair environment. Groups are visited frequently, and suggestions are made regarding the needs of the students. The groups are asked which polygon they will use, where and how in the product design.
	LP4	Score: 3	... Students begin to generate ideas within the limitations that could be solutions to APoKS. (The time given should not exceed 10 minutes.) At this stage, the teacher ensures that the students share their ideas in a fair environment and emphasizes that other students should listen respectfully. The teacher uses the brainstorming method to help students develop ideas in a systematic way. Asks the following questions to students so that they can brainstorm. “What kind of resources and information do you need to solve APoKS?, Can we change the brightness of the bulb using electrical resistors?... With this method, students share...

Table 20 (cont.d)

			Sub-Category
			Ideation
			….the first idea that comes to their mind in the group and all ideas are reviewed, a consensus is reached, and a decision is made for the design they want to make. (The time given is 5 minutes.) The teacher visits the groups frequently and checks whether the designs comply with the limitations. It directs students to the ideation stage by providing guidance without interfering with creativity for inappropriate designs. When all groups decide on their designs, students make a short presentation for sharing between groups.
T56	LP1	Score: 1	The teacher explains the ideation notebook and tells them how to use it, and they are asked to fill in the notebook. They are expected to think about the research they have done during the process of Fact Finding and write down the ideas they have developed in their notebooks. Students should be able to freely share the ideas they find in the classroom and exchange ideas with their friends. Students should not proceed to the product development stage without passing the ideas they come up with the teacher's approval.
T56	LP4	Score: 2	… They are expected to think about the research they have done during the process of Fact Finding … Students should be able to freely share the ideas they find in the classroom and exchange ideas with their friends…

In the ideation section, teachers' plans were analysed. In the T27 plan analysed, it is thought that there are significant differences in the ideation sections of the two lesson plans. While the first plan briefly stated that students would develop ideas in this section, the fourth plan asked questions to support students' ideas and enable them to think of different ideas. Stating that teacher would have a brainstorming, teacher tried to improve the ideation section and explained in detail how to achieve this. It is seen that there are similar changes in the plan of another analysed T56. In addition to the first plan, in the final plan, teacher asked questions that would direct the students to brainstorm and supported the subject of the lesson. However, teacher did not explain the activity in the process in detail.

Another sub-category under the main category of STEM lesson plan integration is the product development part. In this section, teachers are expected to design how they guide students for the product to be created and how they process course topic knowledge in their lesson plans. In this process, practicing teachers are expected to take on a supervisory and sharing role with the class in recognizing mistakes. At the same time, it is expected to design the plan of the draft product to be created by integrating technology and how it will be produced. This section was evaluated according to these criteria in the evaluation using the STEM Lesson Plan Rubric. Table 21 contains highlights regarding this section.

Table 19

Exemplar Quotations for Components of STEM Integration – Product Development

			Sub-Category
			Product Development
T36	LP1	Score: 1	Food and beverages that students will research on are distributed separately to each group. Students prepare to make measurements using the required amount of food and beverages distributed to both groups. Students divided into two groups will measure the pH values of food and beverages using pH paper. For this purpose, each group will determine the procedures for how the experiment will be carried out. The teacher checks both groups and warns the students to make measurements with precision and care. He supervises the process by asking questions to the students during the experiment. The teacher visually shows the students the information that both groups need to know. It ensures the continuity of the process after making the necessary warnings in a way that both groups can hear when students make mistakes.
	LP4	Score: 3	A detailed explanation of the subject is given to the students. The students are shown how to make drafts of the results obtained as a result of the research and measurements. The student is explained through videos how to draw the results on isometric paper. When students make mistakes, they ensure the continuity of the process after making the necessary warnings in a way that all three groups can hear.
T49	LP1	Score: 1	Students are asked to fill out Product Development Reports in stages. It is requested that the draft of the model they made on isometric paper be added to this report. Students are expected to cut materials to appropriate sizes in line with the mathematical calculations specified in the limitations. In order to show an example to students at this stage, the link https://www.youtube.com/watch?v=vw43V2_g31s, which can guide students at each stage, can be shared.

Table 21 (cont.d)

			Sub-Category
			Product Development
	LP4	Score: 3	After completing their research, students are reminded of the priority topics of 'Human-Environment Relationship and Destructive Natural Phenomena' from the 'Biodiversity' unit. Afterwards, theoretical information is given about the subject of 'Liquid Pressure' from the 'Pressure' unit. … After the necessary subject is explained to the students
T49	LP4		and the sample solution is completed, the Kohoot program measures and evaluates the test prepared by your teacher on the subject online in the classroom, by ensuring the participation of all students in the order specified below. The following steps should be taken to develop a product. Students are asked to fill out Product Development Reports in stages…In line with the limitations, students are asked to design the draft drawing of the garden plan with the Tinkercad 3D drawing program and assemble it appropriately…. Tinkercad is a web editor where you can easily design the 3D model you have created in your mind by combining ready-made 3D models. You can go to the website www.tinkercad.com and become a member for free in 1 minute and start designing immediately…These stages are respectively: 1. Add an object to the scene and adjust its size and positioning. 2. Adding another object or objects to the object in the scene and adjusting their alignment. 3. Make the added objects "Hole", that is, removed, depending on your wishes. 4. Then group these combined objects. The design contents created by the students are added to the product development report. At this stage, students who have difficulty are helped to thin the image below and comment on the image together to have an idea about the structure they want to design. It explains the variables on which the concepts of pressure and pressure force depend in solids, stagnant liquids and gases, which is the subject of the 10th grade physics course for our students who finish product design early or want to make detailed calculations in their design and is given the opportunity to explain the 12th grade biology course topic 'Water and mineral absorption in roots' and arrange the product he designed according to his calculations.

Lesson plans were also analysed for the sub-category of product development. When we look at this section of the lesson plan prepared by teacher T36, we can see the improvement in the fourth plan. In the first lesson plan, it is seen that the teacher designed this section as an experiment. In the fourth plan, we can see the positive effect of the program, where the teacher explains the subject, uses isometric paper, and guides the students for the products they will design. At the same time, when T49's plan was examined, a product development section was planned in a more descriptive and comprehensive way in the fourth plan, like the other teacher's plan.

Another sub-category, Refinement, was analysed in detail in the lesson plans. In this section, the following sections should be designed in teachers' lesson plans: whether time is allocated for refinement of the products, asking for revision by going back to other sections in the lesson plan for products that do not work, whether an explanation is made about how skills in other disciplines will be used during the refinement process. These criteria were evaluated and scored by researchers in a well-developed product development section. Table 22 contains excerpts from the lesson plans prepared by teachers regarding the product development section.

Table 20

Exemplar Quotations for Components of STEM Integration – Refinement

			Sub-Category
			Refinement
T49	LP1	Score: 0	Each group tests the prism they have made in a dark environment using the 3D models they created on their phone/tablet/computer. The guiding teacher can monitor the refinement and inform the students when necessary.
	LP4	Score: 2	At this stage, if a product is not fit for purpose or if the group is not satisfied with the product they have created, it is recommended that they go back to the ideation stage and reconsider their ideas. It is requested that the model developed with Tinkercad be examined and reviewed by checking whether it complies with the limitations and whether the drip water system drips water evenly onto the land. It is checked whether there are elements that need to be improved or changed.
T56	LP1	Score: 1	The teacher first asks the students to test the projects they have made themselves, and then he goes to each group and tests the projects. If there are any omissions or errors, students are warned and asked to reconsider…, and suggestions can be developed for problems that may arise. Students are helped when they get stuck.

Table 21 (cont.d)

			Sub-Category
			Refinement
T56	LP4	Score: 3	The teacher first asks the students to test the projects they have made themselves, and then he goes to each group and tests the projects. If there are deficiencies and errors, students are warned and asked to review again, at this stage they can return to the ideation and product development stages. … to deepen and gain meaning; "Do you think we can integrate this project we have prepared into lamps used at home?"…

When looking at the quotes for the refinement part, there is improvement in the lesson plans of T49 and T56. In T49's first lesson plan, it is not clear what kind of planning was done when looking at the plan. On the contrary, in the fourth plan, the teacher considered the situation where the students' products did not work and added it to plan. Teacher took into consideration the limitations of APoKS and designed a lesson planning accordingly. When another teacher, T56' lesson plan, was analysed, it was not detailed how the activity was planned in the first lesson plan. However, in the fourth plan, the teacher continued to support the students after refinement the products by asking supporting questions. Students asked questions about the problems they would encounter with their products and completed the missing parts with course knowledge.

The last sub-category examined is disseminate and reflect. In this section, the following criteria are expected from the lesson plans prepared by teachers; an evaluation rubric should be prepared, these rubrics should be arranged according to APOKS, an activity should be planned for sharing, and students should be allowed to evaluate their own and friends' plans. Using these criteria, teachers' lesson plans were scored and analysed according to the lesson plan rubric In Table 23, quotes are given from the disseminate and reflect section of the teachers' lesson plans.

Table 22

Exemplar Quotations for Components of STEM Integration – Disseminate and Reflect

			Sub-Category
			Disseminate and Reflect
T48	LP1	Score: 1	Students share photos of their work in groups as a presentation in the classroom environment with the help of the teacher. In this post, the relationship between desks and chairs, …... It has been discussed that ratio and proportion can help with today's problems. Thus, ideas …the impact of mathematics, science, engineering and technology on the solution of a problem that arises today.
	LP4	Score: 3	Plickers application is used to make the best evaluation at the end of the lesson. …… Because plickers, apart from evaluation, aim to gamify the lesson and ensure that the student is motivated, interested, facilitates learning, ….. Not only that, Kahoot application is also used to perform measurement and evaluation. ….. …Thanks to this presentation, students are given the opportunity to share the meanings expressed by the shapes they use in their studies. Students are given rubrics to evaluate themselves and their peers. By sharing these experiences with their friends, students ensure that the knowledge is permanent. By opening a social media account at the end of the course, these models were shared on social media. Thus, it was an encouraging move for students to share in a way that is appropriate for society…
T24	LP1	Score: 0	At this stage, students evaluate themselves and their peers.
	LP4	Score: 2	Students are asked to introduce their products by selecting a spokesperson from each group. After all groups listen to each other, each group is asked to evaluate its own group collectively. After the groups evaluate themselves, the same groups should be formed, and the questions should be solved through the quizizz application. Quiz link: https://quizizz.com/join?gc=91024695

As shown in Table 23, T48 did not reflect what is required in the disseminate and reflect part and only made a summary of the topic. In the fourth lesson plan, a detailed plan was made; the evaluation part, sharing and reflection, and evaluation rubrics were given in the lesson plan. Similarly, we see such an improvement in T24's lesson plan.

Qualitative analysis of the lesson plans supported that integrated STEM PD program has a positive impact on teachers' lesson planning skills. In the lesson plans examined as a whole and when the first and fourth lesson plans were compared, the improvement of teachers in designing and going from the general to the whole is visible. Qualitative analysis of the lesson plans also showed that APoKS's connections to disciplines have strengthened in the process and teachers' creative thoughts have developed regarding its integration into the course content.

4.3 Findings Related to the Third Research Question

In order to answer the third research question, one-way Analysis of Variance (ANOVA) was performed. The third research question aims to investigate in the changes in the scores of the first and fourth lesson plans vary in terms of teachers' discipline areas; science, mathematics, and computer. The mean scores and standard deviations for the first and fourth lesson plans, categorized by discipline, were as follows (Table 24):

- Mathematics teachers showed an increase from an L1_MEAN of 1.6579 (SD = .13213) to an L4_MEAN of 1.6842 (SD = .12897).
- Science teachers' scores rose from an L1_MEAN of 1.8417 (SD = .08610) to an L4_MEAN of 1.9722 (SD = .10798).
- Computer teachers had an L1_MEAN of 1.4271 (SD = .22846) and an L4_MEAN of 1.8646 (SD = .27274).

Table 23

Mean and Standard Deviation of L1_ MEAN and L4_MEAN According to Disciplines

Group	Discipline	N	M	SD
L1_MEAN	Math	19	1.6579	.13213
	Science	30	1.8417	.08610
	Computer	8	1.4271	.22846
L4_MEAN	Math	19	1.6842	.12897
	Science	30	1.9722	.10798
	Computer	8	1.8646	.27274

The normality of score distributions for both the first (L1_MEAN) and fourth (L4_MEAN) lesson plans was verified using Kolmogorov-Smirnov and Shapiro-Wilk tests, ensuring the appropriateness of ANOVA for this analysis (Table 25).

Table 24

L1_MEAN and L4_MEAN of Normality Test According to Disciplines

		Kolmogorw-Smirnov[a]			Shapiro-wilk		
		Statistic	df	p	Statistic	df	p
L1_MEAN	Math	.138	19	.200*	.954	19	.462
	Science	.123	30	.200*	.943	30	.108
	Computer	.221	8	.200*	.956	8	.775
L4_MEAN	Math	.184	19	.092	.934	19	.205
	Science	.131	30	.200*	.947	30	.139
	Computer	.237	8	.200*	.872	8	.159

Table 25

One-Way Analysis of Variance Results

	SS	**df**	**MS**	**F**	**Sig.**
Between Groups	.956	2	.478	2.140	.127
Within Groups	12.062	54	.223		

As seen in Table 26, the one-way ANOVA results revealed a between-groups sum of squares (SS) of .956, with a mean square (MS) of .478, and an F-value of 2.140, leading to a significance (Sig.) level of .127. This indicates that there were no statistically significant differences in lesson plan score changes across the disciplinary fields ($p > 0.05$). Most notably, the eta squared (η^2) value was calculated to be 0.73, suggesting that approximately 73% of the variance in lesson plan score improvements could be attributed to the disciplinary background of the teachers. This substantial effect size indicates a significant disciplinary influence on the observed changes in lesson plan scores, despite the lack of statistical significance in mean differences.

Chapter 5

Discussions and Conclusions

5.1. Analysis of Integrated STEM Lesson Plans

In this study, analysis of the data revealed that after participating a long-term asynchronous integrated STEM PD program, there was a statistically significant improvement in teachers' lesson plan scores. Integrated STEM PD program that was carried out within the scope of this study was designed to help teachers specialize in integrated STEM education and enhance their skills in STEM lesson planning. We argue that some characteristics of the PD program implemented in this study might be the main factor for improving teachers' lesson planning. These characteristics include providing constant feedback, high quality and explicit materials including a lesson plan rubric, and designing the PD as a long-term (i.e., two semesters over eight months) program.

There are some existing research studies supporting our argument that PD programs have a major impact also on teachers' instructional practices and lesson planning. For example, Srikoom (2021) showed that STEM-focused PD programs effectively support and enhance teachers' capabilities in designing STEM lesson plans. Adıgüzel et al. (2023) showed that PD training for K–12 teachers greatly increased the integration of cognitive presence tactics into their lesson plans. According to Adıguzel et al. (2023), this suggests that the PD program positively impacted instructors' teaching styles by improving their capacity to integrate cognitive presence methods into lesson plans. Another study by Guzey et al. (2016) investigated 48 teachers' lesson planning skills after participating to a one-year-long PD program. In this study, 20 new engineering-based STEM curriculum units designed by the teachers during this process were examined (Guzey et al., 2016). Findings showed that PD contributed positively to teachers' abilities to develop new STEM-based curriculum units. Additionally, it has been stated that this development points to potential improvements in teachers' lesson planning skills (Guzey et al., 2016). Similarly, Ozudogru (2022) also found positive and significant relationships between pre-service teachers' final grades, lesson plan preparation competencies, number of reflections on discussion boards, and perceived competencies on the instructional planning scale. These findings emphasize the potential of PD to increase teacher candidates' ability to prepare lesson plans and suggest that there is a positive relationship between PD and lesson planning skills (Ozudogru, 2022).

Another line of research highlights that teachers participating in PD programs have experienced notable enhancements in their confidence, knowledge, and proficiency in teaching STEM subjects. This indicates that such PD endeavors positively influence teachers' perspectives and readiness to incorporate STEM into their instructional methods, potentially leading to better outcomes in lesson planning (Margot & Kettler, 2019). The observed improvement in the scores of the lesson plans created within the context of the integrated STEM PD Program demonstrates that teachers are afforded the opportunity to enhance their professional skills. This not only contributes to their capabilities in lesson planning but also supplements their subject-matter expertise as they acquaint themselves with novel educational approaches. A study by Meyers et al. (2016) demonstrates that ongoing PD can positively influence teachers' instructional behaviors and enhance students' achievement in mathematics. These findings suggest that continuous PD can positively impact and improve teachers' lesson planning and instructional practices.

In STEM PD programs, all participating teachers follow the same online course schedule, which emphasizes the importance of continuous, personalized feedback on their lesson plans. Feedback has been shown to have a positive impact. For instance, Lucenario et al. (2016) found that feedback and suggestions on lesson plans in a program similar to STEM PD significantly improved the quality of these plans. Lamn (2015) also noted that planning, executing, and reflecting on lessons positively influenced these skills. In the STEM PD program in question, weekly feedback on assignments played a key role in individual teacher growth. This program requires teachers to not only carry out each lesson plan but also to write reports based on their observations, leading to notable improvements in their abilities to plan and execute lessons. Research indicates that evaluating the effectiveness of lesson plans through practical application enables teachers to refine their materials and enhance their competencies, thereby improving their planning skills (Mahrus & Dewi, 2023; Suwartono et al., 2022). These findings suggest that including a practical component in teacher PD programs can positively impact teacher growth (Farrell, 2015). Furthermore, teachers engaged in STEM education who actively put their lesson plans into practice demonstrate the increased effectiveness of such programs.

When the designed lesson plans were examined, it was observed that many teachers' final lesson plans included reinforcing materials and activities related to the core objectives of STEM lesson plans, as well as sample drawings. Doşar and Görener (2020) described the product development process in STEM lesson plans as starting with the ideation stage, followed by the introduction of the product and the communication of its processes and characteristics. Examining the main category of "integration of lesson plan", which is treated as a separate subcategory, it appears that teachers' plans evolved holistically. Consequently, not all processes in the lesson plan template are considered in isolation. During this process, teachers integrated the STEM knowledge acquired during the program into their designed lesson plans, enhancing them with more comprehensible sample activities, the use of original materials, and connections to APOKS. It can be said that the educational process plays a significant role in shaping better fourth lesson plans.

In the analysis of teachers' lesson plans, one significant difference that emerged was in the APoKS category. It was noted that there were notable differences in the presentation of APoKS between teachers' first and fourth lesson plans. In their initial plans, teachers predominantly utilized APoKS inputs solely for reflection and introducing the lesson. However, in their fourth plans, they presented APoKS to students using visuals and videos. When examining the learning objectives, the entire lesson plan was scrutinized. The principal category, 'learning objectives,' was also divided into three sub-categories: Cognitive, Other Discipline Achievements, and Social Product Objectives. The plans were assessed for the correlation between the written objectives and the course content. Researchers observed that teachers adeptly articulated cognitive and other disciplinary objective, as they incorporated goals developed by the Ministry of Education in their lesson plans. Furthermore, the articulation of Social Product objective evolved between the first and fourth plans. The objectives, initially stated in simple terms in the initial plans, were later aligned with the ABC method in the final plans, illustrating how these objectives would be achieved within the course content.

5.2 Analysis of Lesson Plans in terms of Teachers' Discipline Area

Analysis of the lesson plans showed that there was no statistically significant difference in teachers' lesson plan scores in terms of their discipline area. Various factors influence the evolution of teachers' lesson planning competencies. These include structured educational initiatives, the intricacies involved in making subject-specific choices, the impact of evaluation and feedback mechanisms, and the significance of subject expertise alongside pedagogical proficiency. Among the limited number of studies investigating lesson planning and discipline area, König et al. (2020) suggests this may be due to the similar levels of complexity in subject-specific planning for teachers from various disciplines. It was also highlighted that sustained participation in PD programs for teachers markedly enhances the quality of lesson planning. Furthermore, Özoğul et al. (2008) noted that the processes of evaluation and feedback can significantly refine planning skills across diverse disciplines.

In the related literature, it is highlighted that STEM education fosters the simultaneous teaching of various disciplines (English, 2016). This interdisciplinary approach allows teachers, regardless of their specific field, to integrate different subjects into their own areas of expertise. Therefore, effective lesson planning requires not only disciplinary knowledge but also reflective abilities. Research also indicates that variations in planning skills among disciplines may primarily stem from differences in subject knowledge and pedagogical expertise (Vogelsang et al., 2022). Additionally, Lucenario et al. (2016) underscore the inherent challenges of lesson planning for teachers, noting that these difficulties are not confined to any discipline. This suggests that challenges in lesson planning are a universal issue across various disciplines, contributing to a noticeable homogeneity in planning skills.

Enhancing the depth of content knowledge in PD programs that cater to teachers from various disciplines is crucial for fostering a robust comprehension of the program's key outcomes (Garet et al., 2001). In the STEM PD program, content knowledge emerges as a significant outcome, ensuring a unified understanding among all participating teachers. This unified understanding is evident in the lesson plans devised by the teachers. Additionally, the literature underscores the importance of the duration of professional development programs. Programs extending over a considerable length of time facilitate a deeper engagement with the material, provide greater opportunities for reflection, and enable the practical application of what is learned in classroom settings. Such extended programs are more effective in instigating enduring changes in teaching methodologies (Desimone et al., 2002). Lasting eight months, the STEM PD program offers teachers a gradual introduction to content, enriched with ample examples and practical exercises. This approach significantly enhances teachers' comprehension of the subject matter throughout the program, positively influencing their ability to plan lessons individually.

Furthermore, the lack of differences in lesson plans among teachers from different disciplines can be attributed to several factors. Firstly, teachers share common objectives in lesson planning, which include understanding student needs, establishing clear goals, designing assessments, and crafting engaging content. The integrated nature of STEM education is a key factor, as it encourages teachers to transcend their individual disciplines and devise comprehensive lesson plans. Additionally, the uniformity in PD programs for STEM teachers contributes to this phenomenon. Such standardization in education content and pedagogical methods can lead to a convergence of lesson planning skills across different disciplines.

Consequently, if the program's evaluation and feedback mechanisms, along with its criteria, are designed to be inclusive of all disciplines rather than discipline-specific, teachers might prioritize these general criteria over discipline-specific methodologies. Research by Fitriati et al. (2023) highlights the significant role of a teacher's background in enhancing their ability to plan lessons, especially for those involved in teacher PD programs. The years of teaching experience, along with social and emotional skills, indirectly contribute to better lesson planning abilities (Jennings & Greenberg, 2009). This underscores the necessity for thorough fieldwork and consideration of teachers' professional knowledge and skills when designing teacher development initiatives.

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