Journal of Turkish Science Education, 2022, *19*(3), 718-739.
DOI no: 10.36681/tused.2022.146

Journal of Turkish Science Education
http://www.tused.org
© ISSN: 1304-6020

Pre-school Teachers' Change of Perceptions of Engineering Through a Professional Development Experience

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ABSTRACT
In this study, an instructional programme was designed and implemented with pre-school teachers to teach them about integrated STEM education. This paper focused on how this instruction changed teachers' perceptions of engineering. The study aimed at exploring what the teachers learned about engineering, one of the STEM disciplines, throughout their exposure to this programme. Thirty teachers participated in the study. Data was gathered via a drawing test and participants' diaries. For the analysis of the drawing test, a numerical coding system developed by Thompson and Lyons (2008) was used. Thematic content analysis was used for the qualitative analysis of the drawing test and the analysis of participant diaries. It was indicated that professional development experience enhanced pre-school teachers' perceptions of engineering. It was found that this programme helped teachers realise their deficiencies in relation to their engineering perceptions of engineering and rectify them. It was found that this professional development experience had positive effects on learning content knowledge in a specific engineering discipline and supporting positive feelings towards engineering.

RESEARCH ARTICLE

ARTICLE INFORMATION
Received: 21.08.2021
Accepted: 15.03.2022

KEYWORDS:
Perception of engineering, conception of engineering, engineering images, STEM education.

To cite this article: Çil, E.. (2022). Pre-school teachers' change of perceptions of engineering through a professional development experience. *Journal of Turkish Science Education*, *19*(3), 718-739.

Introduction

The importance of the STEM approach has been recognised globally. There are numerous reasons why STEM education is gaining in popularity, one of the most being related to commerce: the realisation that countries need a qualified workforce in STEM fields in order for the national economy to not fall behind in terms of global competitiveness. The STEM education approach is considered as the best way to meet this need (National Research Council, 2011).

There are different models of integrated STEM education in the literature, but it is generally understood that STEM education includes various elements relating to the disciplines to be integrated, the quality of cognitive tasks, learning goals, intended outcomes, application models, and learning environments (Shernoff, Suparna, Bressler, & Ginsburg, 2017). It is widely held that engineering is the backbone of integrated STEM education in K-12 education (Çepni, 2017; Moore, Glancy, Tank, Kersten, & Smith, 2014; Moore, Johnson, Peters-Burton, & Guzey, 2015).

Engineers are people who solve real-life challenges such as people's comfort, people's needs, by applying of physics, chemistry and biology (Oware, Capobianco, & Diefes-Dux, 2007). The engineering design process includes the recognition of unique processes, qualities expected from the solution, and the limitations imposed by the local context (Cunningham & Kelly, 2017; Lachapelle, Cunningham, & Lindgren-Streicher, 2006). Engineers need creativity to find applicable and innovative solutions (Cunningham & Kelly, 2017).

The world we live in is surrounded by engineering artifacts. Despite this, many individuals harbour inaccurate knowledge about what engineers do and what engineering is (National Academy of Engineering, 2008). Unsurprisingly, studies report that K-12 students' understanding of engineering varies. Students tend to have stereotypical opinions about engineering including some common misconceptions (Capobianco, Diefes-Dux, Mena, & Weller, 2011; Cunningham, Lachapelle, & Lindgren-Streicher, 2005; Ergün & Balçın, 2018; Ergün & Balçın, 2019; Fralick, Kearn, Thompson, & Lyons, 2009; Gülhan, & Şahin, 2018; Karataş, Micklos, & Bodner, 2011; Lachapelle & Cunningham, 2012; Oware, Capobianco, & Diefes-Dux, 2007). The results of these studies point out that different attempts must be made to better students' understanding of engineering. Studies have been carried out to examine the effects of different educational interventions on students' understanding of engineering (Hammack, Ivey, Utley, & High, 2015; Johnson, Ozogul, DiDonato, & Reisslein, 2013; Lachapelle, & Cunningham, 2007; Nam, Lee, & Paik, 2016; Pekmez, 2018; Taştan Akdağ, & Güneş, 2016; Thompson & Lyons, 2008; Yıldırım & Türk, 2018). These studies indicated the importance of young ages and critical features of applied teaching methods/approaches/techniques in improving the understanding of engineering.

Teachers' perceptions of engineering is particularly important to enable the effective integration of engineering into K-12 classes. Teachers' perceptions influence their teaching practices (Hsu, Purzer, & Cardella, 2011). Teachers' perceptions and understanding influence their students in turn (Liu, Carr, & Strobel, 2009). Teachers must have in-depth knowledge about a concept to be able to help their students understand a specific science concept. Likewise, teachers must have adequate understanding about engineering to improve students' perceptions of engineering. However, studies have reported that teachers are not familiar with engineering and their perceptions of engineering are shallow (Diaz, Cox, & Adams, 2013; Hammack & Ivey, 2016; Hsu, Purzer, & Cardella, 2011; Lachapelle, Cunningham, & Lindgren-Streicher, 2006). It has become vital that professional development experiences must be provided to contribute to teachers' understanding of engineering, learning how to integrate engineering into other STEM disciplines, and ability to implement integrated STEM education successfully in their classes. Such professional development experiences have been reported to have had positive effects on the engineering-related perceptions of P-6 teachers (Lambert, Diefes-Dux, Beck, Duncan, Oware, & Nemeth, 2007), primary school teachers (Deniz, Kaya, Yeşilyurt, & Trabia, 2020), pre-service primary teachers (Kaya, Newley, Deniz, Yeşilyurt, & Newley, 2017), and secondary school pre-service teachers (Kilty & Burrows, 2019) including pre-service science teachers (Ergün & Kıyıcı, 2019) and pre-service chemistry teachers (Aydin-Gunbatar, Tarkin-Celikkiran, Kutucu, & Ekiz-Kiran, 2018).

Pre-school teachers need STEM professional development experiences more than other teachers because they tend to be less knowledgeable than other teachers about STEM fields (DeJarnette 2018; Jamil, Linder, & Stegelin, 2018) and they do not feel themselves qualified enough to teach STEM disciplines (Allen 2016; Shaparan 2012); they do not like these disciplines, and lack confidence in relation to them and thus avoid them (Clements & Sarama, 2016). But it is considered critical not to ignore the potential of the pre-school years to lay a foundation for STEM learning and support lifelong STEM literacy (Allen, 2016; Bagiati & Evangulou, 2015; Jipson, Callanan, Schultz, & Hurst, 2014; Moomaw & Davis, 2010; Sullivan & Beers, 2015; Torres-Crospe, Kraatz, & Pallansch, 2014). A STEM professional development experience was accordingly designed for pre-school teachers and implemented in this study. This study examined how this exposure to this programme of instruction changed teachers' perceptions of the STEM disciplines including technology and engineering, and of the STEM approach. This paper presents data obtained from a larger study; only those findings relating to the engineering discipline are presented.

This study is innovative in that there are not many studies in the literature that focus on teachers' perceptions of engineering at the lower end of schooling (Hammack & Ivey, 2016; Lambert, Diefes-Dux, Beck, Duncan, Oware, & Nemeth, 2007; Karademir & Yıldırım, 2021). It will provide information about the potential of a professional development experience to teach pre-school teachers about engineering and presents a STEM professional development programmes for pre-school teachers which others may emulate.

Research Questions

1. What are pre-school teachers' perceptions of engineering?
2. How do these perceptions change as a result of exposure to a professional development programme on STEM education?

Methods

This study adopted a qualitative research design. Qualitative studies focus on human perception and understanding (Stake, 2010). Data in qualitative studies is collected with an open-ended instrument which gives participants the opportunity to respond according to their own subjective perceptions and understandings (Merriam, 1998). This study focused on exploring pre-school teachers' perceptions of engineering through their own drawings and words.

Context of the Study

The findings presented in this study were obtained from the project entitled "Domain Experts and Pre-School Teachers' Experience in Applied STEM+A Instruction" supported by the Scientific and Technological Research Council of Turkey. The study involved subjecting pre-school teachers to a 7-day programme of instruction about STEM and engineering education in June 2019. The participants worked in groups of five during the research. The project was carried out by Muğla Sıtkı Koçman University. Lecturers from the faculties of science, engineering and technology took part in the project. Other lecturers and advisers in the project worked in the fields of primary education, science education, mother-tongue education, coding education, robotics applications, and art education. These various expert practitioners taught participants what STEM education is and how to implement STEM education in pre-school classrooms.

Participants

As noted earlier, thirty teachers participated in the study. They all volunteered to join the study. Twenty-three participants were female. At the time the study was administered, they were working in different regions in Turkey. They had 3-10 years of teaching experience. It was the first time that any of the participants had been exposed to in-service training about STEM education.

Programme

The goals of the professional development experience implemented within the context of the study were as follows:

1. To develop pre-school teachers' perceptions about science, engineering, and technology.
2. To develop pre-school teachers' perceptions about integrated STEM education.
3. To have pre-school teachers comprehend the theoretical background of integrated STEM education approach.
4. To enable pre-school teachers to implement integrated STEM education effectively in their own classes.
5. To extend the application of integrated STEM education to pre-school classes.

Various activities were carried out to achieve these goals. These activities are presented in Table 1.

Table 1

Instructional Activities

Activity name	Activity topic	Description of the activity
STEM Education Approach	Theoretical basis of STEM Education	Information was given on the history, rationale, and importance of STEM education. The main features of STEM education are explained. In this process, the studies carried out by Moore et al. (2014) and Moore et al (2015) were used. Common mistakes made in STEM education were discussed.
S in STEM	Experiencing science under the guidance of scientists	The activity started with a talk on the concept of science and scientific perspective. Explanations were given about the stages of scientific studies and the process that went through from observation to technological product. After that, the participants carried out three implementations to experience the scientific process. In one of the implementations, plant samples were collected from the campus and classified. In the other implementation, materials used in daily life were classified according to their chemical compositions using natural indicators. In the third implementation, the concept of mass was examined experimentally. The relationships between what happened in these implementation processes and science, scientific perspective, and scientific processes were established.
E in STEM	Experiencing engineering under the guidance of engineers	The activity started with a presentation which focused on engineer and engineering concepts. Giving examples of engineering products, the place and importance of engineering in everyday life was discussed. There was a conversation about branches of engineering and the products they created. Then, an engineering implementation was experienced under the guidance of engineers. The participants experienced a production process of a flexible and self-healing material that has a concrete-like structure and can be used in place of concrete. In addition, samples taken from this material and concrete were subjected to the bending test. They compared the properties of the two materials.
T in STEM	Experiencing technology under the guidance of experts working in the field of technology	The activity started with a presentation focusing on the general concept of technology, the relationships between the concepts of science, engineering, and technology. After that, the participants experienced three technological applications. In one of the applications, products were taken from a 3D printer. In the other application, a wooden coffee table was designed. The production stages of this coffee table were observed. Wooden materials were coloured with natural dyes. In the third implementation, a thermal camera was used for measuring heat. The focus was on the concept of energy efficiency. By using heat energy, polypropylene-based plastic pipes were welded together with the help of fittings. Thus, designs were prepared for the intended purpose.
Poster design	Designing visual works of art having the themes of science, engineering, and technology	The activity started with a conversation on the concepts of science, engineering, and technology. The importance of science, engineering and technology was emphasized. The relationships between these concepts were discussed. Visual works such as posters, banners were designed for these concepts. Designs were prepared with a power point.

STEM Education in Pre-school Period	Theoretical framework and implementation models of STEM education in pre-school period	The activity started with the question of at what *age it is appropriate* to *start teaching STEM. D*iscussions on the compatibility of STEM education with the developmental characteristics of Pre-school children were mentioned in the literature. The history, importance, and characteristics of STEM education in pre-school period were explained. Then, models (e.g., project-based, problem-based, design-based, and robotic implementations) for implementation of STEM education were discussed. It was stated that engineering-based STEM education in pre-school period was popular in the literature. In addition, it was stated that STEM education was integrated into all educational activities performed such as reading in mother tongue and games. These integrations were exemplified (Çil, 2017).
Engineering Design- Based STEM Education	Sample activities for engineering design-based STEM education	First, the process of engineering design was explained on a diagram. Then, engineering design-based STEM education was explained. After that, three engineering design-based STEM activities were carried out. In one of these activities, a multi-storey car park was designed. In the other activity, designs were created with the required features (for example, the highest ramp from which a car can descend safely using Legos). In the third activity, real-life engineering designs were discussed. The study groups chose an engineering product that they wanted such as tower. They did research about the features of the structure. Using the materials provided, they designed and constructed a similar version of the structure. For example, they constructed a tower with plastic glasses with the desired height and durability.
STEM plus arts	Integration of art into STEM Education	This activity started with a presentation of what art is and its basic features. The principles of art are mentioned. The relationship of art with science, mathematics, technology, and engineering has been discussed. In this process, examples of Turkish architectural art (e.g. historical arch bridges) were used. After that, the activity continued over the cistern theme. The cisterns were chosen because they are a STEM example and important for Muğla, where the project was carried out. Kanuni Sultan Süleyman (or Suleyman the Magnificent) had these cisterns built for the Rhodes excursion and they are located in Muğla. The activity continued with the design and construction of the cistern with the given materials. The activity was completed with the testing of the cisterns.
Storybook	Benefiting from native language activities in early STEM education	The activity started with the explanation of the place and importance of mother tongue activities in STEM education in Pre-school period. Within the context of STEM education, information was given about when, how and for what purposes mother tongue activities could be used. The story books that teachers can use in their classes within the context of STEM education were introduced. The scarcity of Turkish story books has been mentioned. The activity continued with the teachers' writing a story book. The creation of the story books was based on the work of Cunningham and Lachapelle (2016). The storybooks introduced children to an engineering challenge they might face in real life. In addition, the book included the hero / heroes solving this difficulty. During the story writing process, the story book, Our Bridge, written for this project was distributed to the participants. The writing steps of the book were shared with the participants. By following the similar steps, the participants were given the opportunity to write their own story books. The activity was completed when the study groups presented their story books to all participants.

Coding Education	Theoretical foundations /framework of coding education and sample activities for pre-school coding education	The activity started with the explanation of the theoretical foundations of the coding training. Information was given about coding education in pre-school period. The relationships between coding education and STEM education were explained. Five coding training activities were carried out. All these activities were done without a computer. The following are the subjects of activities: the concept of variable, the ant getting food, the concept of numbers, determining the route of a school bus, and the arrangement of toys in a child's room.
Robotics for STEM education	Educational robotics and its use in STEM education	The theoretical foundations of educational robotics are explained. Strengths and weaknesses of educational robotics were mentioned. The place and importance of educational robotics in STEM education was explained. Lego Mindstorm ev3 Education was introduced. The activity continued with sample activities about how to use educational robotics in STEM education. Three sample activities were performed. A car was designed in one of these activities. The car was programmed to follow the desired route. In the other sample implementation, the mechanism with impeller was designed and by using a motor, the mechanism is programmed to perform the desired movement. In the third implementation, the fire ladder was designed and programmed.
Applications	Benefiting from applications in STEM education	This activity started with discussions on the necessity and importance of using applications in STEM education in Pre-school period. Applications that can be used to support STEM education in Pre-school period (e.g. Bridge Basher, Play and Learn Science, Build a Bridge, STEM & Maker Junior) were introduced. The participants were taught how to access and use these applications. The participants could download and use each application. They talked about when, how and for what purposes to use these applications.
Student Centres	Organization of learning environments in a way that contributes to the implementation of STEM education	This activity was carried out in a public kindergarten. Existing learning centres (such as Science, Art, Book, Block, Dramatic Play) in Pre-school classrooms were checked in terms of STEM education. A discussion was carried out about how to benefit from these learning centres during the implementation of STEM education and what can be done to make these learning centres more suitable for the nature of STEM education. Arrangements were made with the available facilities. In the organized learning environment, engineering design-based STEM activities such as bridges, walkways and pendulums were carried out.
STEM Education in out-of School Learning Environments	Benefiting from out-of-school learning environments in STEM education	The activity started with the explanation of the place and importance of out-of-school learning environments in STEM education. The places that are examples for STEM + A integration in Muğla city centre and its immediate surroundings were visited. The clock tower, the cisterns built for Suleyman the Magnificent's excursion to Rhodes, a natural stone workshop, and a farm with good agricultural practices were visited. STEM integration was discussed during the visit in every place. Explanations were given on how to use these places as part of STEM education.
Designing a STEM Activity	Designing a STEM activity and integrating it into the daily plan	This activity started reminding participants how to implement engineering-based STEM education. After that, the study groups were asked to design an engineering-design based STEM activity. The activities were related to the STEM disciplines. For example, science subject / concept / process that would be gained with the contribution of this activity was determined. The engineering branch the activity was related to and its relation with the engineering design process were determined. The activity was

		integrated into the daily schedule. In this process, the implementation of the activity was related to the other activities such as mother tongue activities and games. The volunteering groups could include activities such as visiting out-of-school learning environments and robotic applications. The activity ended with the presentation of the plans .
Action Plan	Planning actions to contribute to the popularization of STEM education	In this activity, the participants were asked to plan what to do after the project to develop themselves further in STEM education and to spread STEM education in their immediate environment (students, schools, colleagues, etc.). The planning process included and specified what activities to do, their purpose, target audience and time. The implementation of these plans was tracked during the fall semester of 2019-2020 academic year.

Instrumentation

The data of this study was gathered via a Drawing Test and participant diaries. The participants were asked to draw what came to their minds about an engineer and engineering and explain their drawings. The study drew on the "Draw an Engineer Test" instrument developed by Knight and Cunningham (2004). It is widely used as a data collection tool in the field of engineering education. This test is used to assess ideas of individuals of all ages about engineers and engineering (Capobianco, Diefes-Dux, Mena, & Weller, 2011). The first draft consisted of four items including two drawings and two descriptions. The pilot study was carried out with 30 pre-service pre-school teachers. It was found in the pilot study that 87% (n = 26) of the participants combined the two drawing items and drew only one. The test was accordingly revised. After these revisions the test was used as an instrument in this study. The participants responded to this test twice before and after the professional development experience in this study.

The second data collection tool of this study was participants' diaries. is participant diaries. Diaries are records of participant experience and are one of the most common data collection tools in qualitative research as they provide an insight into individuals' opinions, emotions, and reflections (Yi, 2008). All participants regularly kept their diaries.

Data Analysis

For the drawing test, a numerical coding system was used to assess participants' perceptions of engineering. The key developed by Thompson and Lyons (2008) was used as a guideline. This consists of four thematic groups based on primary characteristic properties of engineers. Points were allocated based on the drawing attributes placed within these four thematic groups. This criteria and scoring were presented in Table 2.

Table 2

Scoring Guide

Thematic Group	Points			
	0	1	2	3
Engineering Artifacts	Don't know. Irrelevant pictures or descriptions	Tools or descriptions used in works such as fixing, building Artifacts or description used in the works done by a technician, a mechanic, or a repairman	Artifacts or description such as designing, presentation information, sharing opinions, doing experiments to find a solution to a problem	

Diversity of Fields	Don't know. Irrelevant pictures or descriptions	A correct description or depiction of works carried out in a single engineering field	A description or depiction of multiple engineering field	
Engineering Processes	Don't know. Irrelevant pictures or descriptions	A description or depiction of physical repairs (e.g. Repair, Construct, Build, Make, Product Realization) A description or depiction of processes related to verification and validation (e.g. Product testing or problem diagnosis)	A description or depiction of cognitive processes (e.g. Create, Design, Invent, Improve a product, Redesign, Share or present information, Make better) A description or depiction of an authentic problem solution (e.g. Find an original solution to a problem, Collaborate, Research)	A description or depiction of multiple processes including at least one cognitive process
Portrayals of Engineering	Don't know. Irrelevant pictures or descriptions	A description or depiction of engineering as a driver or a machine operator	A description or depiction of engineering as a builder, a repairman, or a technician	A description or depiction of engineering as an inventor, a creator, a designer, a problem-solver, or an experimenter

Note: Table was adapted from Thompson and Lyons (2008; pp: 199-200).

The Shapiro-Wilk test for Normality was used to examine whether or not the data were normally distributed. It was found that they were not. The data were then tested for kurtosis. Because the value of skewness-kurtosis did not fall between +1 and -1, it was decided that non-parametric tests had to be employed (Çepni, 2018). The Wilcoxon Signed Ranks Test was used to compare engineering perception scores before and after the professional development experience. Thematic content analysis was administered to the drawing test for an in-depth examination of the participants' perceptions of engineering. Thematic content analysis is used to reveal themes and sub-themes obtained from the content of qualitative data (Braun & Clarke 2006; Fereday & Muir-Cochrane 2006). The participants' illustrations were coded and themes and sub-themes were derived from the coded data. Some themes including engineering products, engineering activities, gender of an engineer, design artifacts, building/fixing artifacts, and laboratory artifacts were adapted from the study by Knight and Cunningham (2004). However, these themes were not enough to categorize all the data obtained. Thus, there was a need to generate new themes and sub-themes. Frequency and percentages were calculated for each sub-theme.

Thematic content analysis was also used for the data obtained from the diaries. Before starting data analysis, diaries were read a few times. During the reading process before the analysis, the researcher became familiar with participants' idiosyncratic use of language and expressions. Then, the diaries were read and coded. Until the researcher was satisfied with the codes, the data were coded repeatedly. Sub-themes and themes were derived from the codes. Themes and sub-themes were revised until it was assured that themes and sub-themes were represented in the best way. Frequencies of the categorised themes were calculated.

The same researcher analysed the data twice at different times to ensure reliability. It was determined that there was less than 10% inconsistency between the two analyses. This inconsistency was reconciled with another researcher's opinions.

Findings

The findings obtained from the analyses of drawing test and participant diaries were presented under separate sub-titles.

Findings Obtained from the Analysis of Drawing Test

The Wilcoxon Signed-Rank Test was used to test for significant differences. The findings obtained were presented in Table 3.

Table 3

Findings Obtained from the Analysis of the Drawing Test with the Wilcoxon Signed Ranks

Thematic Group	After instruction-before instruction	N	Mean rank	Sum of ranks	z	p
Total	Negative rank	5	8.20	41.00	-3.697*	0.000
	Positive rank	23	15.87	365.00		
	Equal	2				
Engineering Artifacts	Negative rank	1	5.00	5.00	-2.804*	0.005
	Positive rank	11	6.64	73.00		
	Equal	18				
Diversity of Fields	Negative rank	2	8.00	16.00	-3.259*	0.001
	Positive rank	16	9.69	155.00		
	Equal	12				
Engineering Processes	Negative rank	5	8.60	43.00	-3.259*	0.001
	Positive rank	20	14.10	282.00		
	Equal	5				
Portrayals of Engineering	Negative rank	3	7.50	22.50	-3.187*	0.001
	Positive rank	17	11.03	187.50		
	Equal	10				

*Note: *Based on negative ranks.*

When Table 3 is examined, it is found that there is a statistically significant difference between the total scores of participants' engineering perceptions before and after the instruction ($z=-3.697$, $p<.05$). This applies also to each thematic group (for engineering artifacts $z= -2.804$, $p<.05$; for diversity of fields $z= -3.259$, $p<.05$; for engineering processes $z= -3.259$, $p<.05$; for portrayals of engineering $z= -3.187$, $p<.05$). Thematic analysis was administered on the drawing test for an in-depth exploration of participants' perceptions. The findings obtained are presented in Table 4.

Table 4

Findings Obtained from the Thematic Content Analysis of the Drawing Test

Theme	Sub-theme	Before instruction		After instruction	
		f	%	f	%
Engineering Products	Products of civil engineering (Building, road, bridge, tower)	15	50	24	80
	Products of mechanical engineering (car, washing machine, plane, computer, television, telephone)	11	36,7	10	33,3
	Products of agricultural engineering (plants)	0	0	3	10
Engineering branches	Civil	5	16,7	0	0
	Mechanical	3	10	1	3,3

	Electrical electronics	2	6,7	1	3,3
	Agricultural	2	6,7	1	3,3
	Genetics	1	3,3	0	0
	Energy systems	1	3,3	0	0
	Space	1	3,3	0	0
	Computer	0	0	1	3,3
	Geology	0	0	1	3,3
	Topographical	0	0	1	3,3
Engineering activities	To design	3	10	5	16,7
	To construct structures	5	16,7	0	0
	To produce	1	3,3	5	16,7
	To draw	1	3,3	0	0
	To draw a project	1	3,3	0	0
	To invent/discover	1	3,3	1	3,3
	To overthink	1	3,3	0	0
	To calculate	3	10	1	3,3
	To experiment	1	3,3	0	0
	To solve a problem	1	3,3	11	36,7
	To develop tools, machines	2	6,7	0	0
	To develop methods and techniques	1	3,3	0	0
	To develop technology	0	0	3	10
	To innovate	0	0	3	10
Importance of engineering	To ease daily life	8	26,7	10	30
Properties of engineering	Interdisciplinary	0	0	11	36,7
Building/ fixing tools	Helmet /safety hat	12	40	6	20
	Glasses	3	10	0	0
	Hammer	1	3,3	1	3,3
	A pair of pliers	1	3,3	0	0
	Tool kit, wrench	1	3,3	2	6,7
	Work machine	1	3,3	1	3,3
	Shovel	0	0	1	3,3
Objects in laboratory	Glass flask	3	10	1	3,3
Design objects	Computer	6	20	3	10
	T ruler	5	16,7	2	6,7
	Ruler	6	20	4	13,3
	Plan/map/model	2	6,7	3	10
	Pencil	1	3,3	1	3,3
	Book/notebook	1	3,3	0	0
	Calliper /compass	1	3,3	0	0
	Protractor	1	3,3	0	0
	Calculator	1	3,3	1	3,3
Gender of an engineer	Female	2	6,7	6	20
	Male	8	26,5	11	33,3
	Not specified	4	13,3	3	10
Social context of engineer's workplace	Individual work	6	20	5	16,7
	Group work	1	3,3	3	10
Workplace of an engineer	Indoor	2	6,7	0	0
	Outdoor	7	23,3	5	16,7
No response		2	6,7	0	0

When Table 4 is examined, it is revealed that the products that were introduced by civil engineering into our lives are generally included in the participants' drawings both before and after the instructional programme. While 50% of the participants drew and wrote about engineering and engineers with reference to a specific branch (e.g., civil, mechanical, electrical and electronics) before the programme, this ratio decreased to 20% after the instruction. Building a structure was determined as the engineering activity with the highest frequency before the programme. Designing and calculating were identified as the engineering activity with the second highest frequency. After the programme, the engineering activity with the highest frequency was problem-solving. Designing, developing technology, and innovation were other sub-themes with high frequency. While there was no participant who mentioned that engineering was an interdisciplinary field before the instructional programme, 36.7% of the participants mentioned this attribute after the it. The participants who included building/fixing tools used by an engineer in their drawings and explanations before the instruction decreased 33.3%. Examples of participants' drawings are presented in the Appendix 1.

Findings Obtained from Participant Diaries

The findings obtained from the analysis of participant diaries are presented in Table 5.

Table 5

Findings Obtained from the Participant Diaries

Theme	Sub-theme	f	%	Sample Statement
Self-evaluation	Revising, understanding of engineering	15	50	"I realized during the activity in engineering faculty that I approached the questions of who engineer is and what engineering is from a rigid perspective." (Participant 9).
Characteristics of engineering	Problem-solving	3	10	"Engineering is problem-solving. While solving a problem, there are some limitations for engineers. Engineers generate solutions suitable for the desired qualities within these limitations." (Participant 7)
	Creativity	1	3,3	"We did a series of implementations in engineering faculty. What I realized in this process is that engineering means creativity." (Participant 21)
	Place of engineering in everyday life	1	3,3	"We visited towers and etc., in the city centre of Muğla. We also visited a natural stone workshop and a farm where good farming practices were carried out. I realized that engineering has an indispensable place in our life." (Participant 7)
	The relationship of engineering with science, mathematics, and technology	4	13,3	"We made and poured concrete and then tested its durability in engineering faculty. We used science and mathematics to make concrete. While testing its durability, we used mathematics and technological tools. I realized that engineering consisted of science, mathematics, and technology." (Participant 1) "I learned that engineering was very much integrated with physics, chemistry, biology, mathematics, and technology." (Participant 2)
	The relationship between art and engineering	5	16,7	"We visited a workshop where marble is processed. I observed the artifacts that were created with the combination of art and engineering." (Participant 3)
Content knowledge	Learning basic concepts/subjects/applications of engineering	10	33,3	"Thanks to the implementation carried out in civil engineering laboratory, I observed that there was a flexible (or bendable) concrete." (Participant 10)
Affective learning	Interest in engineering	1	3,3	"This is the first time I have been interested in engineering. I have never examined and considered engineering so much before." (Participant 15)

When Table 5 is examined, half of the participants indicated in their diaries they realised there were inaccuracies and / or gaps in their understanding at some time during the professional development experience. Half of the participants clearly stated that they had learned as a result of the programme the basic attributes of engineering such as problem solving and creativity, and integration with other disciplines. Ten of the participants (33.3%) stated that they had learned new content knowledge in engineering during their professional development experience. Only one of the participants explicitly stated that there had been a change in that person's feelings towards engineering.

Discussion

This study investigated how a professional development experience focusing on the STEM approach could change pre-school teachers' perceptions of engineering. Based on the findings obtained from the analysis of the drawing test before the professional development experience, it can be concluded that pre-school teachers were not completely ignorant of what engineering is and what engineers do; however, their engineering perceptions were limited and incomplete. These results support the studies which report that teachers tend to have a limited understanding of engineering as a discipline (Hsu, Purzer, & Cardella, 2011; Lambert, Diefes-Dux, Beck, Duncan, Oware, & Nemeth, 2007) and tend to exhibit stereotypical opinions about engineering (Diaz, Cox, & Adams, 2013; Hammack & Ivey, 2016; Lachapelle, Cunningham, & Lindgren-Streicher, 2006; Karademir & Yıldırım, 2021). Before the professional development experience, there were teachers who depicted engineering only as a specific branch usually civil mechanical engineering, the engineering process as the physical processes such as fixing, building and designing, and / or validation processes such as product testing. There were also teachers who described engineers as people who construct buildings and regarded mostly fixing and building implements as engineering tools and equipment. It is reported in the literature that students mostly envisage engineering as civil, mechanical and/or electrical (Çil & Özlen, 2019; Ergün & Balçın, 2018; Ergün & Balçın, 2019; Fralick, Kearn, Thompson, & Lyons, 2009; Karataş, Micklos, & Bodner, 2011). It is seen in many studies carried out with different age groups that the most common misconception about engineering is the description of engineers as mechanics or technicians (Capobianco, Diefes-Dux, Mena, & Weller, 2011; Cunningham, Lachapelle, & Lindgren-Streicher, 2005; Ergün & Balçın, 2018; Ergün & Balçın, 2019; Fralick, Kearn, Thompson, & Lyons, 2009; Gülhan & Şahin, 2018; Karataş, Micklos, & Bodner, 2011, Lachapelle, Cunningham, & Lindgren-Streicher, 2006; Lachapelle & Cunningham, 2007; Lachapelle & Cunningham, 2012; Oware, Capobianco, & Diefes-Dux, 2007). The main reason for these results might be that the teachers did not receive training on engineering before; therefore, they lacked knowledge (Hammack, Ivey, Utley, & High, 2015).

When the scores obtained from the drawing test applied before and after the professional development experience were compared, it was determined that there were significant improvements in total scores of teachers' perceptions of engineering ($p=.000$). In each of the thematic groups for engineering perceptions (engineering artifacts, diversity of fields, engineering processes, portrayals of engineering), a statistically significant increase was observed after the professional development experience (Table 3). The findings obtained from the thematic content analysis indicate that most of the participants described engineering as design, innovation developing technology, and related engineering with other disciplines in the post-test. According to the findings obtained from the analysis of the participant diaries, the professional development experience encouraged participants to view the engineering process as one of problem-solving and creativity, and better realise the relationship between engineering and technology, mathematics, other sciences and the arts, and better understand the place of engineering in daily life. Based on all these findings, it can be concluded that the professional development experience administered within the scope of this study improved the engineering-related perceptions of pre-school teachers. The results of this study may be largely explained with reference to the obvious fact that the professional development experience focused primarily on STEM disciplines. During the activities targeting the S, E and T in STEM, the participants had an opportunity to experience the disciplines of science, engineering, and technology under the guidance of experts in that field. In the E activity in STEM, they were enlightened about engineering is what and what an engineer does. In addition to this, they had an opportunity to experience the engineering process in practice when they worked like engineers in the laboratory. Receiving theoretical and applied education about engineering under the guidance of engineers may have improved teachers' perceptions of engineering. In the professional development experience section that focuses on STEM disciplines, poster design activity may also be another reason for the results. In this activity, teachers discussed what the concepts of science, engineering and technology are, the similarities and differences, and interactions. A visual art product was designed for each of the science, engineering, and technology disciplines. The participant groups usually designed posters and / or banners for each discipline. This activity may have enabled the participants to reconsider their understanding of engineering and reconstruct it in their minds. The literature states that a direct and reflective teaching approach can be effective in teaching the nature of engineering and eliminating misconceptions about engineering (Deniz, Kaya, Yeşilyurt, & Trabia, 2020; Hammack, Ivey, Utley, & High, 2015). After experiencing STEM disciplines in a professional development experience, the focus was on the integrated STEM education approach. In this process, engineering design-based STEM education was discussed both theoretically and practically. The main purpose of these activities in the professional development experience is to develop teachers' knowledge and skills to implement the integrated STEM education approach in their classrooms. However, as this process at the same time provides an opportunity for teachers to engage in engineering design process, it may have caused positive effects on teachers' perceptions of engineering. It was reported in the literature that integrated STEM education approach improved both students (Farland-Smith, & Tiarani, 2016; Lachapelle & Cunningham, 2007; Nam, Lee, & Paik, 2016; Pekmez, 2018 Taştan Akdağ, & Güneş, 2016; Thompson & Lyons, 2008; Yıldırım & Türk, 2018) and pre-service teachers' (Aydin-Gunbatar, Tarkin-Celikkiran, Kutucu, & Ekiz-Kiran, 2018; Ergün & Kıyıcı, 2019; Kaya, Newley, Deniz, Yeşilyurt, & Newley, 2017; Kilty & Burrows, 2019) perceptions of engineering.

Based on the findings obtained from the participant diaries, it can be concluded that a professional development experience on STEM education can make contributions to pre-school teachers to realize the deficiencies and / or mistakes in their own engineering understanding and to change, improve and develop them. In addition, it is claimed that an exposure to such a professional development experience may contribute to pre-school teachers' learning of subject matter knowledge within an engineering discipline. In addition to these, it can be concluded that professional development experience on STEM has a potential to enhance pre-school teachers' positive feelings towards engineering. There are studies in the literature which report that an exposure to engineering education and / or STEM education promote individuals' positive attitudes towards engineering (Hammack, Ivey, Utley, & High, 2015; Nadelson, Callahan, Pyke, Hay, Dance, & Pfiester, 2013). Examining the participant statements in their diaries, it can be stated that there are some reasons for these results including experiencing a real engineering application under the guidance of engineers, organizing field trips to observe engineering products and processes in their own settings and engineering design-based STEM activities.

It was determined that civil engineering and mechanical engineering are dominant in the engineering perceptions of teachers both before and after the professional development experience. Based on this finding, it can be concluded that the participants' perceptions of engineering are mostly shaped by these two engineering branches; it follows that various other engineering branches are neglected. Similar results were obtained in studies conducted with students (Çil & Özlen, 2019; Koyunlu-Ünlü & Dökme, 2016). This may be due to the fact that these engineering branches are the main engineering branches, they are the oldest engineering branches, and they are effective in the development of other engineering branches.

Conclusion and Suggestions

Pre-school teachers' perceptions of engineering may be limited, incomplete and / or inaccurate. For this reason, it is suggested that professional development experiences should be designed and implemented to develop pre-school teachers' knowledge and understanding of the field of engineering. These professional development experiences can include activities such as meeting with engineers and participating in real-life engineering practices with them. In addition, an explicit direct instruction could be given on who engineers are and what engineering is, what engineers do, and how they work. Learning about integrated STEM education can also positively affect teachers' perceptions of engineering. Thus, professional development experiences which interactively and practically teach theoretical foundations of integrated STEM education and application models should be designed and implemented. Positive feelings towards engineering can be promoted through professional development experiences that focus on engineering and integrated STEM education. In addition to this, pre-school teachers can self-evaluate themselves about their engineering perceptions and subject matter knowledge in engineering is enriched. It can be stated that civil and mechanical engineering are the most common engineering branches in pre-school teachers' perceptions of engineering. However, there are many different branches of engineering. Thus, it is recommended that pre-school teachers should participate in a professional development programme–to experience the subject, scope, processes, and applications of various engineering branches.

Acknowledgements

The professional development experiences called "Domain Experts and Pre-School Teachers Experience Applied STEM+A Instruction" was funded by The Scientific and Technological Research Council of Turkey known as TUBİTAK (ID number is 218B539).

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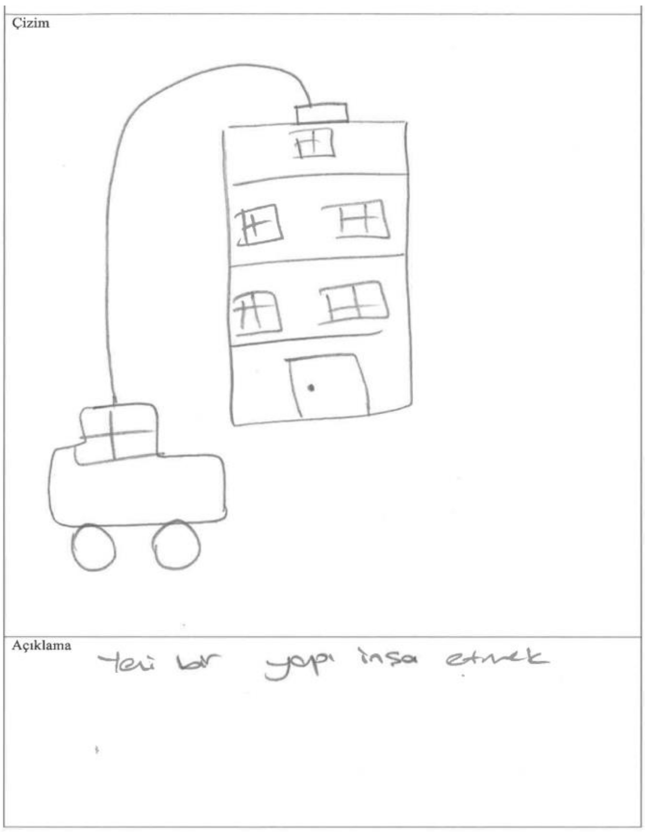
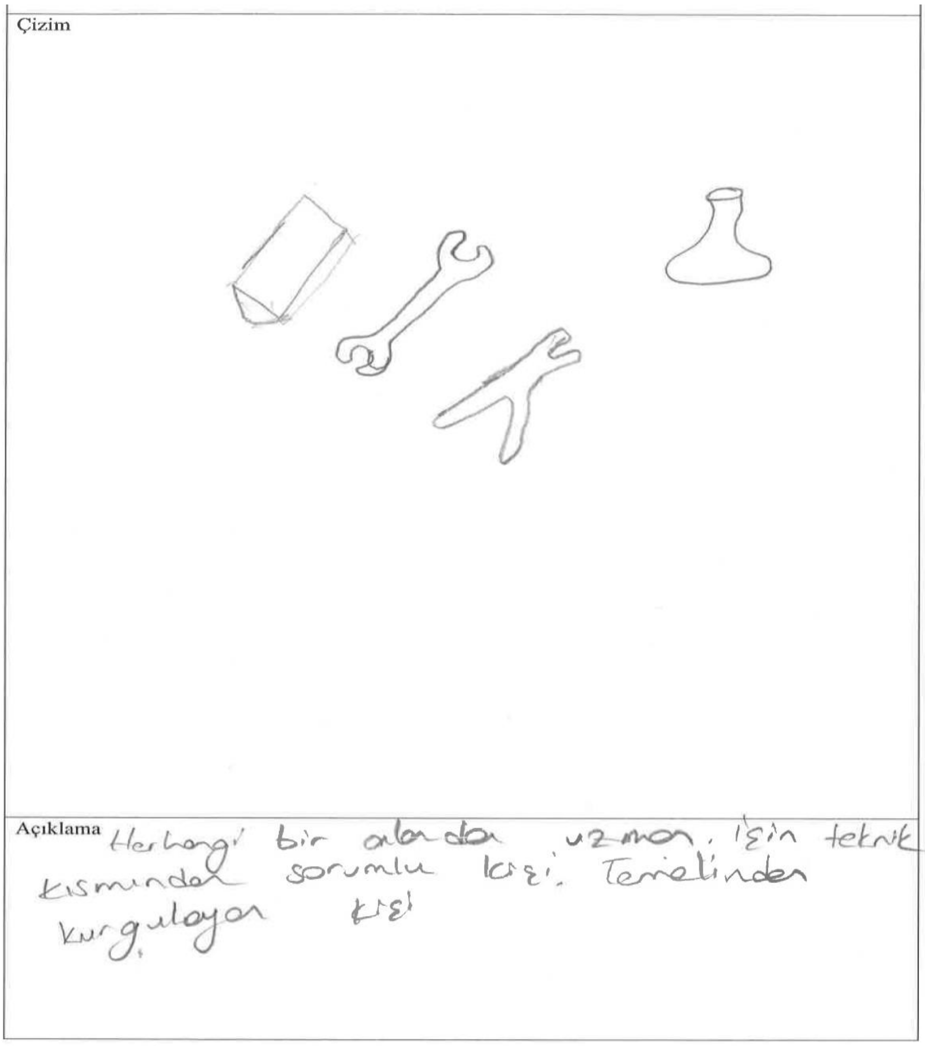
Appendix: Examples from Participant Drawings



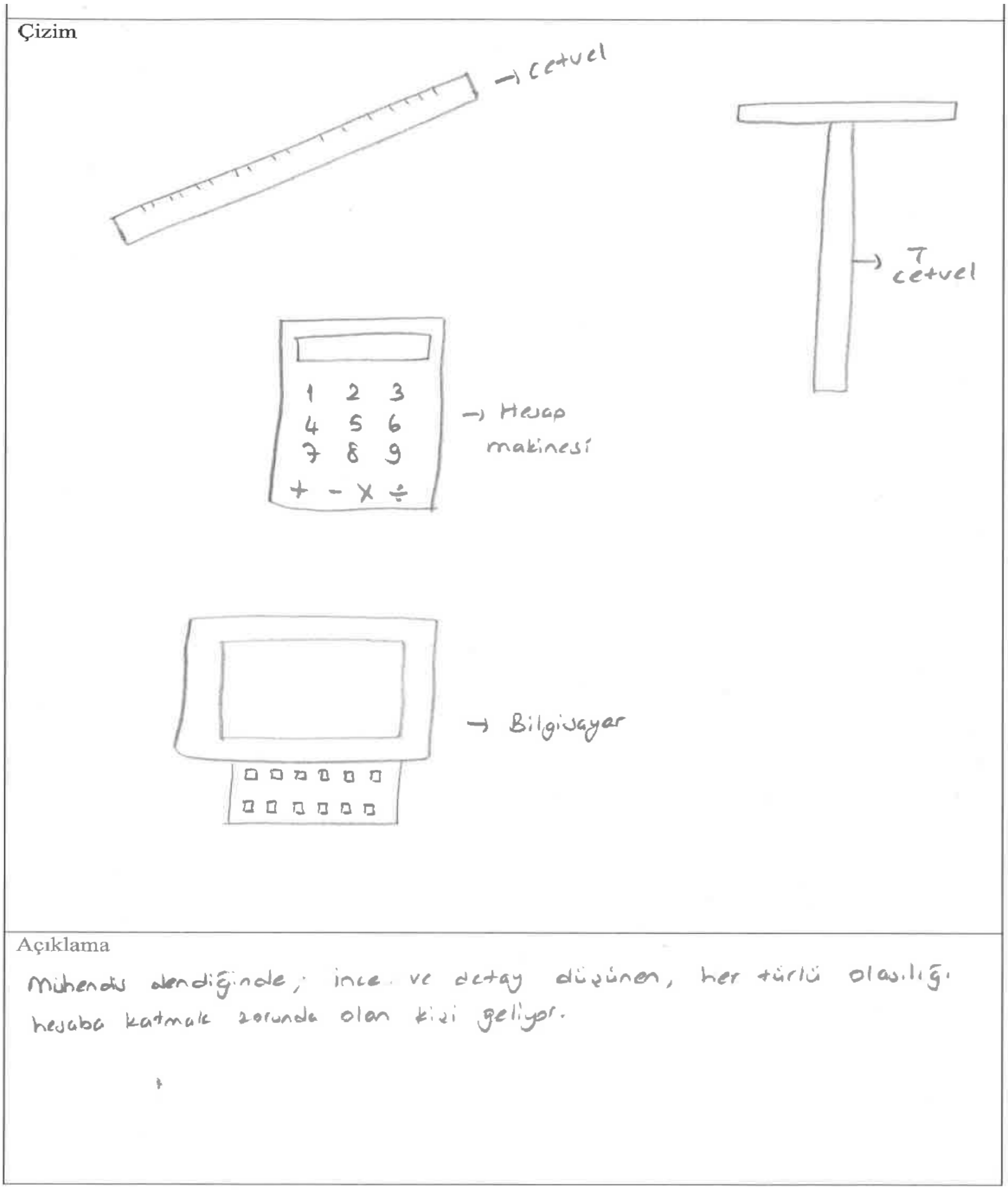
An example drawing for the sub-theme of building (Participant 27/ Before professional development experience)

Explanation in the drawing: To construct a new structure.



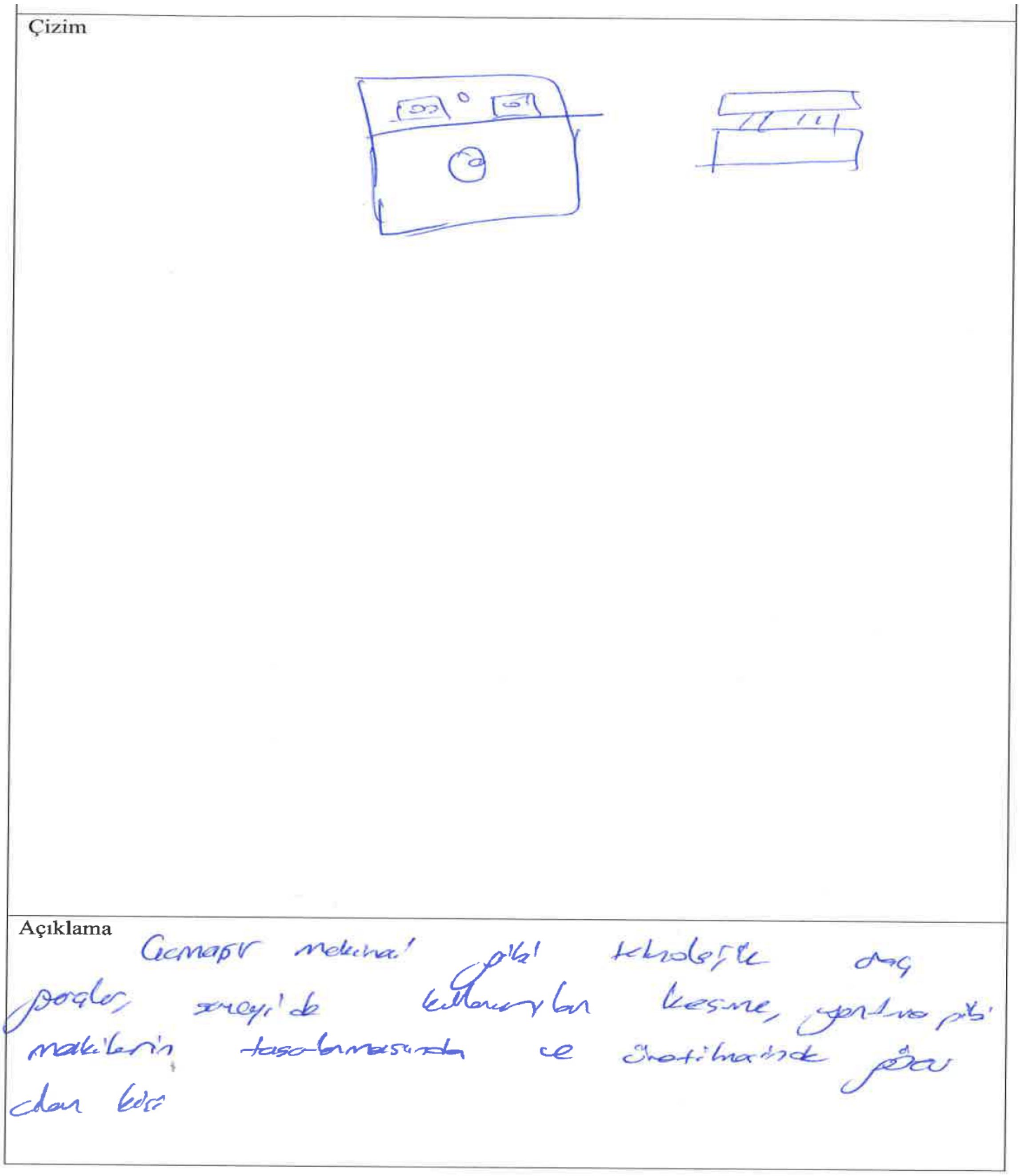
An example drawing for sub-theme of building/fixing objects (Participant 7/ Before professional development experience)

Explanation in the drawing: A person who is an expert in any field. A person who is who is in charge of the technical aspect of a job. A person who practises /plans from its foundation.



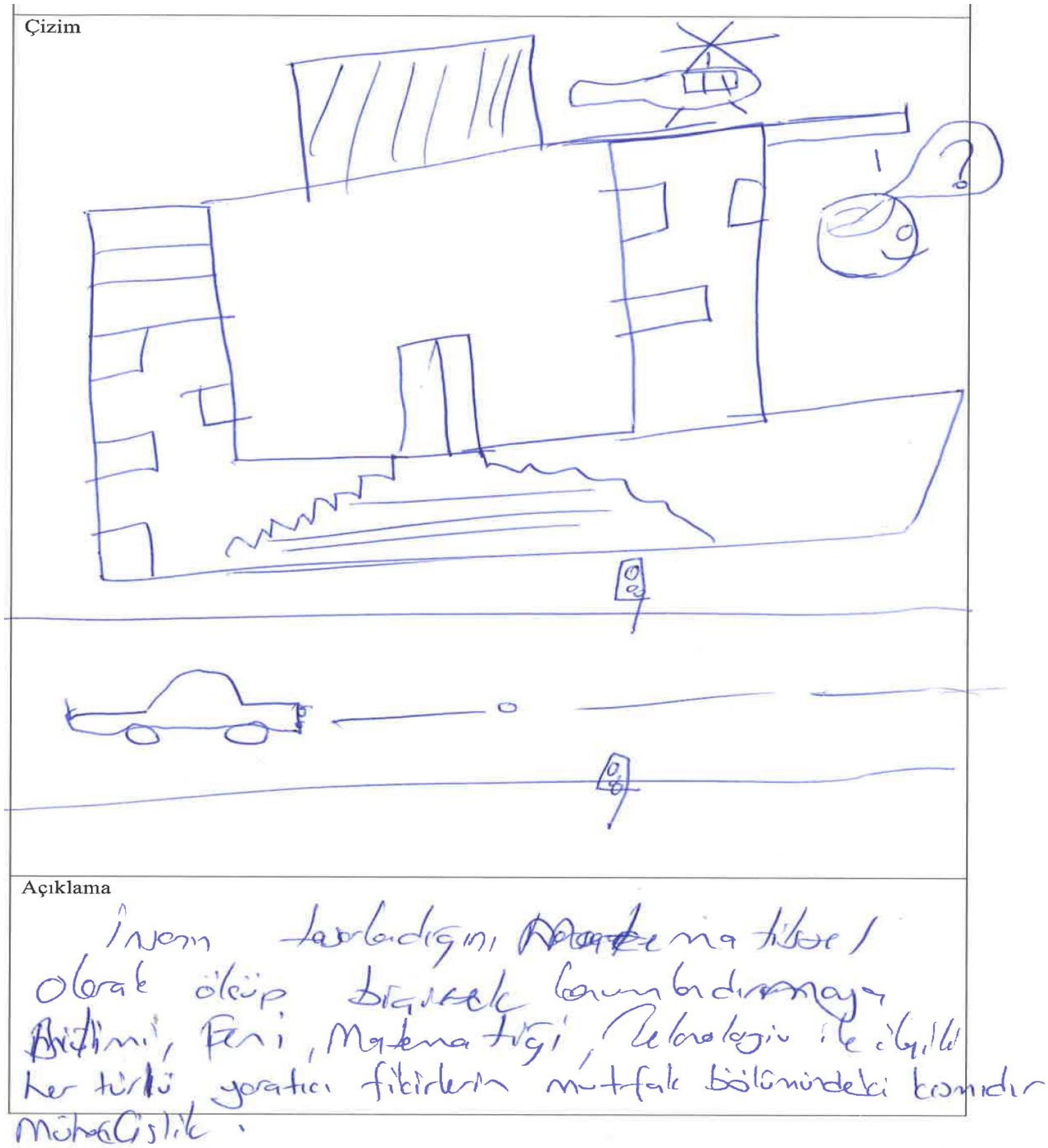
An example drawing for the sub-theme of design objects (Participant 5/ Before professional development experience)

Explanation in the drawing: In my opinion, an engineer is someone who thinks too much, focuses on details and even pays attention to small details.



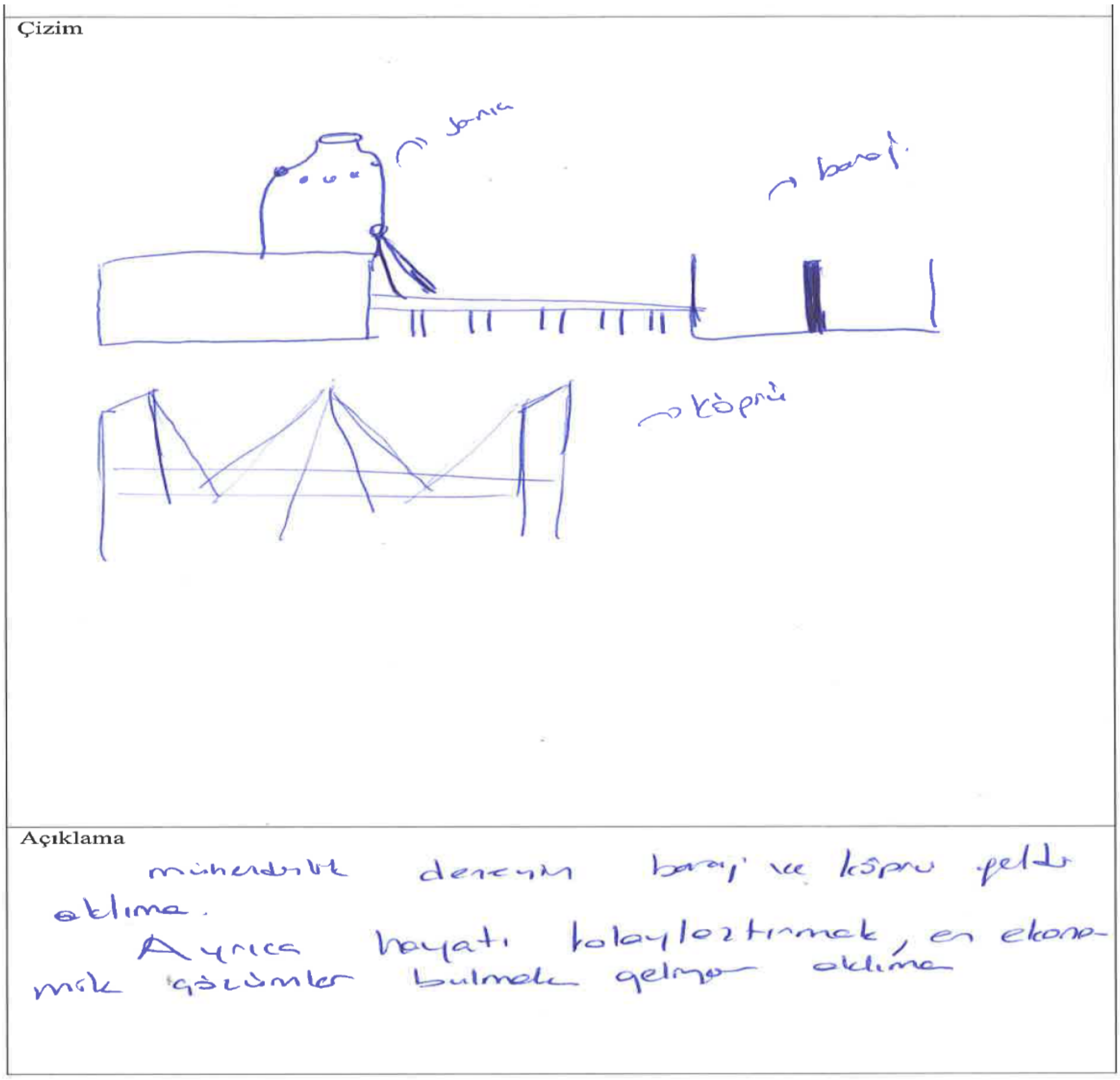
An example drawing for the sub-theme of designing and producing (Participant 27/ After professional development experience)

Explanation in the drawing: A person who works in the design and production processes of technological tools such a washing machine or machines that cut or carve.



An example drawing e for the sub-theme of interdisciplinary and designing (Participant 3/ After professional development experience)

Explanation in the drawing: Engineering is science that measures mathematically what a person designs or produces or engineering is the driving force behind any creative idea that is associated with science, mathematics, and technology.



An example drawing for the sub-theme of problem solving and facilitating daily life
(Participant 18/ After professional development experience)

Explanation in the drawing: Bridges and dams come to my mind when engineering is mentioned. In addition, making life easy and finding the most reasonable and economical solutions come to my mind about engineering.