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Changes in Preschool Teachers' Perceptions About Integrated STEM Education After a Professional Development Experience

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ABSTRACT This study explored how a professional development experience changed preschool teachers' perceptions of integrated STEM education. In addition, the research examined what teachers learned about STEM education with this experience. The study employed a qualitative research design, precisely a case study approach. Thirty preschool teachers participated in the study. The professional development program spanned seven days, with a total duration of 48 hours. Data for the research study were gathered through a questionnaire that included drawing and open-ended items, as well as through participant journals. Thematic analysis was employed as the data analysis method. The qualitative data were coded and categorized during the analysis process. Prior to the professional development, it was found that preschool teachers had different perceptions regarding integrated STEM education. These perceptions were superficial and exhibited inaccurate and incomplete understandings of STEM education. It was revealed that the professional development experience eliminated teachers' misunderstanding about STEM education and enabled them to gain a more complex understanding of STEM education. In addition, the study revealed that the professional development experience significantly enhanced teachers' understanding of the theoretical background of STEM education, facilitating their application of STEM and resulting in positive change in teachers' feelings towards STEM education.

Keywords STEM education, preschool teacher, perception

1. INTRODUCTION

In the 1990s, the term STEM was used to explain the subjects included in STEM education and the importance of learning them. At the beginning of the 2000s, STEM transformed and evolved into a concept for learning and teaching approach (Ergün, 2009; Yıldırım, 2018). While there are many explanations of STEM education in the literature, one comprehensive and widely accepted explanation is provided by Moore et al. (2015). STEM education integrates the learning and teaching of science and mathematics subjects with the applications and technologies related to engineering. Some characteristics of STEM education are different from other teaching methods:

1. Description of one or more subjects and the applications of science and mathematics disciplines as significant learning outcomes.
2. Integrated engineering practices and engineering design technologies.
3. Utilization of science and mathematics concepts during the validation process of engineering design or engineering practices concerning specific technologies
4. Emphasis on the development of 21st-century skills
5. Solving real-life problems or tasks in a teaching context involving teamwork

One of the ways for countries to secure a leading position in the global competition for scientific, economic, and technological dominance is to have a qualified workforce trained in STEM disciplines. However, very few young people are interested in pursuing careers in STEM. Most children determine which subjects they like and are good at during their higher education stages. Half of these children lose their interest in STEM fields by the time they reach the 8th grade, and thus, they do not want to pursue careers within these fields (Allen, 2016; Campbell et al., 2018). Although students are engaged in learning STEM disciplines, they often lack interest in pursuing careers in

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these fields (Brophy et al., 2008). This situation raises the question of when to start STEM education. Today, young children are described as individuals with unlimited potential to become scientists, problem solvers, engineers, innovators, creators, and leaders (Torres-Crospe et al., 2014). In recent years, stimulation's role in early brain development has been understood more clearly. Many educators acknowledge that experiences at early ages, especially during the first eight years of life, are decision-makers for individuals' future lives. Based on these, it has been accepted that the optimal focus on STEM education should be in preschool settings (Allen, 2016; Moomaw & Davis, 2010; Torres-Crospe et al., 2014). The potential of early childhood prior to elementary education must not be disregarded to lay the foundation of STEM learning and foster lifelong STEM literacy (Jipson et al., 2014). This perspective has gathered increasing support in the literature (Bagiati & Evangulou, 2015; Soylu, 2016; Sullivan & Bers, 2015).

Although the significance of STEM education across all age groups has gained global recognition, problems occur during its implementation at various learning levels, from preschool to higher education (Campbell et al., 2018; Li et al., 2019). The reasons for these problems can be attributed to several factors. One of the reasons for the problems is the teachers. The pedagogical requirements of STEM education are new, various, and extensive, requiring teachers to undergo intensive professional development (Aslam et al., 2018; Singer et al., 2016; Timur et al., 2019). Compared to other teachers, preschool teachers require more professional development in STEM education because most preschool teachers possess limited knowledge about STEM fields due to their educational background (DeJarnette, 2018; Jamil et al., 2018). Second, they do not feel qualified enough to teach science, mathematics, and engineering disciplines (Allen, 2016; Sharapan, 2012). Moreover, preschool teachers harbor dislike, fear, or avoidance of these disciplines (Clements & Sarama, 2016; Soylu, 2016).

Another critical reason for teachers' resistance to implementing STEM education is their lack of knowledge about what STEM education is (Margot & Kettler, 2019; Saratapan et al., 2019). Teachers' implementation of STEM education mainly depends on understanding what it is (Jamil et al., 2018; Radloff & Guzey, 2016; Ring et al., 2017; Kelley et al., 2016) since teachers' perceptions/concepts influence their practices (Ring et al., 2018). The conceptualization of STEM education is complex for teachers due to ambiguities and the acceptance of multiple definitions in the literature (Bybee, 2013). Due to all these reasons, a comprehensive professional development program was developed for preschool teachers and implemented in this study. In the context of this study, teachers primarily experienced STEM disciplines under the guidance of field experts during the STEM teacher training. For example, they participated in a study conducted by an engineer, enabling them to gain practical insights and knowledge about the engineering discipline. Then, they learned the theoretical background, history, reasons, and significance of integrated STEM education. In addition, the teachers underwent hands-on training to learn the application of STEM education in the preschool period. Previous studies (Çil, 2022) have highlighted that this type of teacher training has changed the participants' perceptions about STEM disciplines. The primary purpose of this study was to explore the changes in preschool teachers' perceptions towards integrated STEM education following their participation in the professional development experience. In line with this purpose, the study sought to answer the following research questions:

1. What are the perceptions of preschool teachers regarding STEM education? How does a comprehensive professional development experience change these perceptions?
2. What do preschool teachers learn about STEM education through the comprehensive professional development experience?

This study is essential for several reasons. First, there is a lack of research focusing on teachers' conceptualization of STEM education. The existing studies have been mainly carried out with elementary, middle, and secondary school teachers (Aslan Tutak et al., 2017; Aydın-Günbatar et al., 2018; Radloff & Guzey, 2016; Radloff & Guzey, 2017; Ring et al., 2017; Ring et al., 2018). As a result, the studies carried out with preschool teachers are quite limited in the literature (Simoncini & Lasen, 2018). This study differs from Simoncini and Lasen's study (2018) in that it explores the changes in teachers' understanding of STEM education following comprehensive professional development. Many studies in the literature offer opportunities for professional development experience to elementary, middle, and secondary school teachers. However, there is a noticeable lack of such opportunities provided to preschool teachers (e.g., Aldemir & Kermani, 2017; DeJarnette, 2018; Jamil et al., 2018; MacDonald et al., 2020; Uğraş, 2017; Uğraş & Genç, 2017; Yıldırım, 2021). Therefore, this study can significantly contribute to the existing literature about this subject, particularly concerning preschool teachers.

2. METHOD

2.1 Research Design

This study employed a qualitative research approach, specifically utilizing a case study research design. Case study design allows for an in-depth and detailed examination and analysis of a particular system, such as an individual, a group, an institution, or a program. The case study explores and describes the chosen case by collecting detailed and in-depth data from multiple sources, including observation, documents, and interviews (Merriam & Tisdell, 2015). This study examined the preschool teachers'

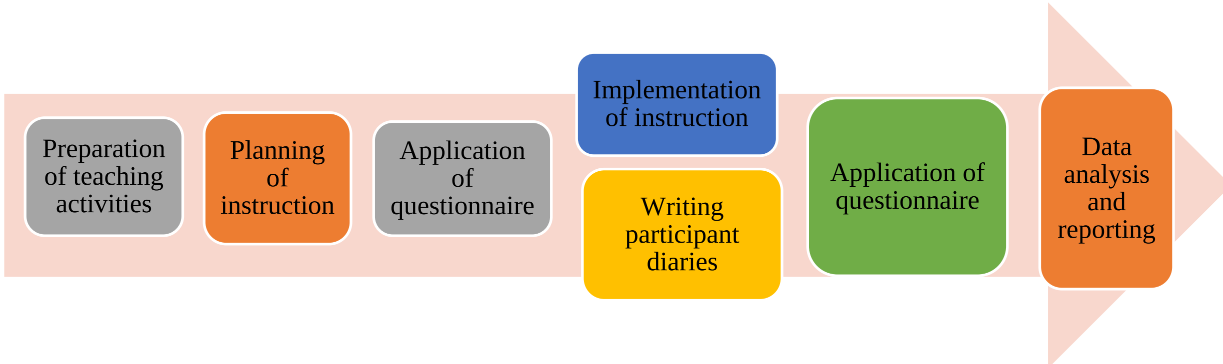

Figure 1 The scheme of the research mechanism

understanding of integrated STEM education. In addition, the study examined any changes in the teachers' perceptions of STEM education following their participation in a professional development training program. The study's exploration of preschool teachers' understanding and perceptions of STEM education and the impact of professional development on these perspectives contributes to the existing knowledge in the field. These teacher perception changes were investigated using various data sources, including drawings, open-ended questions, and participant journals. Due to these reasons, the case study research design is compatible with the purposes of the study. The research mechanism is presented in Figure 1.

2.2 Context of the Study

The study was conducted as part of the "Preschool Teachers' Experience of STEM+A Applied Training with Field Experts" project, which received funding from the Scientific and Research Council of Turkey (TUBITAK) and was carried out by Muğla Sıtkı Koçman University. The project was undertaken by Muğla Sıtkı Koçman University, where preschool teachers received training on STEM education in the project. The instruction lasted seven days, with 48 hours dedicated to professional development. Throughout the training process, the participants worked collaboratively in groups of five. The project was led by a science educator with expertise in STEM education, serving as the coordinator.

Moreover, a project expert specializing in preschool teacher education was involved. Nineteen instructors were responsible for training teachers in the project, including four academics from the Faculty of Science, two from the Engineering Faculty, and four from the Faculty of Technology. Under the guidance of academics, the participants worked as scientists, technologists, and engineers. In addition, the project team consisted of three academics specialized in science education and one specialized in elementary education, all of whom have publications in the field of STEM education. The project team included a retired academic with expertise in art education who taught the integration of art into STEM. In addition, an academic specializing in Turkish Language and Literature contributed to the team, offering guidance on integrating native language teaching into STEM education. Within the project team, two academics with expertise in the field of computer and programming taught coding, utilizing applications in STEM education. A professional experienced in creative drama was included in the project team to facilitate effective communication within team meetings. In addition, four mentors were involved in the project, guiding the study groups throughout the instructional process. Two of these mentors are doctors, and the others are scientists.

2.3 Participants

A total of thirty preschool teachers voluntarily participated in the study. Among the participants, 23 of them were female, and 7 of them were male. The participants had a teaching experience of 3 to 10 years in the field. They taught 4 to 5-year-old children. In addition, none of the participants had received detailed training on integrated STEM education before their involvement in the study. Before this study, 26.7% of the participants attended short-term in-service training, including three or four hours organized by the national education directorates in the provinces where they worked. The participants stated that during these trainings, they were introduced to the fundamentals of the integrated STEM education approach and presented the theoretical information about the teaching approach.

2.4 Data Collection Tool

The data for this study were collected via questionnaires and participant journals. Each data collection tool is explained below.

Questionnaire

The questionnaire included three items. First, the participants were asked to visualize and create in their minds when they first heard the concept of STEM education. Secondly, the participants were asked to provide explanations of their drawings. Finally, the participants were prompted to provide their definitions of STEM education. The questionnaire explored participants' perceptions through visuals and verbal definitions. The purpose of this approach was to reveal the participants' perceptions in a more accurate and detailed manner. An expert review team reviewed the initial draft of the questionnaire. A pilot was carried out with preservice preschool teachers and preservice science teachers. The questionnaire was administered both before and after the instruction.

Participant Journals

Each participant received a journal notebook on the first day of the instruction. They were asked to write their feelings and opinions in these journals based on their everyday experiences. All participants kept journals throughout the process and submitted them on the final day of the instruction. The primary purpose of the participant journals was to gather diverse and in-depth data.

2.5 Instruction

The instruction conducted within the context of the study served the following purposes:

1. Promoting preschool teachers' understanding of science, engineering, and technology.

2. Supporting preschool teachers' positive feelings and attitudes towards science, scientist, engineering, engineer, and technology.

3. Enhancing preschool teachers' understanding of integrated STEM education approach.

4. Improving preschool teachers' pedagogical content knowledge related to integrated STEM education.

5. Fostering preschool teachers' positive feelings towards integrated STEM education.

6. Encouraging/triggering preschool teachers to implement integrated STEM education.

The instruction consisted of various activities, which are presented below.

Introduction to STEM Education Approach

This activity explored the background, philosophy, and theory of the STEM education approach. The participants were given the historical context, importance, and reasons for adopting the STEM education approach. In addition, the activity involved defining STEM education and emphasizing its characteristics. During this process, the activity drew upon the framework proposed by Moore et al. (2014) and the definition put forth by Moore et al. (2015). The common mistakes made during STEM education were highlighted. Finally, participants exchanged ideas regarding the future of STEM education and its potential impact on preschools in the activity.

S in the STEM

During this activity, the participants engaged in the scientific process under the guidance of the scientists. The activity started with a science talk. The participants conducted two different experiments in a chemistry lab. In the first experiment, the participants utilized an indicator to classify substances as either acids or bases. In another experiment, they compared the materials by determining their density. The participants went for a short walk along the campus hiking trail after the experiments. During the walk, they observed different plant species and collected samples from these plants. They classified and studied the collected plant samples at a cafeteria located in the campus woods.

E in the STEM

The activity started with a presentation focused on defining engineering and providing examples of engineering achievement in our lives. Subsequently, the participants engaged in an engineering process under the guidance of field experts. They delved into producing and testing material with self-healing properties capable of replacing concrete while possessing similar qualities.

T in the STEM

Firstly, the activity started with a brief talk introducing the concept of technology. Then, the participants explored various technology applications under the guidance of the field experts. The participants had an opportunity to engage with three different technological applications. For example, the participants were designing a coffee table in the laboratories of Woodworking Industrial Engineering. They had the chance to observe and understand each step of the production process of the coffee table. The participants painted furniture using natural paints. In addition, the participants observed the complete process of creating products using a 3D printer from the initial stage to the final stage in the Microelectronics Systems Laboratories of Information Systems Engineering. The participants used thermal cameras to measure and compare the energy efficiency of structures with and without heat insulation in the Energy Efficiency Laboratories of Energy Systems Engineering. Moreover, the participants joined polypropylene pipes using fittings and a welding machine. Finally, after the pipes were heated to their melting point, they were shaped into STEM letters.

Poster Design

First, the participants talked about the concepts of science, scientist, engineering, engineer, and technology. In this process, they utilized their experiences with these three activities mentioned above. Then, the participants created three posters, each focusing on science, engineering, and technology.

STEM Education in Preschool Period

This task included a presentation on the appropriateness of STEM education concerning the developmental characteristics of preschool-aged children. It involved the benefits of starting STEM education early and explored various application models of STEM education, such as project-based, problem-based, and design-based approaches. It was mentioned in the literature that engineering design-based STEM was widely accepted. A diagram illustrating the engineering design process was presented. Then, the participants explained the design-based STEM education implementation process tailored for early school-age children. The importance of integrating various instructional activities such as games, reading in the native language, field trips to out-of-school settings, and inviting experts to the classroom was highlighted during the implementation of engineering design-based STEM education in early childhood education. Each integration was explained with examples.

A Sample Implementation of Engineering Design-Based STEM Education

Three engineering design-based STEM activities were implemented in this task, displaying the integration of instructional activities such as games, toys, and readings. One of the activities involved designing a multi-story car park. First, the participants had a construction set designed for a multi-story car park. They were given 15-20 minutes to engage and play with the toy freely. Then, pictures depicting the car parking problems in big cities were presented. These pictures were shared one by one, and each situation in the pictures was discussed. Afterward, the pictures showing attractive car park designs that accommodated many cars in a small space were displayed. Each photograph was discussed. Then, the participants were provided with work machines, three cars, and three motorcycles. They were asked to design a parking lot using cardboard/paperboard that could accommodate all the vehicles at the same time. The group that utilized the least amount of cardboard/paperboard while designing the parking lot with the desired features was chosen as the most successful group.

Art in STEM Education

The activity involved a presentation that discussed the art and interactions between art and various disciplines such as science, mathematics, engineering, and technology. The fundamental principles of art and the relationships between art and science, mathematics, engineering, and technology were highlighted. In addition, the traditional structures in Turkish architecture were emphasized, focusing on their structural properties. The activity continued with cisterns because many were constructed during the reign of Kanuni Sultan Süleyman, known as Suleiman, the Magnificent, in the city center and surrounding areas of Muğla. The participants were provided with basic materials and designed and constructed a cistern with the desired properties.

Story Writing in STEM Education

Information was given regarding the importance of native language activities in STEM education during the preschool period. The books used in STEM education were highlighted, drawing attention to the limited number of materials tailored for Turkish language instruction. The activity proceeded with creative writing activities. A story-writing activity, including an engineering design challenge designed for the children, was conducted. The participants were provided with a short storybook titled Our Bridge, written by the educators of this activity. The participants read the storybook. The academics explained the step-by-step process of creating the storybook. Following these steps and using the sample storybook, the participants wrote their own stories.

Coding Education

The activity started with a presentation addressing the following questions: What is programming? Why is programming education important? What is the relationship between programming and STEM education? Why is programming education crucial in early childhood education? What are the reasons for integrating programming education in early childhood education? What are the programming tools and types of programming tools used in early childhood education? Then, five activity examples were implemented.

STEM Education via Robotics Applications

Firstly, the activity provided information about educational robotics, its theoretical background, and historical development. The participants were explained the Lego Mindstorm ev3 Education set and its components. Three activities were carried out to teach STEM education through robotics applications. In one of these activities, the participants designed a three-wheeled vehicle. They programmed the device to follow a predefined path. In the second activity, participants utilized the components provided in the Lego kits, such as cogwheels, beams, axles, fittings, and bearings, to design a mechanism where the cogwheels were interconnected. This mechanism was programmed to execute the desired tasks, such as constant motor rotation. In the third activity, the participants used the pieces from the Lego kits to design a fire brigade ladder. By programming the mechanism, it was activated.

The Use of Mobile Device Applications in STEM Education

The participants were introduced to mobile device applications such as Bridge Basher, Play and Learn Science, Build a Bridge, and STEM and Maker Junior. These applications were selected for their suitability with the developmental characteristics of the preschool children and their potential to promote STEM education. The participants had the opportunity to use these applications on their own mobile devices. They also discussed using these applications as part of the STEM education. The activity ended with explanations of how teachers could utilize these applications.

Organization of Preschool Educational Settings for STEM Education

This activity occurred within a state preschool in the city center of Muğla. In this activity, a real preschool classroom was arranged to facilitate the implementation of a STEM education approach. First, the existing learning centers, such as the science, game, book, and block centers, were examined. The learning centers that could contribute

Figure 2 Photos from activities implemented throughout the instruction

to implementing STEM education were identified. In addition, the learning materials within these centers were examined. A discussion took place to explore the other learning materials that could be found in these centers to promote STEM education. The participants engaged in engineering design tasks using simple and inexpensive materials such as Lego pieces, wooden components, and cardboard. They undertook projects such as creating a walking track, constructing ramp systems, exploring a pendulum, and building bridges.

Out-of-School Settings and STEM Education

This activity included visits to historical towers, cisterns, and other STEM-related examples located in the city center of Muğla and its immediate surroundings. In addition to this, the participants visited a center that utilizes good agricultural practices. Moreover, a visit was organized to a marble workshop. The participants received an explanation of how to use each structure, center, and workshop within the context of STEM education. It was also emphasized that out-of-school settings could be visited for different purposes in STEM education. These included engaging in an engineering design challenge, solving an engineering design problem, and exploring the knowledge necessary to solve engineering design challenges.

STEM Activity Design

In this activity, the participants designed an engineering design-based STEM activity that could be integrated into a daily lesson plan. While preparing a daily lesson plan, various activities, including native language and games, were incorporated into the engineering design-based STEM activity. Different instructional activities, such as robotics applications, visits to out-of-school settings, and the utilization of mobile device applications, were included in their daily lesson plans. Photos from the activities implemented during the teaching process are presented in Figure 2.

2.6 Analysis of Data

During the questionnaire analysis, the drawings and accompanying explanations were examined together. The explanations were utilized to understand the drawings better and reduce subjectivity. In this process, existing studies on the visualization of STEM education in the literature were thoroughly reviewed. The codes developed by Bybee (2013), Radloff and Guzey (2016), and Ring et al. (2017) were analyzed. The participants' responses were analyzed by categorizing them based on the existing codes found in the literature. It was revealed that the codes in the literature were insufficient to categorize all the data obtained. Thus, there was a need to develop new codes. The process of adding new codes and re-categorizing the data was repeated until the researcher was satisfied with the codes. The codes and their definitions are presented in Table 1.

Thematic content analysis was employed to analyze the last item of the questionnaire and participants' journals. The thematic content analysis identifies and extracts essential, fundamental, and common themes and sub-themes in the qualitative data (Braun & Clarke, 2006). Through this analysis, themes emerge from the qualitative

Table 1 The codes used in the analysis of drawing test and their definition

Code's name	Identification of the code
Integrated disciplines	The teacher presented all disciplines included in the STEM. He is inclined to integrate the four disciplines into one another.
STEM as a seperate discipline	The teacher presented all disciplines included in the STEM. But he did not incorporate the disciplines. The disciplines are isolated from one another.
Two STEM disciplines in isolation from one another	The teacher presented two disciplines included in the STEM. For example, he did not involve disciplines of science and mathematics. He did not incorporate these two disciplines. He presented two disciplines in isolation from one another.
Engineering design process as a context	The teacher has a tendency to consider engineering design process as a context for teaching and learning other disciplines in STEM.
Teamwork	The teacher explains that STEM develops students' teamwork skills.
Problem solving	The teacher explains that STEM develops students' problem-solving skills.
Creativity	The teacher explains that STEM develops students' creativity skills.
Curiosity	The teacher explains that STEM enhances students' sense of curiosity
Interest	The teacher explains that STEM develops students' interest in STEM disciplines and/or school.
Happiness	The teacher explains STEM as a learning environment in which students are happy.
Robotics and/or coding	The teacher explains STEM education as a coding education and/or robotics application.
Computer-assisted teaching	The teacher explains STEM as a computer assisted teaching and/or an education through technological devices such as tablet.
Examples of common activities used in STEM education	The teacher explains STEM education as a range of activities frequently encountered in many resources including bridge, tower, and windmill constructions.
A traditional classroom design	A traditional class design in Turkey
No response	No drawing and explanation

data. Themes are not imposed by out-of-context (Fereday & Muir-Cochrane, 2006). The analysis process began with the research author reading the participants' texts to gain a thorough understanding of their statements. The sections included within the participants' texts, aligned with the purpose of the research, were highlighted with colored pencils. This systematic approach facilitated identifying and organizing the data based on meaningful sections and relevant themes. Then, a code list was generated. The participants' texts were re-read, and the codes were reviewed. Once the researcher was satisfied with the developed codes, the codes started to be categorized, leading to themes and sub-themes. Themes and sub-themes were revised a few times. In this process, themes and sub-themes were labeled.

The research author analyzed the data twice with a ten-day interval to ensure the reliability of the data analysis. However, there were differences between the researcher's analyses. Thus, the researcher sought the opinion of another expert to resolve these differences. The two researchers reached a consensus and agreed upon the final interpretation of the data. In addition to this, the consistency between two different coders was considered. Another researcher analyzed a quarter of the questionnaires and journals. The consistency between the two different coders was found to be 96%. Any inconsistencies were resolved through discussions between the coders. Then, frequencies and percentages were calculated.

3. FINDINGS

The data collected from the questionnaire was analyzed to address the first research question. The findings derived from the participants' STEM drawings are presented in Table 2 and Figure 3. When Table 2 and Figure 3 were

Table 2 The findings obtained from the participants' STEM drawings

Code's name	Before Instruction		After Instruction	
	f	%	f	%
Integrated disciplines	11	36.7	17	56.7
STEM as a separate discipline	6	20	1	3.3
Two STEM disciplines isolated from one another	1	3.3	0	0
Engineering design process as a context	2	6.7	7	23.3
Teamwork	0	0	1	3.3
Problem solving	1	3.3	7	23.3
Creativity	3	10	5	16.7
Curiosity	1	3.3	2	6.7
Interest	0	0	1	3.3
Happiness	0	0	1	3.3
Robotics and/or coding	0	0	1	3.3
Computer-assisted teaching	4	13.3	1	3.3
Examples of common activities used in STEM education (pasta bridge and etc.,)	1	3.3	0	0
A traditional classroom design	2	6.7	0	0
No response	1	3.3	0	0

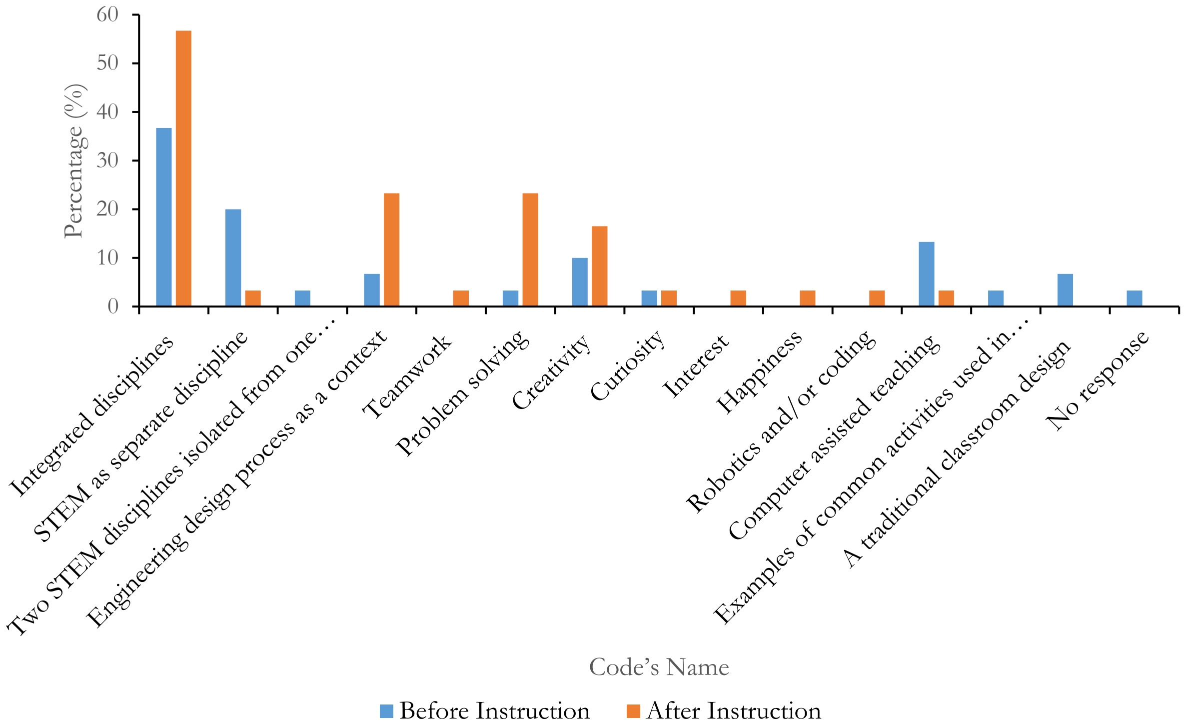

Figure 3 The findings obtained from the participants' STEM drawings

examined, it was evident that 36.7% of the participants perceived STEM education as an interdisciplinary learning and teaching approach before professional development. After the professional development, this ratio increased by 20%. Before the professional development, 23.3% of the participants stated that STEM involved the isolated learning or teaching of two or four disciplines. However, after the professional development, this understanding decreased by 20%.

Additionally, the findings revealed that after the professional development, there was a 16.6% increase in the proportion of participants who viewed STEM education as learning science and mathematics within the context of the engineering design process. These findings highlight the positive impact of the professional development program on participants' perceptions and understanding of STEM education. Following the professional development, the number of participants who perceived STEM education as a means of developing 21st-century skills increased by 30%. Moreover, there was a 10% increase in the proportion of participants who viewed STEM education as a positive learning process that elicits positive student feelings. Wrong and incomplete understanding of STEM education decreased by 23.4% after professional development. Examples of the participants' drawings can be found in Appendix 1.

When the participants' verbal descriptions of STEM education were analyzed, the findings presented in Table 3 and Table 4 were obtained. When Table 3 was examined, it was found that 53.4% of the teachers described STEM education as an approach where disciplines are taught and learned independently. Moreover, 13.3% of the

Table 3 The participants' descriptions of STEM education before the instruction

Category	f	%	Example Sentence
Interdisciplinary teaching	9	30	"It is an education that establishes a bond between the disciplines such as science, mathematics, and engineering." (Teacher 3)
STEM disciplines in isolation from one another	7	23.4	"It is an education that involves science, mathematics, and engineering." (Teacher 15)
Teaching two of the STEM disciplines independently from one another	9	30	"It is an education in the fields of science and mathematics." (Teacher 30) "It is teaching science and technology to children of different ages." (Teacher 12)
Developing skills	8	26.7	"It is a system that aims at using scientific knowledge in daily life as a skill rather than memorizing it. It is an education that allows problem-solving, doing research, and creativity." (Teacher 2)
Material Design	4	13.3	"STEM education facilitates developing materials in science and technology education." (Teacher 29)

Table 4 The participants' descriptions of STEM education after the instruction

Category	f	%	Example Sentence
Developing 21st century skills	16	53.3	"It is an education approach using technology and engineering disciplines together to develop children's problem-solving, creativity, critical thinking, teamwork, and collaborative skills." (Teacher 18)
Learning within the context of everyday life	2	6.7	"It is an approach which integrates mathematics, technology, and engineering. In addition, it highlights real life experiences, and teaches them by adapting them to the real life." (Teacher 12)
Interdisciplinary education	30	100	"STEM is an acronym that stands for the disciplines of science, technology, engineering, and mathematics. The first letters of the words are used. It is the integration of all disciplines." (Teacher 19)

participants described STEM education as the process of designing materials. In other words, it was detected that 66.7 % of the participants held incomplete perceptions or misunderstandings about STEM education prior to the professional. Upon reviewing the Table, it was revealed that after the professional development, all participants emphasized interdisciplinary education in their descriptions of STEM education. In addition, 53.3% of the participants added that students acquire 21st-century skills in their descriptions, and 6.7% of them highlighted learning within everyday life.

The participants' journals were analyzed to address the second sub-problem, and the findings were presented in Table 5. Upon examining Table 5, it became evident that 36.7% of the participants provided highly detailed descriptions in their journals, including all the essential characteristics of STEM education. In their journals, nearly all participants included their learnings about implementing STEM education in the preschool period. Between 6.6 %

Table 5 Findings obtained from the participants' journals

Theme	Sub-theme	f	%	Example sentence
Learning about theoretical background of STEM education	Basic characteristics of STEM education approach	11	36.7	"STEM education has five basic characteristics: Focusing on the concepts of science and mathematics, implementing science and mathematics in engineering, integrating four disciplines, focusing on real-life problems and developing 21st-century skills" (Teacher 25)
	Basic characteristics of STEM education approach in preschool period	3	10	"There are several characteristics of STEM education that are a must in early childhood education. These include the following: Concrete experience, a single question leading to research, action-reaction acting simultaneously, contexts including games and toys that draw children's interest, activities that integrate with language." (Teacher 11)
	History of STEM education	5	16.7	"STEM education approach evolved in the Unites States of America. Different countries started to implement it in their own countries due to some reasons." (Teacher 20)
	Importance and justification of STEM education	3	10	"We need STEM education in order to be able to develop and produce the technologies that will dominate the world. Our students who are glued to the tablets and telephones cannot use these devices efficiently and effectively. In the future, we must be the producers but, not the consumers of them." (Teacher 23)
Learning about application models of STEM education	Engineering design-based STEM education	27	90	"There are different ways to implement STEM education including engineering design-based STEM, robotics applications, project-based STEM, and SOS models. But it is widely used as engineering design-based approach. Engineering tasks are provided in the engineering design-based STEM activities. Knowledge is both acquired and explored. Designs are developed with the integration of disciplines. In early childhood education, the process is supported with games and story reading." (Teacher 20)
	STEM education with Robotics applications	25	83.3	"I realized the following in robotics applications: there is no limit to turn dreams into reality. Technology removes many obstacles. It is much easier to make our dreams come true. While creating our designs with our robotic sets in STEM education, many are elliminated." (Teacher 7)
	Benefiting from stories in STEM education during the preschool period	11	36.7	"It is very important to use stories in STEM education. Stories are very important in preschool period. I think stories certainly have a very important place in STEM education. While practising STEM education in my class, I will absolutely use story reading." (Teacher 7)
	Benefiting from out-of-school settings in STEM education	12	40	"We went to the natural stone workshop. It was really an interesting trip. I came up with an idea that I could organize similar trips within the context of STEM education in the school where I work." (Teacher 10)

Table 5 Findings obtained from the participants' journals (*Continued*)

Theme	Sub-theme	f	%	Example sentence
Learning about application models of STEM education	Benefiting from out-of-school settings in STEM education	12	40	"We went to the natural stone workshop. It was really an interesting trip. I came up with an idea that I could organize similar trips within the context of STEM education in the school where I work." (Teacher 10)
	Benefiting from mobile device applications in STEM education	24	80	"We learned the applications that could be used on smart phones and tablets to enhance STEM education. These applications could be used both in the classroom and outside the school under the control of the families. I almost have already shared these applications with parents." (Teacher 13)
Making an inference for the application	Recognizing the importance of following engineering design process step-by-step	3	10	"We constructed our design idea without drawing in the cistern activity, but the product was unsatisfactory. I learned through experience that it was very important to design the product on the paper during the engineering design process." (Teacher 7)
	Testing the design created and recognizing the importance of evaluation	6	20	"What I realized during the robotics applications is that it is very important to develop a design after testing the design, analysing the deficiencies in the design, and making accurate evaluations." (Teacher 30)
	Recognizing the importance of content knowledge	2	6.6	"Today we designed a cistern and constructed it. We succeeded in developing a product. But I was not satisfied with it. I believe that my lack of content knowledge in science had an effect on my design. If I had good content knowledge of science, we would have designed a much better cistern now." (Teacher 24)
	Recognizing the importance of teamwork	2	6.6	"While conducting robotics applications, I realized the importance of teamwork. Design process is much more productive with teamwork." (Teacher 1)
Affective learning	Tendency towards the implementation of STEM education	21	70	"What I have learnt here will not finish here. We, participants, will implement STEM education across Turkey." (Teacher 28)
	Attitudes and values	3	10	"I liked STEM education thanks to this training. Can a teacher implement something that he does not like or internalize? It is now much easier for me." (Teacher 25)

and 20% of the participants expressed an awareness of the critical factors to consider when integrating engineering design-based STEM in the classroom. 80% of the participants felt optimistic about the STEM education approach. In addition, they practiced this approach with their own children and strongly liked and internalized the STEM education approach for their students.

4. DISCUSSION

This study focused on revealing preschool teachers' perceptions towards integrated STEM education and investigated how these perceptions evolved after a detailed and comprehensive professional development experience. Based on the findings of this study, it can be concluded that preschool teachers had simple, diverse, and superficial perceptions of STEM education. In addition, it can be determined that preschool teachers exhibited certain misunderstandings and incomplete understanding of STEM education. These findings align with the existing studies in the literature (Radloff & Guzey, 2016; Ring et al., 2017; Simoncini & Lasen, 2018). One of the misconceptions and incomplete understanding about STEM education is that the four disciplines included in STEM are taught in isolation. Another is that two disciplines are taught separately and independently (Campbell et al., 2018; Radloff & Guzey, 2016; Ring et al., 2017; Simoncini & Lasen, 2018). In addition, teachers described STEM education as an approach involving activities such as computer-assisted education, material design, and building pasta bridges; however, there are some other misunderstandings and lack of understanding among teachers. The primary reason for these results is preschool teachers' insufficient exposure to comprehensive STEM education training.

Following a comprehensive professional development experience, the preschool teachers described STEM education as an approach that integrates four disciplines, fosters the development of 21st-century skills, emphasizes learning in real life, and incorporates an integrated engineering design process. In other words, teachers' understanding of STEM aligns with Moore et al. (2014) and Moore et al. (2015). Following the professional development, it was found that a small number of teachers still had misunderstandings and incomplete understandings regarding STEM education. Based on these findings, it can be concluded that the comprehensive professional development enhanced the accuracy and depth of preschool teachers' understanding of STEM education.

These findings are consistent with the results obtained from the studies carried out with elementary, secondary, and high school teachers in the existing literature (Aslan Tutak et al., 2017; Aydın-Günbatar et al., 2018; Radloff & Guzey, 2017; Ring et al., 2017; Ring et al., 2018). One of the reasons for the obtained findings is that professional development can be utilized to educate teachers about STEM education. During the professional development, all subjects were taught, enhancing learning through integrating theory and practice, primarily focusing on practice-based learning. Firstly, the subjects were introduced through a brief explanation of the underlying theory, followed by multiple model implementations on each subject. That is, throughout the professional development, the teachers learned about STEM education and engaged in practical applications. It is stated in the literature that when providing professional development for teachers on STEM education, offering opportunities for experiential learning is considered a practical approach to learning it (DeJernatte, 2018; Nadelson et al., 2013; Shernoff et al., 2017). The literature supports the notion that providing teachers with opportunities for hands-on learning during professional development is an effective method for learning about STEM education. By incorporating a "learning by doing" approach, teachers can engage in direct experiences and applications of STEM principles, enhancing their understanding and mastery of the subject matter.

Another reason is that professional development allows teachers to create products, including activities, daily lesson plans, and storybooks, to use in their classes while implementing STEM education. While developing these products, teachers can understand STEM education much better. As a result of the professional development experience, more teachers described STEM education as a learning process that promotes students' curiosity, interest, and happiness. Based on these findings, it can be concluded that the professional development experience contributed to the teachers' understanding of STEM education, enabling them to support their students' affective characteristics. The reason for this is that teachers themselves must have experienced these feelings throughout the STEM implementations. The participants experienced various STEM education implementation models, such as engineering design-based STEM and STEM via robotics applications, as if they were students. It was observed that the teachers enjoyed this process, demonstrated interest in the activities, took photos of the process, and shared them on their social media accounts.

This study also investigated what preschool teachers could learn about integrated STEM education through a comprehensive professional development experience. Based on the findings from the participant journals, professional development enhanced preschool teachers' understanding of the theoretical background of STEM education. This result aligns with existing literature on the topic (Aldemir & Kermani, 2017; Erdoğan & Çiftçi, 2017; Ong et al., 2016; Yıldırım, 2021). Throughout the professional development process, the participants clearly understood the definition, history, reasons, and importance of STEM education. These issues were discussed before teaching how to implement STEM education. Thus, the finding is not surprising. It can be concluded that professional development contributed to the teacher's understanding of the implementation of integrated STEM education in multiple ways.

The literature also documented similar findings (Aslan Tutak et al., 2017). The rich content of the professional development can be identified as one of the reasons for these findings. Throughout the professional development, the participants had an opportunity to experience different implementation models of STEM education, including engineering design-based STEM, STEM through robotics applications, STEM in out-of-school settings, and the utilization of mobile device applications in STEM in early childhood education. It can be concluded that professional development contributed to the teachers making inferences about the factors they need to consider when implementing STEM education in their classes. The primary reason is that teachers worked as if they were students in the professional development program. For example, the teachers actively engaged in the activities focusing on the STEM education models, assuming the students' role. The teachers must have realized what challenges students may encounter and what reactions they may give during the STEM implementations. It could be concluded that professional development experience positively affected the participants' feelings towards integrated STEM education. This result is consistent with the existing literature (DeJernatte, 2017; Kaya et al., 2017; Ong et al., 2016). Therefore, the teachers learned about the STEM education approach, including its underlying reasons and importance. The literature suggests that teachers' knowledge could change their feelings (Jamil et al., 2018).

5. CONCLUSION

This study implies that preschool teachers who have not received comprehensive professional development may possess superficial and limited understanding and misunderstanding regarding STEM education. Hence, providing professional development opportunities on STEM education to preschool teachers could be a precious attempt. An approach to STEM professional development involves bridging the gap between theoretical knowledge and its implementation. Also, STEM disciplines, the institutional background of STEM education, and the implementation of STEM education through learning by doing or experiential learning could be taught in this STEM professional development program. In addition, it was observed that while engaging in STEM activities, the teachers, assuming the role of students themselves, acquired in-depth knowledge about basic concepts and topics in the science discipline, which was very important in this study. Thus, future STEM education professional development training for preschool teachers is recommended to focus on a specific science topic, such as ecosystems and energy. Therefore, this approach can be practical in designing the entire training session around this theme. Both visualizations and verbal descriptions allow for exploring teachers' understanding of STEM. There is a compatibility between the findings obtained from visualization and verbal descriptions. Moreover, some findings emerged only from either visualizations or verbal descriptions. Thus, it is suggested that future studies focusing on teachers' understanding, perceptions, and conceptualizations of STEM education should collect different data types.

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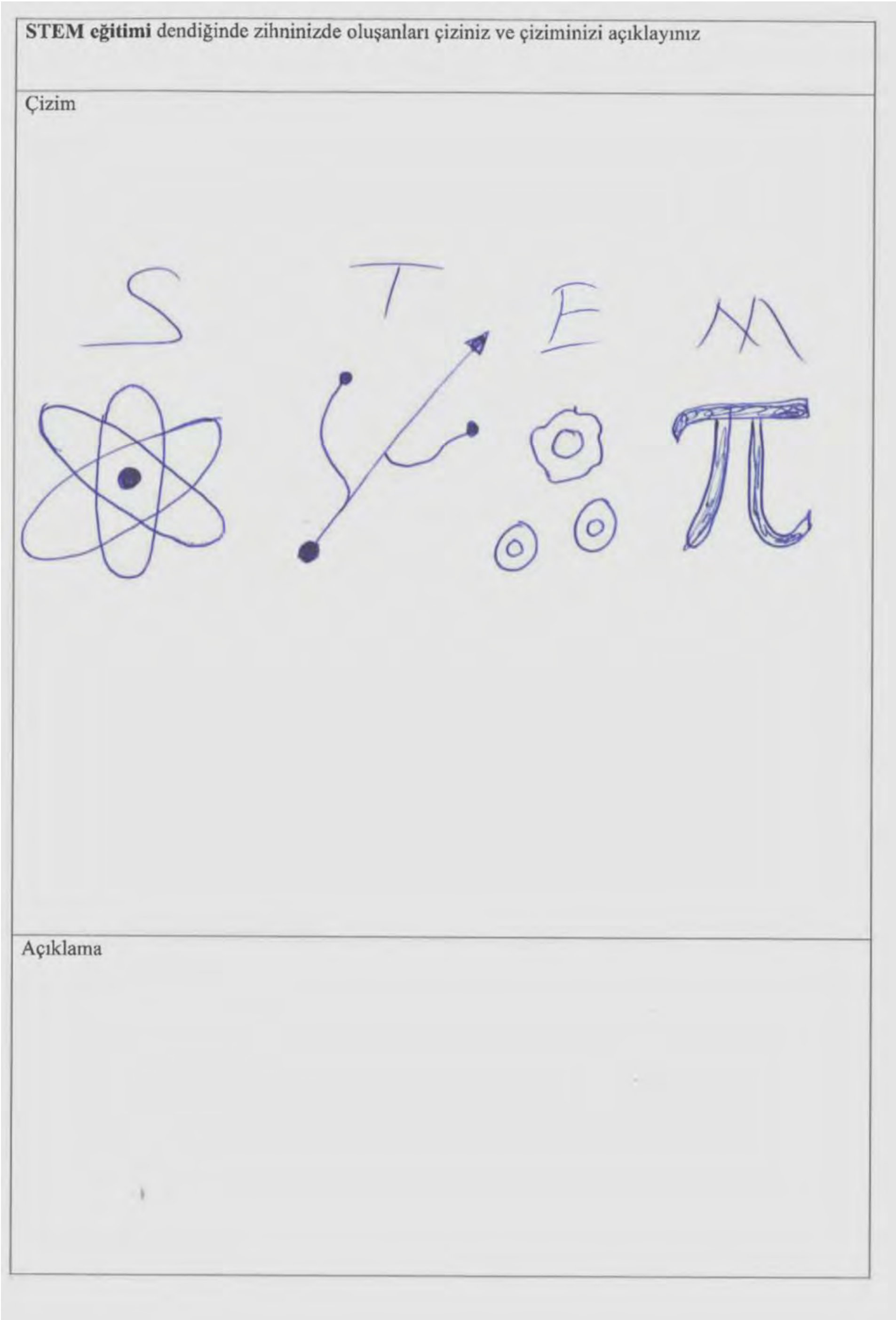
APPENDIX

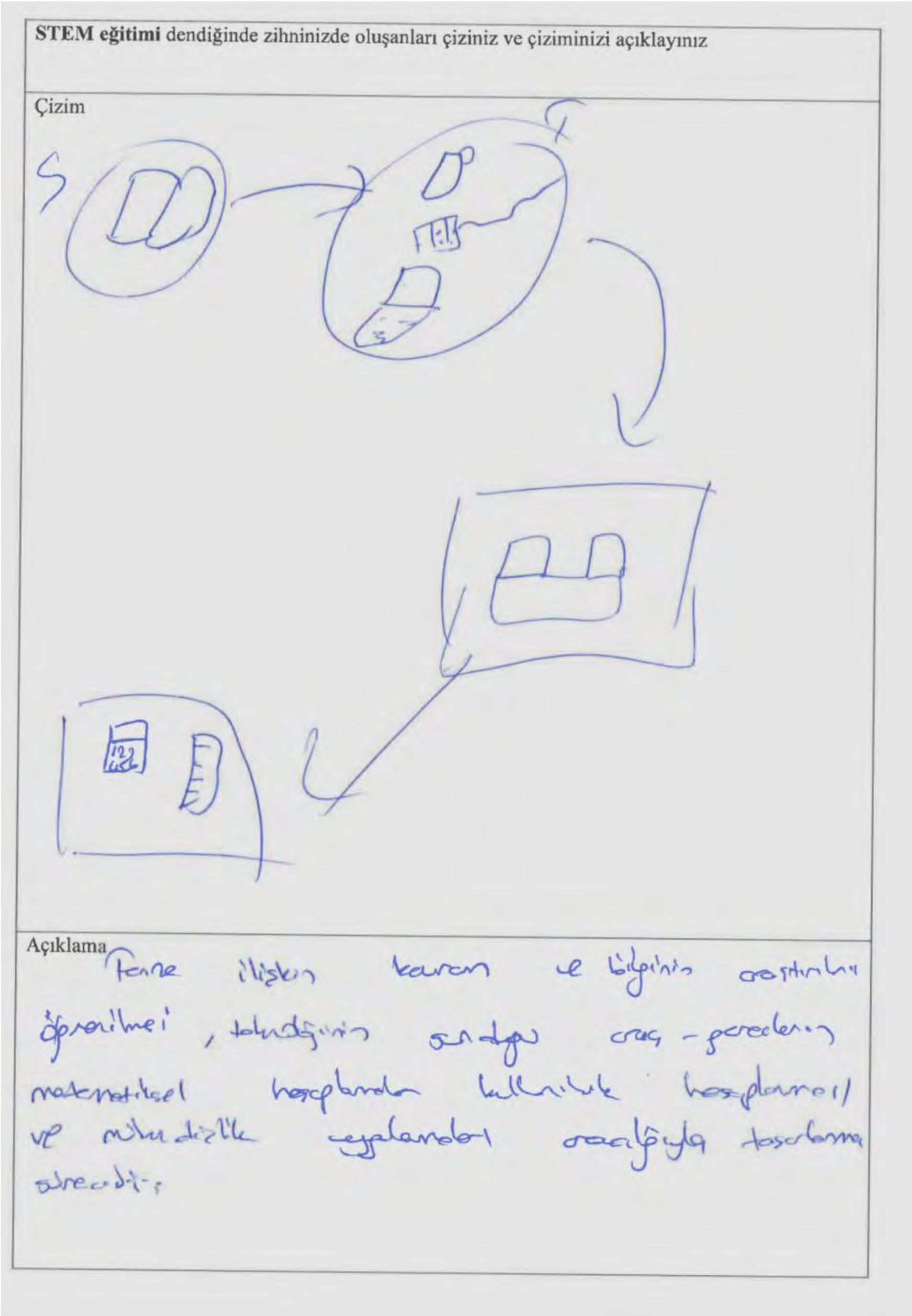
Appendix 1. Examples from participant drawings

Integrated disciplines (Teacher 16)

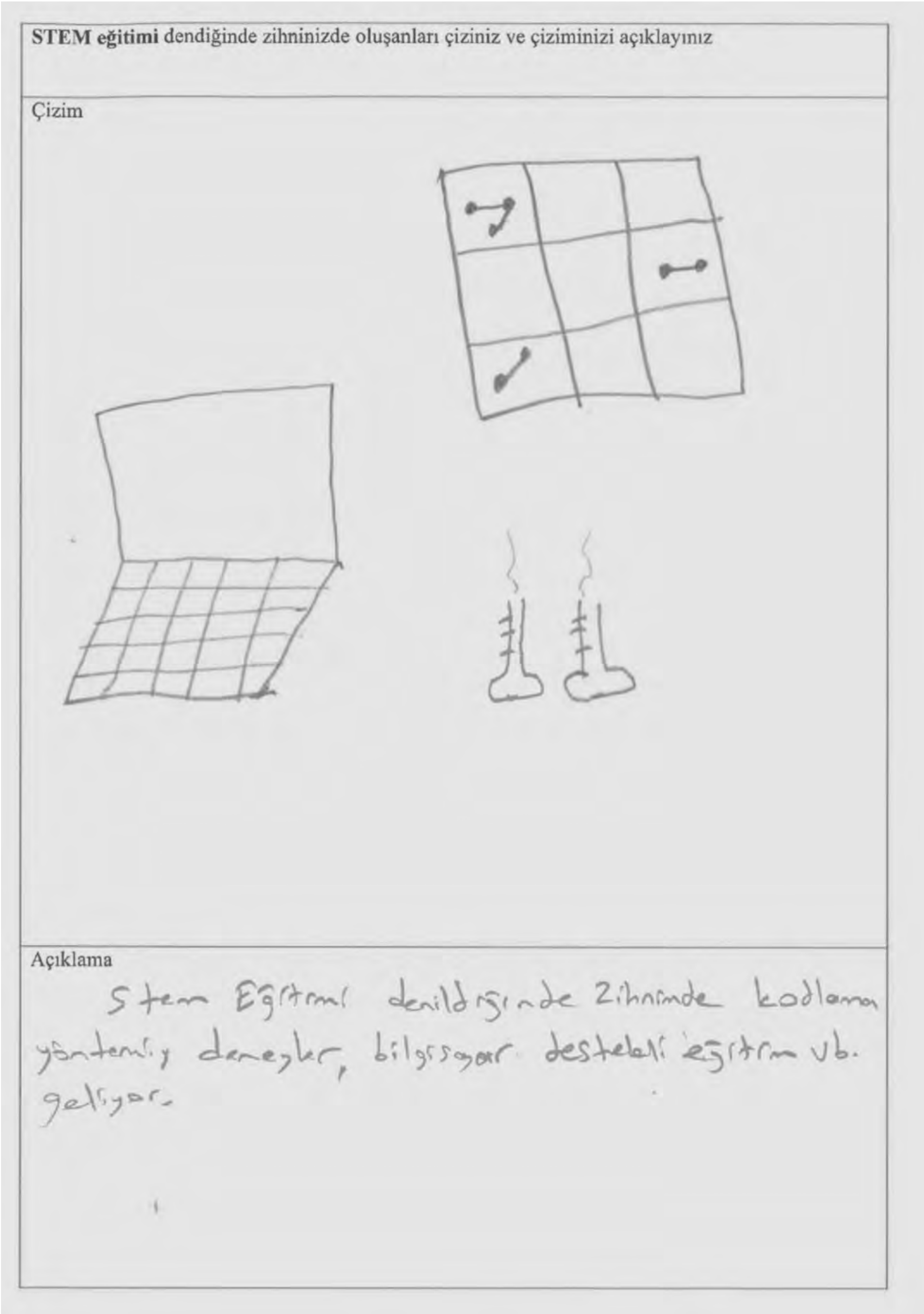
STEM is like a table in which science, technology,engineering, and mathematics form the one leg of it. These discipline should be integrated into each one another other and then a product is released. Each of these disciplines is significant in this design.It is a design in which each of these disciplines is important.



STEM as separate discipline (Teacher 26)



Engineering design process as a context (Teacher 27)
It is an engineering design process about examining and learning concepts and knowledge about science, mathematical calculations using technological equipment and tools, and designing through engineering applications.



Robotics and/or Coding (Teacher 22)
What comes to my mind about STEM education is coding method, experiments, computer-enhanced education, and so on.