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Integrated STEM Teaching: Innovative STEM Training for Preschool and Primary School Teachers

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Defne Yabaş* **Tuğba Abanoz****

Abstract

The effective implementation of STEM education relies on qualified and well-educated teachers who employ good practices for integrated STEM education. Quality STEM education equips children with the necessary skills to address 21st-century challenges, playing a critical role in developing critical thinking, communication, collaboration, creativity, problem-solving, and responsibility. In this context, preschool and primary school teachers were recommended to attend STEM Professional Development (PD). This study aimed to determine the impact of the EarlySTEM Leader Teacher PD Program on teachers' ability to design STEM lesson plans, using mixed method. Researchers analyzed the STEM lesson plans prepared by preschool and primary school teachers (n=33) who participated in the integrated STEM PD program. All participants who met the graduation criteria were included in the study. The plans were evaluated using the Authentic Problems of Knowledge Society (APoKS) rubric. The findings showed that the Integrated STEM PD program positively influenced teachers' lesson planning skills, specifically when writing the APoKS. The implications of the study were discussed in detail.

Keywords: Early STEM education, teachers' professional development, early childhood, primary school, preschool.

**Corresponding Author:* Assoc. Prof. Dr., Bahçeşehir University, Faculty of Educational Sciences, Elementary Education, İstanbul, Turkey. E-mail: defneyabas@gmail.com, https://orcid.org/0000-0001-5575-510X

**Assist. Prof. Dr., Ankara University, Faculty of Educational Sciences, Early Childhood Education, Ankara, Turkey. E-mail: tabanoz@ankara.edu.tr, https://orcid.org/0000-0001-8905-4002

Bütünleşik STEM: Okul Öncesi ve İlkokul Öğretmenleri için Yenilikçi Mesleki Gelişim Programı

Makale Türü	Başvuru Tarihi	Kabul Tarihi
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Defne Yabaş* **Tuğba Abanoz****

Öz

STEM eğitiminin etkili bir şekilde uygulanması, bütünleşik STEM eğitiminde iyi uygulamalar gerçekleştiren nitelikli ve iyi eğitimli öğretmenlere bağlıdır. Kaliteli STEM eğitimi, çocukları 21. yüzyıl zorluklarının üstesinden gelmek için gerekli becerilerle donatır ve çocukların eleştirel düşünme, iletişim, iş birliği, yaratıcılık, problem çözme ve sorumluluk alma becerilerinin gelişiminde kritik bir rol oynar. Bu bağlamda, okul öncesi ve ilkokul öğretmenlerinin STEM Mesleki Gelişimine (MG) katılmaları önerilmektedir. Bu çalışmanın amacı, ErkenSTEM Lider Öğretmen Mesleki Gelişim Programı'nın öğretmenlerin Bilgi Temelli Hayat Problemi (BTHP) oluşturma üzerindeki etkisini belirlemektir. Araştırmada nitel ve nicel verilerin dahil olduğu karma desen kullanılmıştır. Araştırmacılar, Bütünleşik STEM MG programına katılan okul öncesi ve ilkokul öğretmenlerinin (n=33) hazırladıkları STEM ders planlarını analiz etmişlerdir. Programın mezuniyet kriterlerini sağlayan tüm öğretmenler çalışma grubuna dahil edilmiştir. BTHP üzerine kurgulanan STEM ders planları, BTHP rubriği kullanılarak değerlendirilmiştir. Bulgular, Bütünleşik STEM MG programının öğretmenlerin ders planlama becerilerini, özellikle de BTHP yazarken olumlu yönde etkilediğini göstermiştir. Çalışmanın sonuçları ayrıntılı olarak tartışılmıştır.

Anahtar Sözcükler: Erken STEM eğitimi, öğretmen mesleki gelişim programı, erken çocukluk, ilkokul, okul öncesi.

* *Sorumlu Yazar:* Doç. Dr., Bahçeşehir Üniversitesi Eğitim Bilimleri Fakültesi, Temel Eğitim Bölümü, İstanbul, Türkiye. E-posta: defneyabas@gmail.com, https://orcid.org/0000-0001-5575-510X

** Dr. Öğr.Üyesi, Ankara Üniversitesi, Eğitim Bilimleri Fakültesi, Temel Eğitim Bölümü, Ankara, Türkiye. E-posta: tabanoz@ankara.edu.tr, https://orcid.org/0000-0001-8905-4002

Introduction

STEM, an acronym for science, technology, engineering, and mathematics, has become an integral part of 21st-century education. It's not just about imparting knowledge and skills in these areas but also about a dynamic process that is shaped by the experiences and interests of both students and teachers. This approach involves integrating at least two STEM disciplines, aiming for a comprehensive understanding of these interconnected fields (Corlu, 2017).

The importance of STEM education is immense, as it critically influences students' future career paths. Lack of exposure to STEM can limit opportunities in related fields (Bennison & Geiger, 2020). Recognized globally as essential for instilling 21st-century skills, STEM education transcends geographical boundaries (Choi & Hong, 2013). These skills are categorized into three dimensions: learning and innovation, literacy, and life skills, with the "4Cs" - critical thinking, communication, collaboration, and creativity - being pivotal for learning and innovation (Pardede, 2020).

STEM education cultivates these competencies, enabling students to develop as critical thinkers, collaborators, communicators, and innovators, crucial for success in the modern world (Nesmith & Cooper, 2019). By engaging young learners in hands-on STEM activities, educators can nurture their innate curiosity, creativity, and resilience, preparing them to thrive in an increasingly complex and technologically driven world. Furthermore, early exposure to STEM education can help bridge existing equity gaps by providing all children, regardless of their background, with equal opportunities to explore, experiment, and innovate (Buchter et al., 2017; Coley & Loh, 2018). Therefore, investing in high-quality STEM education during the early years is essential for ensuring that every child has the skills and confidence needed to succeed in the 21st century. Research indicates that meaningful hands-on experiences during preschool and primary school significantly influence children's perceptions and attitudes towards STEM (Bybee & Fuchs, 2006; Dejarnette, 2018).

Integrating STEM, particularly science and mathematics, into early childhood education is based on themes from children's play and interests (Campbell et al., 2018). Providing young children with meaningful science experiences develops essential science process skills like observation, classification, and reasoning, as well as engineering process skills such as teamwork and presentation (Abanoz, 2020; Başaran, 2018). Teachers implementing STEM education have observed positive impacts on children's abilities in research, problem-solving, and design, focusing on cognitive processes and social product outcomes (Abanoz & Yabas, 2023).

Proficient and knowledgeable educators play a crucial role in fostering children's comprehension of STEM concepts, practices, and cognitive habits. Competent teachers can leverage children's innate curiosity and promote developmentally suitable, STEM-integrated play to facilitate learning (Campbell et al. 2018; Clements et al., 2020; Nesmith & Cooper, 2019; Moomaw, 2013). Researchers highlight the importance of educator confidence in delivering STEM education in early childhood settings. Park et al. (2017) found that teaching experience, awareness of STEM's importance, and potential challenges positively influence educators' confidence. Low self-efficacy among educators, coupled with inadequate preparation and a lack of early childhood STEM and engineering curricula, contributes to the lack of STEM instruction (Dubosarsky et al., 2018).

In this context teachers are central to providing up-to-date scientific knowledge. However, there's a perception of a gap in their expertise, especially in the multidisciplinary realm of STEM (Mohd Saat et al., 2021). Studies indicate improvements in teachers' knowledge and skills in STEM education through professional development (PD) programs (Annawati et al., 2022; Akgündüz & Mesutoğlu, 2021; Ayob, 2020; Qablan, 2021; MacDonald et al., 2021). These programs also positively impact teachers' engineering self-efficacy and the implementation of engineering activities in classrooms (Nesmith & Cooper, 2019). Teachers' self-efficacy and classroom practices have evolved, leading to more effective STEM teaching strategies and positive perceptions about STEM (Avery & Reeve, 2013; Du et al., 2019; Gardner et al., 2019). STEM PD workshops aid in merging theoretical knowledge with teaching practices (Avery & Reeve, 2013).

Maass et al. (2019) highlight three challenges teachers face in implementing STEM education: the new nature of STEM education, the lack of clear understanding of individual subjects' roles, and a focus on one or two disciplinary expertise areas. According to McClure et al. (2017), elementary and early childhood education has been called the most "STEM-phobic." Although early childhood education is a unique opportunity to introduce STEM, many educators are underprepared to fully engage young children in rich STEM experiences (Clements et al., 2020). This potential is therefore often untapped. For this reason, PD for educators is essential to early childhood STEM education. Despite the importance of integrating disciplines in STEM, research shows a lack of integrated STEM theory and practice in pre-and in-service education (Brown & Bogiages, 2019). Effective integration of STEM activities requires a robust understanding of content-knowledge and skills, which can be enhanced through PD programs (Mohamad Hasim et al., 2022).

Early STEM: Integrated Teaching Framework

The STEM integrated teaching framework is a theoretical roadmap for STEM teaching developed based on different sources of information and data for STEM practitioner teachers, teacher educators, and researchers (Corlu, 2017). The framework offers a real-life problem-oriented pedagogy. The themes that allow the content and process integration represent the STEM disciplines (Figure 1).

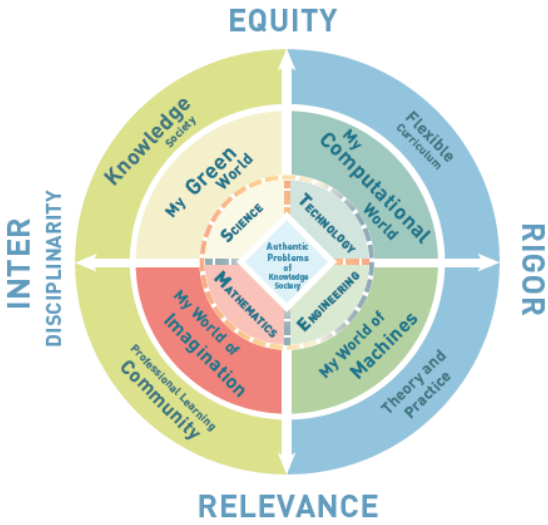

Figure 1. *The integrated teaching framework for EarlySTEM (Corlu, 2017)*

At the center of the STEM framework is the concept of Authentic Problems of Knowledge Society (APoKS), intricate challenges that reflect the dynamic nature of the 21st-century knowledge society (Yabas & Corlu, 2021). APoKS should align with children's interests and experiences, fostering the integration of multiple STEM disciplines and allowing for diverse solutions. Teachers and children collaboratively tackle these problems, engaging in cognitive processes and social production (Yabas & Corlu, 2021).

Regarding the lesson planning skills, teachers are expected to select a primary and at least one integrated STEM discipline, developing APoKS within the STEM cycline (cycle+line) model. These problems, contextualized in stories with characters and real-life issues, create an engaging learning environment. APoKS are crafted with specific constraints to guide understanding of product qualities and development processes, also introducing related professions and tasks (Corlu, 2017).

After writing the APoKS teachers are guided the follow The STEM cycline model (Figure 2) delineates a lesson process encompassing cognitive processes and social product creation, with children exploring APoKS, ideating solutions, and creating diverse social products like experimental designs, algorithms, prototypes, and mathematical models (Aşık et al., 2017).

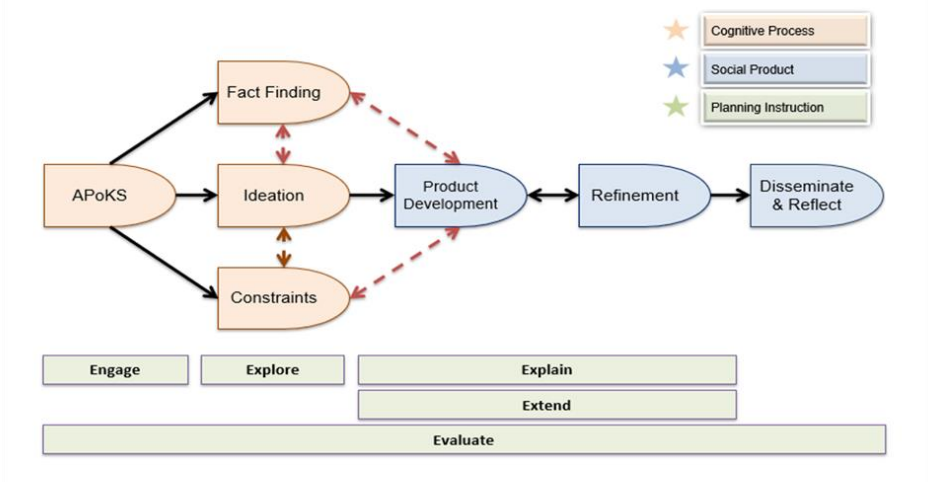

Figure 2. *STEM learning cycline (Corlu, 2017)*

Based on this theoretical framework, the study aims to determine the impact of the EarlySTEM Leader Teacher Professional Development (PD) Program for preschool and primary school teachers on creating APoKS. It is known that early childhood teachers' PD is crucial for improving both their teaching, their students' outcomes and interest in STEM (Moomav & Davis, 2010). Thus, working on the processes and practices of PD is believed to contribute to the relevant literature. The effectiveness of PD programs varies, indicating a need for quality PD guidelines for early childhood teachers. From this perspective, this research presents the implementation of integrated STEM education PD and its impact on teachers' lesson planning skills in STEM.

The research questions were as follows:

1) Is there a statistically significant difference in teachers' rubric scores on APoKS between the first and second STEM lesson plans?
2) How did social product objectives and social products change between the first and second STEM lesson plans?
3) How did the main and integrated disciplines change between the first and second STEM lesson plans?

Method

In the study of teachers' lesson planning skills, researchers utilized a dual-pronged approach, combining qualitative and quantitative methods within an embedded design framework, as outlined by Creswell and Plano-Clark (2018). This innovative approach integrated a qualitative strand into a quasi-experimental design, enhancing the depth and breadth of understanding.

The quantitative aspect involved analyzing lesson plan scores using a detailed evaluation rubric, allowing for a structured assessment of planning effectiveness. Concurrently, the qualitative component focused on document analysis, extracting additional insights from the teachers' comprehensive lesson plans.

By integrating these qualitative and quantitative findings, the study's robustness was reinforced. This methodological synergy, encompassing both depth and precision, provided a comprehensive exploration of teachers' lesson planning skills. The embedded design approach facilitated a nuanced examination of the topic, showcasing the effectiveness of combining diverse research methodologies to capture the complexity of teachers' competencies in educational research.

Study Group

In this study, 33 teachers, who are responsible for educating aged 5-10 children, participated in the EarlySTEM Leader Teacher Professional Development (PD) program. This group included 10 preschool and 23 primary school teachers, predominantly female, with 26 in total. All held undergraduate degrees in preschool or primary school education and had at least three years of teaching experience. Their participation was voluntary, highlighting their dedication to the field.

These teachers were affiliated with different schools under the same private educational institution, located in urban areas, and serving upper- and middle-class demographics. They were involved in implementing a standardized early STEM curriculum from kindergarten to fourth grade, developed collaboratively between the institution and a university's STEM Education and Research Centre.

This was their first experience creating their own integrated STEM lesson plans, adding a new dimension to their teaching. The STEM Leader Teacher PD program, designed by the university in partnership with the educational institution, combined academic and practical aspects, enhancing the teachers' skills, and contributing to STEM education.

Research Context

The research context was the Early STEM Leader Teacher PD program. This online PD program was organized by the STEM Education and Research Center of a private university in Turkey. Since 2015, the center has been a hub for STEM teachers, teacher educators/researchers, and pre-service teachers, making it one of the region's largest communities in this field. As evidence of its impact, more than 1,000 teachers participate in the center's online or face-to-face STEM PD programs each year (Corlu, 2017).

The EarlySTEM PD program was launched in September 2021, designed with an asynchronous online format. It provided weekly content for participant teachers to follow. The program aimed to foster sustainable interactions between teachers and teacher educators. The STEM Leader Teacher PD program spanned approximately four months and required 80 hours of engagement.

The program's content comprised digitally recorded workshops, online theoretical and practical lessons, as well as interactive tasks for teachers (Figure 3).

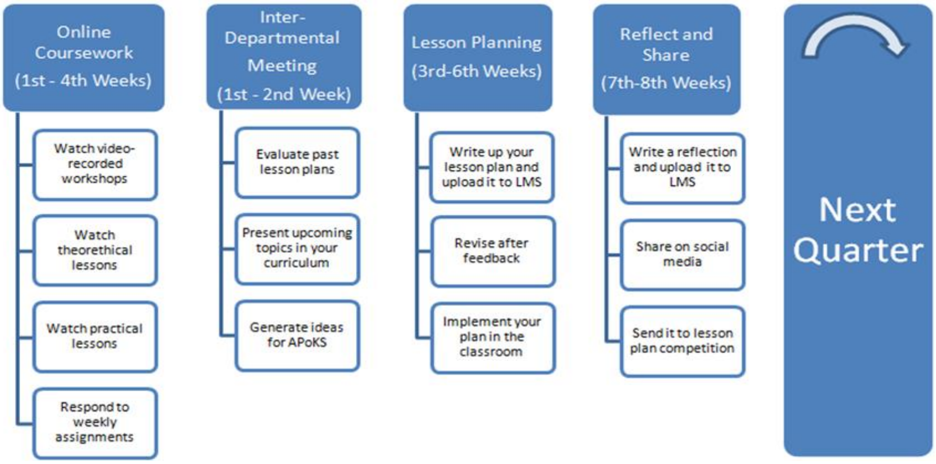

Figure 3. *Early STEM PD flow*

In the 2021-2022 academic year, the program consisted of two 8-week cycles in which teachers developed, implemented, and evaluated a STEM lesson in each cycle. The major topics and tasks in the program were as follows:

- Introduction to early STEM curriculum: In this section, teachers watch video-recorded workshops, theoretical lessons, and practical lessons. Teachers also complete and respond to weekly assignments on STEM education.
- How to write an APoKS: In this section, teachers are guided to write a real-life problem that allows interdisciplinarity, flexibility, and multiple solutions. Teachers are encouraged to create engaging problems related to the 21st-century contexts.

- Information about interdepartmental meetings: In interdepartmental meetings, teachers are expected to evaluate past lesson plans, present upcoming topics in the curriculum, and generate ideas for APoKS.
- STEM Cycline: Teachers are introduced to sections of the STEM cycline.
- STEM Lesson Plan Format and sample lesson plans: Teachers review the STEM Lesson Plan format covering all the sections in the STEM cycline. Sample lesson plans are also provided for the teachers to guide them when writing their own plans.
- Engineering Workshop: A sample APoKS centered around an engineering problem is presented with teaching-learning ideas, materials, and resources.
- Science Workshop: A sample APoKS centered around a science problem is presented with teaching-learning ideas, materials, and resources.
- Technology Workshop: A sample APoKS centered around a technology problem is presented with teaching-learning ideas, materials, and resources.
- Mathematics Workshop: A sample APoKS centered around a mathematics problem is presented with teaching-learning ideas, materials, and resources.

In the STEM lesson plans, the teachers had to design a curricula unit based on an APoKS. After the APoKS, they developed the lesson content according to the STEM cycline.

Data Collection and Analysis

Our study primarily focused on the STEM lesson plans created by teachers during the initial and subsequent cycles of the PD Program. These plans provided crucial insights into their instructional strategies. The PD program included a dedicated STEM lesson plan template and guide, designed according to the STEM: Integrated Teaching Framework, to ensure a cohesive pedagogical approach.

The STEM lesson plan template encompassed various components, including target objectives across STEM disciplines, necessary materials, and the integration of the APoKS. Lesson content was structured into phases: Fact-finding, Ideation, Product Development, Testing, Dissemination, and Reflection, each vital to the learning process.

These plans were crucial in shaping the participants' teaching methods, aligning with the principles of the STEM: Integrated Teaching Framework, and aiming to provide holistic learning experiences. Our analysis of these plans offered insights into the educators' ability to integrate diverse STEM elements into their teaching.

Developed following the STEM Learning Cycline (Corlu, 2017) and the 5E learning cycle, the lesson plans began with APoKS presentation, followed by fact-finding, ideation, and constraints exploration. Product development and refinement phases aligned with explaining and extending concepts. Formative assessments were integrated throughout, with summative assessments in the dissemination and reflection phases.

The lesson plans were evaluated using the APoKS rubric, assessing criteria like originality and interdisciplinarity on a 4-level scale. The frequency of scores for each criterion was documented for both cycles, and total rubric scores were calculated by summing points for each criterion. Mean scores were determined for both cycles, and descriptive statistics and the t-test for paired samples were used for analysis.

Social product objectives in the plans were categorized based on the 4Cs: Communication, Collaboration, Critical Thinking, and Creativity. Frequencies of these objectives were presented for both cycles, with examples from the teachers' plans quoted by the researchers.

Reliability and Validity

The STEM Lesson Plan Evaluation Rubric was originally developed by teacher educators who designed the STEM Leader Teacher Professional Development Program for middle and high school teachers. Over 5000 teachers from these levels participated in the program and used the original version of the rubric. The researchers adapted this rubric for early childhood education teachers.

To ensure inter-rater reliability, each researcher independently analyzed the teacher's lesson plans' APoKS concerning criteria such as originality of authentic context, resource utilization, flexibility of alternative solutions, integration of cognitive and social product processes, interdisciplinarity, professions and responsibilities, and constraints. Afterward, the researchers discussed their ratings and arrived at a mutual score for each criterion in the rubric.

During the data collection and analysis period, the researchers sought the input of a peer debriefer and maintained an audit trail to enhance trustworthiness. Sharing and elaborating on the STEM Leader Teacher PD flow (Figure 3) contributed to the concept of "transferability" in qualitative research. This approach allows readers of the research to develop an understanding of similar processes and adopt more conscious practices. To further enhance the transferability of the research results, detailed descriptions with direct quotations were utilized.

Ethical Procedures

The ethics committee permissions were obtained with the letter dated 07.12.2021 and numbered E-20021704-604.01.02-2245 of the Scientific Research and Publication Ethics Committee of Bahcesehir University.

Results

Regarding the first research question, we analyzed teachers' total mean scores for their first and second lesson plans. We observed an improvement in the second lesson plans' mean scores (Table 2).

Table 1. *Descriptive results for lesson plan scores*

	Mean	SS	Skewness	Kurtosis
Lesson Plan 1	18.67	5.62	-.63	-.28
Lesson Plan 2	22.55	4.98	-1.17	.87

We observed an improvement in the scores of second lesson plans. As the kurtosis and skewness values implied a normal distribution, we conducted a paired sample t-test to test the statistical significance. Paired sample t-test analysis to the mean scores indicated a statistically significant improvement regarding the total rubric scores ($t=4.25$, $p<.05$) (Table 3).

Table 2. *T-test results of the lesson plan's improvement*

	N	Mean	sd.	df.	T	p
Lesson Plan 1	33	18.67	5.62	32	4.245	.00
Lesson Plan 2	33	22.55	4.98			

The effect size of Cohen's d was calculated as 1.06, indicating a large effect.

In addressing the second research question, which focused on social product outcomes, teachers predominantly emphasized communication and cooperation among the 4Cs in both their first and second lesson plans (n=25 for cooperation, n=26 for communication in the first plans; n=16 for cooperation, n=25 for communication in the second plans). However, teachers included fewer creativity and critical thinking outcomes in both sets of lesson plans.

Researchers also observed a decline in the inclusion of creativity and critical thinking outcomes in the lesson plans. Specifically, in the first plans, only n=12 included critical thinking, and n=5 included creativity. This trend continued in the second plans, with even fewer instances of critical thinking (n=6) and creativity (n=3) being incorporated. (Table 4).

Table 3. *Social product objectives in STEM lesson plans grouped by 4Cs.*

Skills	Lesson Plan 1 (f)	Lesson Plan 2 (f)
Collaboration	25	16
Critical thinking	12	6
Communication	26	25
Creativity	5	3

The target objectives related to cooperation and communication mainly described the skills presented in group work. Examples of outcomes teachers included in their lesson plans were as follows:

Ss (students) express themselves in front of the group (communication).
Ss can develop friendships (cooperation).
Ss ask questions about what they listen to and watch. Ss answer questions about what they listen to and watch (communication).

Ss can take responsibility for themselves and their environment and fulfill their responsibilities (cooperation).

Teachers rarely included creativity and critical thinking objectives in their lesson plans. They mainly described the relevant skills in a problem context. Some of the teachers' outcomes in their lesson plans were as follows:

Ss suggest creative solutions to the problem (creativity).
Ss sketch pictures to develop ideas, solve problems, and understand relationships in the design process (critical thinking).
Ss explain the reason for the solution they chose (critical thinking).

Regarding the social product, teachers primarily directed their students to develop 2D/3D models or working prototypes (n=23) in the first lesson plans. In the second lesson plan, even though most of the lesson plans required the development of 2D/3D models or working prototypes, the frequency of algorithms and programs as social products increased (n=0 for the first, n=12 for the second lesson plan) (Table 5).

Table 5. *Social products in the first and second STEM lesson plans*

Type of Social Product	Lesson Plan 1 (f)	Lesson Plan 2 (f)
2D/3D models or working prototypes	23	14
Experiment design	9	4
Mathematical model	1	3
Algorithms and programs	0	12

A sample APoKS where the teacher directed the students to create a 2D/3D model was as follows:

Ahmet and Ali have many toy cars. They have a shortage of places to put their toy cars. Their mothers were also overwhelmed by this situation. They have brought used boxes from the supermarket. The mother asks the children to build a small parking lot for their toy cars with the boxes. In this way, the children will learn to play together and create a space for their cars (T101).

As in the sample APoKS, most teachers focused on developing models from recycled materials in their first lesson plans. In her second lesson plan, T101 included a computer game production in APoKS.

Emine, a preschool teacher for a younger age group, wants to teach shapes to her students. She realizes that her students confuse the pictures of square and rectangular shapes with each other. For this, she thinks she can teach her students the names of shapes more easily with a computer game. It can be a matching game. The game can have a warning system so that children get immediate feedback. Can you help Ms. Emine?

Teachers used different subjects to write their APoKS. Table 6 shows teachers' selected topics in their first and second lesson plans.

Table 6. *Topics of APoKS in STEM Lesson Plans*

Topic	1st Lesson Plan (f)	2nd Lesson Plan (f)	Topic	1st Lesson Plan (f)	2nd Lesson Plan (f)
Recycling	10	2	Geometry	1	2
Nutrition	1	0	Force	1	1
Plants	4	1	Transportation	2	2
Electricity	2	1	Numbers and patterns	0	3
Engineering design	3	1	Money	0	1
Animals	1	3	Coding/robots	0	8
Environment	5	6			
Materials	1	0			
Measurement	2	2			

Researchers observed a notable pattern in the first set of lesson plans, as teachers primarily chose recycling topics. The APoKS written by teachers in these plans involved the development of 3D tools and models using recycled materials. However, in the second set of lesson plans, teachers opted for different topics that were more STEM-related. These topics encompassed coding/robotics, numbers and patterns, and the environment.

As for the third research question, the analysis revealed that teachers predominantly based their lesson plans on the engineering discipline in the first cycle (n=17). In the second cycle, teachers shifted their focus and developed their plans with technology as the main discipline (n=11) (Table 7). Interestingly, mathematics did not serve as the primary discipline in the first cycle lesson plans, and only a few lesson plans in the second cycle were centered on mathematics. On the other hand, the first STEM lesson plans prepared by the teachers were predominantly centered around the science discipline.

Table 7. *Main disciplines in STEM lesson plans*

Main Discipline	Lesson Plan 1 (f)	Lesson Plan 2 (f)
Science	16	9
Technology	0	11
Engineering	17	10
Mathematics	0	3

Teachers mainly focused on building machines and working prototypes in their engineering-based lesson plans. In the first lesson plans, researchers observed that teachers mostly anticipated 2D/3D model development in their lesson plans. Parallel to this finding, they focused on engineering knowledge and skills throughout the learning process. For example, T34, in her first lesson plan, described the APoKS to show students the need to develop a helpful machine for agriculture:

> *Defne lived in a cute village with fertile soil that would sprout if a seed fell on the ground. Watching the soil turn from seed into sprout and sprout into fruit and vegetable always made her happy. However, many people from their villages moved to the city. Her mother and father, farmers, sadly told Defne that not enough people lived in the village anymore to help them in their fields. Moreover, thirst had arisen in their village. Defne first became very upset when she learned that crimson tomatoes and beautiful cucumbers would no longer grow in her gardens. But then "It's too early to give up! I will solve this problem," she said. According to Defne, agriculture was the future of the world. And she wouldn't stop working with her family to make the world a better place.*

The few lesson plans based on mathematics discipline described the APoKS to emphasize the need to teach mathematics concepts to the children with the help of technology:

> *Kübra teacher is doing rhythmic counting in math class. She observed that some students were struggling. To help her students, she decided to design a computer game. The difficulty of the game should match the students' needs. In this way, students will practice rhythmic counting, and they will not struggle anymore.*

Teachers mostly integrated the main discipline with mathematics in both cycles (n= 22 for the first, n= 21 for the second plans). Engineering was the second most discipline that was integrated with the main discipline (Table 8).

Table 8. *Integrated disciplines in STEM lesson plans*

Integrated Discipline	Lesson Plan 1 (n)	Lesson Plan 2 (n)
Science	4	2
Technology	3	1
Engineering	10	18
Mathematics	22	21

Teachers used the knowledge and skills of the mathematics discipline to support the solution of APoKS. They have mostly integrated measurement, shapes, and patterns themes into their lesson plans. The constraints of APoKS gave clues about which mathematical concepts or skills teachers included in the lesson plans. For example, T41 wrote the constraints to engage students in weight and height measurements: "The designed product should not be made of heavy materials so Badem (the dog) can pull it. The walker's length should be at the appropriate height of Badem."

Discussion, Conclusion and Recommendations

The study focused on the impact of a Professional Development (PD) program on teachers' STEM lesson planning, particularly in writing APoKS (Authentic Problems of Knowledge Society). Researchers observed a significant improvement in teachers' total scores, suggesting the effectiveness of the PD program. Key aspects of the program included:

- Emphasis on authentic, real-life problems in line with previous research (Owens et al., 2018).
- Integration of theory and practice, enhancing teachers' engagement and empowerment (John et al., 2018; Avery & Reeve, 2013).
- Opportunities for teachers to join a broader STEM community, share resources, and receive feedback, which are valued elements in PD (Owens et al., 2018).

The PD program helped teachers focus on communication and cooperation in their lesson plans, although there was a notable absence of critical thinking and creativity objectives. This could be attributed to a prioritization of group work and a lack of clarity in defining objectives for critical thinking and creativity (Stehle & Peters-Burton, 2019; Walan, 2021; Amran et al., 2021). The scarcity of creativity and critical thinking objectives can be explained by Vincent-Lacrin (2022), who notes the difficulty teachers face in making creativity and critical thinking tangible within lesson objectives, often leading to their underrepresentation. The effectiveness of integrating these skills depends on teachers' attitudes and their capacity to cultivate a learning environment conducive to risk-taking. Kelly (2016) posits that prioritizing communication and collaboration may serve as foundational steps toward enhancing creativity and critical thinking, suggesting a sequential approach to skill development. Ellerton & Kelly (2022) add that the application of creativity and critical thinking in STEM subjects requires intricate planning and a deep understanding of their interconnectedness, potentially deterring educators from including these objectives in lesson plans due to the complexity involved. Additionally, preschool teachers may lack extensive content knowledge in mathematics and science, affecting their ability to integrate creativity and critical thinking to these subjects (Moomaw, 2013).

This study found that teachers primarily focused on 2D/3D model production in STEM lesson plans. A shift towards including digital programs in the second set of plans was noted. This shift could be attributed to teachers' attempts to tailor STEM activities to align with children's developmental stages. Helping and enabling teachers to integrate technology into their teaching grew less of a daily curricular mandate and more of a source of support and value for their profession (Vaughan & Beers, 2017). The inclusion of concrete products in lesson plans may be a strategic decision, recognizing that many children are in the preoperational and concrete operational stages, where tangible experiences are crucial. Activities such as 2D/3D modeling and programming provide these hands-on experiences. Wan et al. (2021) noted in a review that research on the impact of STEM activities frequently emphasizes programming and traditional engineering design, reflecting this educational approach.

The findings reveal that mathematics is often marginalized in STEM lesson plans, treated more as a support than a focus. Herbert and Cripps Clark (2020) note that this oversight limits engagement with math concepts in real-world contexts. Mathematics is predominantly seen as auxiliary, aimed at supporting activities through calculations or measurements (Fitzallen, 2015). This approach may dilute the potential for mathematics to enrich STEM education by applying learned concepts in meaningful ways (Clements & Sarama, 2020). Consequently, this superficial integration risks portraying engineering tasks as trivial, akin to tinkering or crafting, rather than substantive educational experiences (Nesmith & Cooper, 2019).

Research has shown that STEM education plays a crucial role in equipping students with the knowledge and skills needed to address pressing environmental challenges. By engaging in hands-on, inquiry-based activities that integrate environmental topics seamlessly into STEM curricula, students can grasp the interconnectedness between scientific concepts and ecological sustainability. This approach not only enhances students' critical thinking, problem-solving, and creativity but also instills a sense of responsibility towards sustainable practices (Chatzopoulos et al., 2023; Nguyen, 2023).

Long-term PD programs based on integrated STEM education theory and practice are recommended for implementation to enhance teachers' proficiency. The Early STEM PD model can be adapted in various contexts for early childhood and primary school teachers. Co-teaching models and scientist-teacher-student partnerships (Mohd Saat et al., 2021; Yabas et al., 2023) are alternative approaches for STEM PD.

The improvement in teachers' APoKS writing skills suggests a growing interest in real-life contexts. Future research should encourage the development of complex, dynamic authentic problems to stimulate creativity and critical thinking. Additionally, further studies on the relationship between creativity development and STEM activities, focusing on children's creativity gains and the enactment of lesson plans, are recommended to deepen understanding of STEM teacher education.

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References

Abanoz, T. (2020). The examination of the impact of science education activities based on STEM approach on preschool term children’s science process skills. [Unpublished doctoral dissertation]. Gazi University.

Abanoz, T., & Yabaş, D. (2023). My world of machines: An integrated STEM education curriculum for early childhood teachers. *European Early Childhood Education Research Journal, 31*(3), 470-487. https://doi.org/10.1080/1350293X.2022.2127822

Akgündüz, D., & Mesutoğlu, C. (2021). Science, technology, engineering, and mathematics education for industry 4.0 in technical and vocational high schools: Investigation of teacher professional development. *Science Education International, 32*(2), 172-181. https://doi.org/10.33828/sei.v32.i2.11

Amran, M. S., Abu Bakar, K., Surat, S., Mahmud, S. N. D., & Mohd Shafie, A. A. (2021). Assessing preschool teachers’ challenges and needs for creativity in STEM education. *Asian Journal of University Education, 17*(3), 99-108. https://doi.org/10.24191/ajue.v17i3.14517

Annawati, B. D., Tamah, S. M., & Kumala Dewi, C. D. C. (2022). Improving early childhood teachers’ professionalism in STEM education. *International Journal for Cross-Disciplinary Subjects in Education (IJCDSE), 13*(2), 4678-4684.

Aşık, G., Doğança Küçük, Z., Helvacı, B., & Corlu, M. S. (2017). Integrated teaching project: A sustainable approach to teacher education. *Turkish Journal of Education, 6*(4), 200-215. https://doi.org/10.19128/turje.332731

Avery, Z. K., & Reeve, E. M. (2013). Developing effective STEM professional development programs. *Journal of Technology Education, 25*(1), 55-69.

Ayob, A. (2020). STEM-STEAM in early childhood education in Malaysia. Retrieved from https://www.childresearch.net/projects/pdf/projects_fullpaper_2020_03.pdf (25.07.2023).

Başaran, M. (2018). The applicability of STEM approach in preschool education (Action research). [Unpublished doctoral dissertation]. Gaziantep University.

Bennison, A., & Geiger, V. (2020). Numeracy across the curriculum as a model of integrating mathematics and science. In J. Anderson & Y. Li (Eds.), *Integrated approaches to STEM education* (pp. 117-136). Springer.

Brown, R. E., & Bogiages, C. A. (2019). Professional development through STEM integration: How early career math and science teachers respond to experiencing integrated STEM tasks. *International Journal of Science and Mathematics Education, 17,* 111-128.

Buchter, J., Kucskar, M., Oh-Young, C., Welgarz-Ward, J., & Gelfer, J. (2017). Supporting STEM in early childhood education. Policy Issues in Nevada Education, 1-12. Retrieved from https://digitalscholarship.unlv.edu/co_educ_policy/2.

Bybee, R. W., & Fuchs, B. (2006). Preparing the 21st century workforce: A new reform in science and technology education. *Journal of Research in Science Teaching, 43*(4), 349-352. https://doi.org/10.1002/tea.20147

Campbell, C., Speldewinde, C., Howitt, C., & MacDonald, A. (2018). STEM practice in the early years. *Creative Education, 9,* 11-25. https://doi.org/10.4236/ce.2018.91002

Chatzopoulos, A., Tzerachoglou, A., Priniotakis, G., Papoutsidakis, M., Drosos, C., & Symeonaki, E. (2023). Using STEM to Educate Engineers about Sustainability: A Case Study in Mechatronics Teaching and Building a Mobile Robot Using Upcycled and Recycled Materials. *Sustainability, 15*(21), 15187.

Choi, Y., & Hong, S. H. (2013). The development and application effects of STEAM program about "World of Small Organisms" unit in elementary science. *Elementary Science Education, 32*(3), 361-377.

Clements, D. H., & Sarama, J. (2020). Mathematics in early learning environments. In L. E. Cohen & S. Waite-Stupiansky (Eds.), *STEM in early childhood education* (pp. 63-80). Routledge.

Clements, D. H., Vinh, M., Lim, C.-I., & Sarama, J. (2020). STEM for inclusive excellence and equity. *Early Education and Development, 32*(1), 148–171. https://doi.org/10.1080/10409289. 2020.1755776

Coley, R. J., & Loh, M. N. (2018). STEM starts early: Grounding science, technology, engineering, and math education in early childhood. New America.

Corlu, M. S. (2017). Bütünleşik öğretmenlik çerçevesi [Integrated teaching framework]. In M. S. Corlu & E. Çallı (Eds.), *STEM kuram ve uygulamaları* [STEM: Theory and Practice] (pp.1-10). Pusula.

Creswell, J. W., & Plano Clark, V. L. (2018). *Designing and conducting mixed methods research* (3rd ed.). SAGE.

Dejarnette, N. K. (2018). Implementing STEAM in the early childhood classroom. *European Journal of STEM Education, 3*(3), 18. https://doi.org/10.20897/ejsteme/3878

Du, W., Liu, D., Johnson, C. C., Sondergeld, T. A., Bolshakova, V. L. J., & Moore, T. J. (2019). The impact of integrated STEM professional development on teacher quality. *School Science and Mathematics, 119,* 105-114. DOI: 10.1111/ssm.12318.

Dubosarsky, M., John, M. S., Anggoro, F., Wunnava, S., & Celik, U. (2018). Seeds of STEM: The development of a problem-based STEM curriculum for early childhood classrooms. In L. English, & T. Moore (Eds.), *Early engineering learning, early mathematics learning and development* (pp. 249–269). Springer. https://doi.org/10.1007/978-981-10-8621-2_12.

Ellerton, P., & Kelly, R. (2022). Creativity and critical thinking. In A. Berry, C. Buntting, D. Corrigan, R. Gunstone (Eds.), *Education in the 21st century: STEM, creativity and critical thinking* (pp.9-29). Springer

Fitzallen, N. (2015). STEM education: What does mathematics have to offer? In M. Marshman, V. Geiger, & A. Bennison (Eds.), *Mathematics education in the margins* (Proceedings of the 38th annual conference of the Mathematics Education Research Group of Australasia) (pp. 237–244). Sunshine Coast: MERGA.

Gardner, K., Glassmeyer, D., & Worthy, R. (2019). Impacts of STEM professional development on teachers' knowledge, self-efficacy, and practice. *Frontiers in Education, 4*(26), 1-10. DOI: 10.3389/feduc.2019.00026.

Herbert, S., & Cripps Clark, J. (2020). Putting the M back into STEM: Lessons from STEM professional development. *Australian Mathematics Education Journal, 2*(4), 11-17. https://search.informit.org/doi/10.3316/informit.654706729725825

John, M. S., Sibuma, B., Wunnava, S., Anggoro, F., & Dubosarsky, M. (2018). An iterative participatory approach to developing an early childhood problem-based STEM curriculum. *European Journal of STEM Education, 3*(3), 07. https://doi.org/10.20897/ejsteme/3867

Kelly, R. (2016). *Creative development: Transforming education through design thinking, innovation and invention.* Brush Education.

Maass, K., Geiger, V., Ariza, M. R., & Goos, M. (2019). The role of mathematics in interdisciplinary STEM education. *ZDM- Mathematics Education, 51*(6), 869–884. https://doi.org/10.1007/s11 858-019-01100-5.

MacDonald, A., Danaia, L., Sikder, S., & Huser, C. (2021). Early childhood educators' beliefs and confidence regarding STEM education. *International Journal of Early Childhood, 53*(3), 241–259. https://doi.org/10.1007/s13158-021-00295-7

McClure, E. R., Guernsey, L., Clements, D. H., Bales, S. N., Nichols, J., Kendall-Taylor, N., & Levine, M. H. (2017). *STEM starts early: Grounding science, technology, engineering, and math education in early childhood*. The Joan Ganz Cooney Center at Sesame Workshop. https://eric. ed.gov/?id=ED574402.

Mohamad Hasim, S., Rosli, R., Halim, L., Capraro, M. M., & Capraro, R. M. (2022). STEM professional development activities and their impact on teacher knowledge and instructional practices. *Mathematics, 10*(7), 1109. https://doi.org/10.3390/math10071109

Mohd Saat, R., Mohd Fadzil, H., Adli, D., & Awang, K. (2021). STEM teachers' professional development through scientist-teacher-students partnership (STSP). *Jurnal Pendidikan IPA Indonesia, 10*(3), 357–367. http://dx.doi.org/10.15294/jpii.v10i3.27845

Moomaw, S. (2013). *Teaching STEM in the Early Years.* Redleaf Press.

Moomaw, S., & Davis, J. A. (2010). STEM comes to preschool. *Young Children*, *65*(5), 12-18.

Nesmith, S. M., & Cooper, S. (2019). Engineering process as a focus: STEM professional development with elementary STEM-focused professional development schools. *School Science and Mathematics, 119*(8), 487–498. https://doi.org/10.1111/ssm.12306

Nguyen, T.P.L. (2023) Integrating circular economy into STEM education: A promising pathway toward circular citizenship development. *Front. Educ. 8*, 1063755. doi: 10.3389/feduc.2023.1063755

Owens, D. C., Sadler, T. D., Murakami, C. D., & Lin, C. (2018). Teachers' views on and preferences for meeting their professional development needs in STEM. *School Science and Mathematics, 118*(8), 370–384. https://doi.org/10.1111/ssm.12306

Pardede, P. (2020). Integrated the 4Cs into EFL integrated skills learning. *Journal of English Teaching, 6*(1), 71–85. https://doi.org/10.33541/jet.v6i1.1900

Park, M.H., Dimitrov, D. M., Patterson, L. G., & Park, D.Y. (2017). Early childhood teachers' beliefs about readiness for teaching science, technology, engineering, and mathematics. *Journal of Early Childhood Research, 15*(3), 275–291. https://doi.org/10.1177/1476718X15614040.

Qablan, A. (2021). Assessing teachers' education and professional development needs to implement STEM after participating in an intensive summer professional development program. *Journal of STEM Education, 22*(1), 75–80.

Stehle, S. M., & Peters-Burton, E. E. (2019). Developing student 21st Century skills in selected exemplary inclusive STEM high schools. *International Journal of STEM Education, 6*(39). https://doi.org/10.1186/s40594-019-0192-1

Vaughan, M., & Beers, C. (2017). Using an exploratory professional development initiative to introduce iPads in the early childhood education classroom. *Early Childhood Education Journal, 45*(3), 321–331. https://doi.org/10.1007/s10643-016-0772-3.

Vincent-Lacrin, S. (2022). Fostering students' creativity and critical thinking in science education. In A. Berry, C. Buntting, D. Corrigan, R. Gunstone (Eds.), *Education in the 21st century: STEM, creativity and critical thinking* (pp.29-49). Springer

Walan, S. (2021). The dream performance–a case study of young girls' development of interest in STEM and 21st century skills, when activities in a makerspace were combined with drama. *Research in Science & Technological Education, 39*(1), 23–43. https://doi.org/10.1080/02635143.2019.1647157

Wan, Z. H., Jiang, Y., & Zhan, Y. (2021). STEM education in early childhood: A review of empirical studies. *Early Education and Development*, *32*(7), 940–962. https://doi.org/10.1080/10409289.2020.1814986

Yabaş, D., & Corlu, M. S. (2021). STEM Leader Teacher. In S. Saraç, H. G. Ogelman, & D. Amca-Toklu (Eds.), *New Generation Teacher* (pp. 119–142). Vizetek.

Yabaş, D., Canbazoğlu-Bilici, S., Abanoz, T., Kurutaş, B. S., & Corlu, M. S. (2023). An exploration of co-teaching in STEM teacher professional development program in Turkey. In S. M. Al-Balushi, L. Martin-Hansen, & Y. Song (Eds.), *Reforming Science Teacher Education Programs in the STEM Era* (pp. 199–215). Springer.