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Examination of Explicit Engineering Emphasis on Students' Knowledge and Views of Engineering through STEM Training[*]

Sevgi AYDIN GÜNBATAR[**], Özal ŞAPKAN[***]

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ABSTRACT

The goal of this mixed-method design study was to compare and contrast the contribution of STEM education on 6th-grade students' (n=62) knowledge and perceptions of engineering and engineers. The data were collected by the use of the Engineering Knowledge Measurement Scale (EKMS) and the Draw an Engineer (DAE) instrument. In the study, two groups, namely, STEM-explicit emphasis on engineering (STEM-EE) and STEM-only (STEM-O), were formed. The data were collected before and after the 16 class hours of training (i.e., for a month) and were then analyzed. In both groups, two STEM activities (thermos and insulated home design) were carried out. However, the explicit emphasis on engineering was made in STEM-EE group. On the contrary, STEM-O group conducted the same STEM activities with no engineering emphasis. The results revealed that the students in both groups had incomplete and inaccurate knowledge and views of engineering (e.g. considering engineers to be workers) before the study. After the training, the students in the STEM-EE group had more accurate and richer views of engineering. Moreover, the students in the STEM-EE group mentioned more different fields of engineering after the study when compared with their peers in the STEM-O group. The explicit emphasis on engineering in STEM implementation using different models should be integrated into STEM activities.

Keywords: STEM, engineering, engineers, explicit integration of engineering into STEM

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1. INTRODUCTION

Recently, the Integrated Science, Technology, Engineering, and Mathematics (I-STEM; from now on STEM will be used through the paper) movement has begun to influence education systems all around the world (Ekiz-Kiran & Aydin-Gunbatar, 2021; Stohlmann, 2018). To increase the number of students who pursue a career in STEM fields, to address the different needs of the 21st century, and the necessary skills for a 21-st century workforce, reform in education systems is imperative (Koehler, Binns, & Bloom, 2016). STEM education has been viewed as a solution for those problems and the listed needs. Although there are different definitions of what STEM education is, it can be defined as "the teaching and learning of the content and practices of disciplinary knowledge which include science and/or mathematics through the integration of the practices of engineering and engineering design of relevant technologies" (Moore, Johnson, & Peters-Burton, 2015, p.24).

With the recent STEM reform, the integration of engineering into K-12 schools has been emphasized (Stohlmann, Moore, & Roehrig, 2012) through the use of the engineering design process (EDP). Among the STEM disciplines, engineering is the one that both learners and teachers are less familiar with (Aydin-Gunbatar, Ekiz-Kiran, & Oztay, 2020; Pleasants & Olson, 2019). Therefore, research into learners' views of engineering, EDP, and how engineers work should be conducted (Antink-Meyer & Brown, 2019). Although some research has been carried out, the very limited studies focused on elementary and/or middle school students' views of the engineering profession (Capobianco, Diefes-dux, Mena, & Weller, 2011; Colston, Thomas, Ley, Ivey, & Utleya, 2017). Emphasis on engineering at middle school is important since the first steps of carrier interest go back to middle school (Colston, et al., 2017; Tai, Liu, Maltese, & Fan, 2006). In addition, implementing STEM activities including EDP may not help learners develop informed views and images of engineering and engineers. The more explicit emphasis on the engineering profession and engineers may be necessary to attain the goals stated. Moreover, cooperation with engineers, engineering

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[**] Prof. Dr., Van Yuzuncu Yil University, Faculty of Education, Department of Mathematics and Science Education, Division of Chemistry Education, Van-TÜRKİYE. e-mail: sevgiaydin@yyu.edu.tr (ORCID: 0000-0003-4707-1677)

[***] M. Ed., Hacı Ali AKIN Middle School, Van-TÜRKİYE. email: ozal.sapkan65@gmail.com (ORCID: 0000-0002-9477-9814)

educators, and science educators is necessary (Aydin-Gunbatar et al., 2020; Colston, et al., 2017; Hammack, Ivey, Utley, & High, 2015).

The history of engineering goes back to the Renaissance (National Research Council, [NRC], 2009). Engineers aim to solve problems that are encountered in daily-life and to make life easier and better through EDP (Dym, Agogino, Eris, Frey, & Leifer, 2005). Although engineers have greatly influenced our lives, many people do not know what engineering is or what engineers do (National Academy of Engineering, [NAE], 2008). Engineers focus on emerging challenges and plan to address them through EDP, i.e. "process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic science and mathematics and engineering disciplines are applied to convert resources optimally to meet a stated objective" (Accreditation Board for Engineering Technology [ABET], 2011, p. 4). With the recent STEM movement, students have the opportunity to become familiar with the engineering profession and EDP. Regarding the recent emphasis on integrating engineering and EDP, Moore et al. (2015) stated that there are three main arguments behind the emphasis on engineering integration, namely, augmenting students' 21st-century skills development, catalyzing students' science and math achievement, and increasing students' STEM interest. Parallel to that point, research revealed that engineering design-based STEM education had a positive influence on students' science achievement (Dedetürk, Saylan-Kırmızgül, & Kaya, 2020; Özer & Canbazoğlu-Bilici, 2021) and understanding of engineers and attitudes about engineering (Colston et al., 2017).

In the related literature, some research has been conducted to examine students' existing views of engineers. Fralick, Kearn, Thompson, and Lyons (2009) compared and contrasted 1,600 middle school students' views of scientists and engineers. Although students' scientist drawings provided more details, engineering drawings included fewer details about what engineers do. The study indicated that students are not familiar with the engineering profession. Moreover, in a cross-age design study, Capobianco et al. (2011) examined how 400 students in grades 1-5 perceived engineers. The results showed that students mostly drew workers/laborers working with hands at construction sites. When asked, students mostly mentioned civil engineering as a field and civil structures as engineers' products. Moreover, engineers were mostly male (Capobianco, et al., 2011; Fralick et al., 2009; Mitchell, Lott, & Tofel-Grehl, 2022; NAE, 2008). Through phenomenographic lenses, Karatas, Micklos, and Bodner (2011) examined 6th graders' views of engineers and the nature of engineering. The results were more promising when compared with previous studies. Students were able to explain the dynamic nature of engineering. Moreover, students revealed that engineers design, plan, and test the products they develop to make them better and safer. Karatas et al. (2011) also reported inconsistencies between different data sources (e.g., drawing vs. interview data). Regarding data, Capobianco et al. (2011) revealed that students' drawings did not include details, thus making it difficult to interpret the drawing. In a more recent study, Koyunlu- Ünlü, and Dökme (2017) analyzed 72 gifted students' engineering images by the use of the 'Draw and Engineer' (DAE) instrument and semi-structured interviews. Gifted students mostly drew male (almost 80% of the participants), and civil engineers (more than 50% of the participants) and computer engineers (25%). Very few students drew software, genetic, and aircraft engineers. Different from previous studies, students' conceptions of engineering were focused on through summer training by Hammack et al. (2015). n=19 middle school students participated in a week-long summer camp. The STEM activities implemented had a chemical engineering emphasis due to the implementer's background. Moreover, the training introduced and emphasized the different types of engineers perform. Results showed that the participants' understanding of engineering improved. Although the students were not sure what engineers do at the beginning, after the intervention they had a more valid understanding of the engineering profession. For instance, more than 30% of the participants stated that chemical engineers do experiments with chemicals after the training whereas 15% of them mentioned that before the intervention. Finally, Hammack et al. (2015) reported that although some of the misconceptions regarding engineering were addressed, some of them still existed.

To examine middle school students' conceptualization of engineers and engineering, Constructivism can be used as a theoretical lens. According to Constructivism, people construct new knowledge through a process in which they take an active role. In this process, prior knowledge structure, observations, and experience also have important roles (Bruner, 1966). Hence, due to differences in prior knowledge, experience, and existent knowledge structure, people's knowledge construction may result in different realities. Regarding the nature and properties of the knowledge constructed, it may have different forms in people's mind, namely, pictorial (e.g., models, pictures) and symbolic representations (e.g., words) that have different properties (Paivio, 1969; Ponte, 1994; Strenberg, Strenberg, & Mio, 2012).

> *[P]ictures aptly capture concrete and spatial information in a manner analogous to whatever they represent. They convey all features simultaneously….Words, on the contrary, handily capture abstract and categorical information in a manner that is symbolic of whatever the words represent. Representations in words usually convey information sequentially (Strenberg, et al., 2012; p.275)*

Furthermore, Constructivist theorists focused on how people learn, and develop models and conceptions which are internal representations formed by people internally through experiencing external representations (Duit & Treagust, 2012). Piaget and Inhelder (1971) analyzed mental images of children and their relation to the function of thought. According to Piaget and Inhelder:

> *... the object can be known only by being conceptualized to varying degrees. The image is indeed still the product of an attempt to produce a concrete and even simili-sensible copy of object. But the copy is fundamentally symbolic since the effective signification is to be found in the concept. (p.xix, italics in original)*

Based on the points listed above, to capture and understand people's knowledge of any concept and/or phenomena, it is necessary to focus both on the pictorial and symbolic structures. Therefore, to be able to dig into how learners' knowledge of engineering and engineers develop through integrated STEM activities that provide great first-hand experience for learners to construct knowledge of what engineers do, this study aimed to collect data that have both verbal and pictorial aspects as highlighted above.

1.1. Statement of the Problem

With the integrated STEM movement, engineering education has received attention recently. Although engineering is a new discipline to be discovered both by teachers and K-12 learners (Cunningham & Carlsen, 2014), the policy and standard documents have widely mentioned engineering. "However, if engineering is expected to be taught to students as described in NGSS, conveying engineering as a set of practices with little mention of engineering concepts or the nature of the discipline distorts the field and promotes misconceptions'' (Pleasants & Olson, 2019, p. 160). As stated in Nature of Science (NOS) literature (e.g., Lederman, 2007), learners' mere participation in a science activity does not ensure their informed NOS understanding. Likewise, to enrich learners' understanding of engineers and EDP, explicit prominence should be put on the engineering component of integrated STEM (Antink-Meyer & Brown, 2019; Pleasants & Olson, 2019). To address the gap, in this study, we aimed to compare and contrast the contribution of STEM education on middle-school students' knowledge and views of engineering and engineers with and without the explicit emphasis on engineering. We think that the results of the study will enrich the literature regarding how integrated STEM applications with explicit emphasis through presentations, assignments, videos, and classroom discussions augment students' knowledge construction of engineering and their views of engineers when compared with integrated STEM applications that do not give explicit attention to engineering.

1.2. Purpose of the Study

To address the gap identified in the literature, this study aimed to examine the contribution of STEM training with explicit engineering emphasis (STEM-EE) and STEM-only (STEM-O) groups on 6th-grade students' knowledge and views of engineering after a four-week-long STEM training.

1.3. Problem of the Study

1. Is there any significant difference between engineering knowledge test scores of students in STEM–EE and STEM-O groups after receiving STEM training?
2. How do STEM-EE and STEM-O training contribute to the students' views of engineering?

1.3.1. Sub-problems of the study

1. Is there any significant difference between engineering knowledge test scores of students in STEM–EE and STEM-O groups before receiving the STEM training?
2. How did students' drawings of an engineer develop regarding the engineer's appearance?
3. How did students' drawing engineer develop regarding the location where the engineer works?
4. How did students' drawings of an engineer develop regarding the engineer's inferred action?
5. How did students' drawings of an engineer develop regarding the objects that the engineer works with?

2. METHODOLOGY

This study used a mixed-method design. Specifically, it is concurrent triangulation mixed methods (Creswell, Clark, & Gutmann, 2003). Throughout the study, the researchers collected quantitative and qualitative data concurrently to examine the participants' development regarding engineering knowledge and views of engineers. For the quantitative part, we employed quasi experimental pre-post design (Fraenkel & Wallen, 2009). For the qualitative part, we employed phenomenology to examine the 6th grade students' views of engineers, engineering, and how they work (Yıldırım & Şimşek, 2006).

2.1. Participants

In this study, convenient sampling was employed (Fraenkel & Wallen, 2009). Both STEM-EE and STEM-O groups were intact ones that were formed by the school management long before the study was conducted. In the STEM-EE group, there were 32 students (12 female, 20 male). In the STEM-O group, there were 30 students (14 female, 16 male). Classrooms were randomly assigned to the STEM-EE and STEM-O groups. Students participated in two different STEM activities each of which took eight hours (four hours a week; 2x four hours in a week, which means each activity took two weeks). In total, the training that was provided took 16 hours (i.e., 4 weeks). The participants were 12 and/or 13 years old during the study conducted. Groups included 4-5 students heterogeneously selected by the teacher in terms of gender and students' academic success level. Both groups were provided with design logs and the necessary materials for the design activities.

2.2. Setting and Implementation

The training was offered in the fall semester of the 2019-2020 academic year. In both groups, the same STEM activities were applied with the same materials provided, in the same sequence, and with the same period time. This way of organization is a great way to control the Hawthorn Effect, which is a positive emotional situation for a group receiving novel treatment. However, the group receiving traditional instruction may become demoralized (Fraenkel & Wallen, 2009). In our design, both groups received quite similar training (Table 1).

Table 1.
Training Details for the Insulated Home Activity

Day	STEM-O Group	STEM-EE Group
1	Introducing the real-world problem: The teacher mentioned the heat insulation problem that he had in his home. Although his gas bills are high, his home is not warm enough. Then, they discuss the problem, its reasons, and possible solutions. (This step is common to both groups)	
2	Introduce heat concept and heat transfer	Introduce heat concept and heat transfer Discuss what an engineer does and show videos of different engineering fields
3	Discuss the features of insulation materials Introduce the design challenge: Design an insulated home (This step is common to both groups)	
4	Working on design: Research the insulation materials and how to use them (Group work with 4-5 students)	Working on design: Research the insulation materials and how to use them (Group work with 4-5 students) Connect-the-Engineer activity (Lamar & Townsend, 2018): What are the types of engineering? Do research, then prepare a text introducing a different field of engineering that attracts your interest
5-6	Working on design: Tests on the materials that the groups decided to use when designing their product	Working on design: Tests on the materials that the groups decided to use when designing their product Present your research on engineering fields
7-8	Presentation of the insulated home: Its presentation to the groups and determining the best design for heat insulation Group work on re-design: Write what you would change and the reason why you would change it. (This step is common to both groups)	

The same sequence and details were planned for the thermos activity as well for both groups. Thermos activity also took two weeks. Both groups were assigned to design a thermos that keeps the hot water hot. The best thermos designed was determined by measuring the temperature of hot water (i.e., about 70°C) for 75 minutes. Three measures were taken for each design. The data collected were inserted into a table.

Two middle school science teachers, one of whom was the second author, implemented the activities over a month. When the researcher is the implementer and/or when different teachers are the implementers in a study, some issues regarding internal validity arise, namely, implementation threat (Fraenkel & Wallen, 2009). To control the threat, first of all, before proceeding to the implementation phase, a joint plan was created by the researchers (i.e., for how the activities are implemented, which steps that teachers will go through, which examples that they will give during introduction phase, etc.) and shared with both the implementers. Second, a third colleague who is from the same school and knowledgeable about integrated STEM approach and its implementation, visited both teachers' classes and controlled their implementation. Third, to guarantee similar implementation, both teachers were provided Design Logs (i.e., based on Wheeler, Whitworth, & Gonczi, 2014) for both STEM activities. Each group in each class had a design log and fulfilled it through the activity, and surrendered it to the teacher at the end of the activity. Finally, the two teachers implementing the STEM activities were male and graduated from the same teacher education program in 2011, which means that they have similar backgrounds. The other implementer received a master degree a year ago. During the implementation, both teachers communicated about their progress and the details of the implementation if they needed. To conclude, implementers have had similar characteristics, which provides evidence for their equivalent abilities to address implementation threat (Fraenkel & Wallen, 2009). Although all those precautions were taken, it could be possible to say that some minor differences might occur between the two teachers' implementation.

2.3. Data Collection and Data Sources

In the study, the Engineering Knowledge Measurement Scale (EKMS) and Draw an Engineer (DAE) instrument were administered to participants both at the beginning and the end of the training (Table 2.).

Table 2.
Details of the Data Collection

Groups	Before training	Training	After training
STEM-EE	EKMS DAE	STEM activities with explicit engineering emphasis	EKMS DAE
STEM-O	EKMS DAE	STEM activities (no explicit engineering emphasis)	EKMS DAE

EKMS was developed by Aydin, Saka, and Guzey (2018). It includes 15 multiple-choice items with four choices. The original EKMS form was designed by Harwell et al., (2015) as two forms one of which was for grades 4-5 and the other for 6-8. EKMS used in this study is the combined version of these two forms. Proof for reliability (i.e., Guttman, Split- Half reliability coefficient was calculated as .71) and proof for the validity of EKMS were provided by Aydin et al., (2018). In this study reliability coefficient was calculated as .75. An example item was provided below.

Bengisu needs to design and build a water purifier for the science exhibition. She brainstormed many different filter materials to be used in her design. She tried them and decided which material to use. What should Bengisu do next?

A. Build and test the purification device
B. Brainstorm about different water filters
C. Asking her teacher about water pollution
D*. Sketching the water purifier
***(The correct answer)**

To focus on the participants' views of engineering, we used DAE, developed by Knight and Cunningham (2004). DAE has two parts, namely, drawing engineers and their work, and explaining the drawn parts. The participants were informed that they were supposed to draw the engineer at work in the ''framed'' part. In the second part, prompts relating to the drawn engineer, the engineer's personal information, where s/he works, describing her/his job, and describing what s/he is doing are asked. The participants were provided with crayons and asked to imagine an engineer and drew her/him. DAE provided both image and written data for analysis. Both instruments were administered as an in-class assignment.

Forms asking questions (i) relating to the existence of relatives who are engineers, (ii) whether the students want to pursue a career in engineering, and (iii) whether the students talk about the engineering profession with their parents were given as homework.

2.4. Data Analysis

EKMS data were coded as 1 for true and 0 for false responses. The data were entered in the SPSS program and prepared for analysis. Missing data and outlier analyses were conducted before the data analysis. Two students' data from STEM-EE and five students' data from the STEM-O group were omitted. Hence, analyses were run for 55 students in total.

For analysis of the data collected with the DAE instrument, four sub-categories were used, namely, engineer's appearance, location, inferences of action, and objects, which were suggested by Fralick et al. (2009). Engineer's appearance covers engineer's gender, hair, clothes that engineer is wearing (e.g., overall, lab cloth, helmet, etc.), and the species in the drawing (e.g., human, non-human). Location sub-category is related to the place where engineer works in the drawing such as indoor, outdoor, and space. Inferences of action is about to code the learners' drawing regarding the action of the engineer (e.g., fixing, designing, calculating or experimenting). Finally, objects category includes the objects which engineers work with (e.g., calculators, robots, blueprints, or civil structures). Deductive coding based on the existing coding list developed by Fralick et al., (2009) was employed. First, 10 participants' DAE data that had rich drawing and explanation were purposefully selected. Then, those data were coded by both researchers independently using the aforementioned checklist. The codes were compared and contrasted, and inter-coder agreement was calculated using Miles and Huberman's formula (1994). The agreement score was .86 (.80 and above is suggested), which is very good to continue with coding. The minor differences were discussed and notes were taken to address those differences in the ongoing coding. The second author coded the rest of the data.

Given the difficulties in interpreting students' drawings as Capobianco et al., (2011) reported, to overcome the difficulty in this study, before the data collection, the participant teachers explained in detail what the students were expected to do with DAE instrument (i.e., warning for both drawing and explanation are required). In addition to that, the DAE includes both drawing and explanation parts, which provides rich data for the researchers. In other words, when we had difficulties, we could use what the student meant by his/her drawing when we read his/her explanation under the drawing. Finally, the use of the mixed-design research also helped the researchers to collect different but related data regarding students' views and knowledge of engineering and what engineers do.

3. FINDINGS

First, the results related to 6th graders' knowledge of engineering will be presented. Then, the results of DAE will be provided.

3.1. Changes in Students' Knowledge of Engineering

To examine whether there is a difference between the groups' EKMS results, first, the assumptions of parametric tests were checked. Due to the small sample size, the Shapiro-Wilks test was run to examine EKMS measurements' normality. The preliminary analysis showed that the distribution of the post-test scores was not normal. Therefore, non-parametric statistics were used. Instead of a t-test, its non-parametric equivalent Mann-Whitney U test was run (Palland, 2007). Second, pre-test scores were examined. The mean rank for STEM-EE was 35.61 (with 1,139; 50 sum of ranks) and 27.12 (with 813; 50 sums of ranks) for STEM-O. According to Mann-Whitney U test results, the p-value was .062, which is higher than the set alpha value (.005). Therefore, there is no statistically significant difference between the two groups' pre-test EKMS scores ($p>0.05$). EKMS pre-test scores of students in both groups are not statistically different.

After the training, to see if any difference exists between the groups' EKMS scores, post-test scores were analyzed using the Mann-Whitney U test. The results revealed a statistical difference between the two groups' post-EKMS scores ($U=10.500$, $z= -6.654$, $p=0.00$, $r=0.85$). Mean rank data received showed that the difference is in favor of the STEM-EE group (mean rank for STEM-EE 46, 17, and 15, 85 for STEM-O). The effect size was calculated as $r=0.85$, which is a large effect size (Pallant, 2007).

When the data were examined closely, it was seen that students in both groups had difficulties with questions 1, 11, and 12. Question-1 asks students about which choice is more important for an engineer to focus on. The correct choice is 'determining the reason why objects are broken easily.' The three distracters are about repairing something. Question 11 asks what the next step would be for an engineer who calculated high-risk factors of earthquake for an area on which a shopping mall is going to be built. The correct answer is disapproving of the plan; however, most of the students answered the question incorrectly thinking that the answer is re-planning. Finally, question-12 is related to the steps of EDP. The next step that should be taken after brainstorming the use of different materials for designing a water purification system and trying them out is asked. The expected answer is planning the purification device; however, most of the students answered incorrectly in the post-test with both groups thinking that the engineer should build the device and test it. To conclude, students in both groups still have problems with EDP steps.

3.2. Results for DAE

3.2.1. Appearance of engineer

Table 3 shows how the students in both groups imagined an engineer's appearance.

Table 3.
The DAE Results for the engineer's appearance

	STEM-EE		**STEM-O group**	
	Before	**After**	**Before**	**After**
Gender	17 M* 13 F	17 M 13 F	19 M 6 F	18 M 7 F
Species	30 Humans	30 Humans	25 Humans	25 Humans
Laborer's clothing	-	2	-	1

*M: Male, F: Female

Regarding gender, a small difference was observed in the STEM-O group's result. When we looked at the results, we realized that except for student-10 in the STEM-O group after the training, all students in both groups drew an engineer with the same gender both before and after the study. In the STEM-EE group, all the female students and two male students drew a female engineer in both administrations of the DAE instrument. In the STEM-O group, compared with the other group, fewer female engineers were drawn both before and after the study. It can be inferred that our participants did not have an opinion of engineering as being 'a male profession.' Regarding an engineer's appearance, participants did not provide rich data (i.e., attire). Only two students drew an engineer wearing a helmet. The 23rd student from the STEM-EE group stated "my engineer checks where the coal is and then he tells the workers." Also, one participant (the 18th one in the STEM-O group) drew a genetic engineer wearing a lab coat just like scientists wear in the post-administration. Another interesting finding regarding the appearance sub-category was that all students drew human beings in both groups (Table 3). Non-human type drawings were not observed in the data.

3.2.2. Location

Table 4 summarizes the data received for the location sub-category.

Table 4.
The Locations Where Engineers Work

	STEM-EE		STEM-O	
	Before	**After**	**Before**	**After**
Indoors	12	15	7	8
Outdoors	18	14	17	17
Space	-	1	-	-
Underground	-	-	-	-
Underwater	-	-	-	-

Before the training, most of the students in both groups drew engineers working outdoors (Table 4). In both groups, the construction site was the most frequently drawn outdoor location (Figure 1-a, b, c).

(a) (STEM-EE-25*) (b) (STEM-O-10). (c) (STEM-EE–11)

Figure 1. Engineers working at a construction site (before the study)
* The number shows the student's code in that group

Regarding indoor locations, students in the STEM-O group drew an office where engineers work indoors before and after the study. In the STEM-EE group, in pre-administration, similar indoor and outdoor drawings were observed. However, in post-administration, students in the STEM-EE group drew laboratories, offices, and atelier/studios as indoors, and shipyards and mines as outdoor locations (Figure 2).

(a) (STEM-EE-16) (b) (STEM-EE-23) (c) (STEM-EE-10)

Figure 2. Different locations drawn after the study by students' in the STEM-EE group

As seen from the drawings, although some of them are unclear and hard to understand, the data received from the "explain your drawing" part of the DAE instrument were very useful in understanding what the student had in mind.

3.2.3. Inferred action

Before the study, the students' views of engineering in both groups were similar, describing engineers mainly as workers who fix something with their hands (Table 5).

Table 5.
Inferred Actions of Engineers in Drawings

	STEM-EE		STEM-O	
	Before	**After**	**Before**	**After**
Fixing/working with hands	11	3	7	6
Measuring	-	-	-	-
Explaining/Teaching	4	9	-	3
Designing	13	18	13	13
Experimenting	-	10	2	2
Observing	2	3	3	1
Studying blueprints	9	2	11	12

In the beginning, 16 students in STEM-EE and 17 students in the STEM-O group confused engineers with workers or building contractors. In the "explain your engineer" part, the students stated that the engineer they drew was fixing the building, building the civil structure, or selling the buildings. Likewise, other students drew types of engineers (automotive or electrical engineers; Figure 3b and 3c), indicating that students knew varying types of engineering. However, they explained that the engineer was fixing the car, which showed that they confused automotive engineers with a mechanic.

(a)
"He is building a brick wall. Then, he will use concrete." (STEM-O-9)

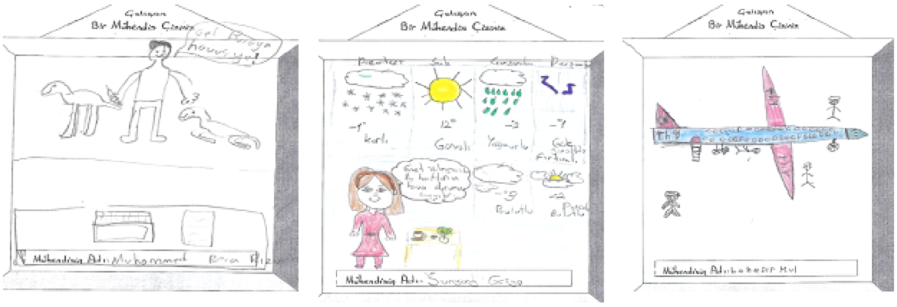
(b)
"She is an electrical engineer. She fixes the lamps that nobody is able to do. She is now climbing up the ladder and going to fix the lamp." (STEM-O-23)

(c)
"He works in a car company. He fixes cars, decorates and modifies the cars' shape." (STEM-EE- 27)

Figure 3. Students' drawing regarding the inferred actions of engineers before the study

The explanations revealed that many students were unaware of what engineers do and how they work. Thus, before the study, the researchers inferred that students' perceptions of engineers and engineering were naïve regarding the higher-order actions and thinking processes necessary for engineering design.

When the DAE data were compared and contrasted before and after the training regarding inferred actions, development was observed in the STEM-EE group's drawings whereas very few changes occurred in the STEM-O group's drawings (Table 5). Six students from the STEM-O group drew engineers fixing/working with hands, indicating that they still confuse engineers with workers. Three students from the STEM-O group drew engineers explaining/teaching something to workers after the study. By contrast, students' drawings in the STEM-EE group correctly (for the most part) showed important changes regarding the actions that engineers are supposed to do. After the study, they drew engineers experimenting, designing, and observing (Figure 4), though some of them still drew engineers working with hands (n=3).



(a)
"He is experimenting with animals. He is testing a new drug that is used to achieve a higher yield from animals."
(STEM-EE-18)

(b)
"She studies and analyzes meteorological events, and presents information for our use."
(STEM-EE-19)

(c)
"My engineer is an aircraft engineer. He draws blueprints and calculates the cargo load that the aircraft would be able to carry."(STEM-EE-1)

Figure 4. STEM-EE group students' drawings after the study

The STEM-EE group's drawings after the study were more detailed. Furthermore, their explanations of the drawings were richer when compared with their drawings before the study and the drawings of the STEM-O group after the study. The explanations after the study included the verbs such as to design, test, research, calculate, use and present data, and experiment to explain what the engineer is doing. That development and enrichment are also parallel to the increase in the types of engineering mentioned after the training (Figure 5).

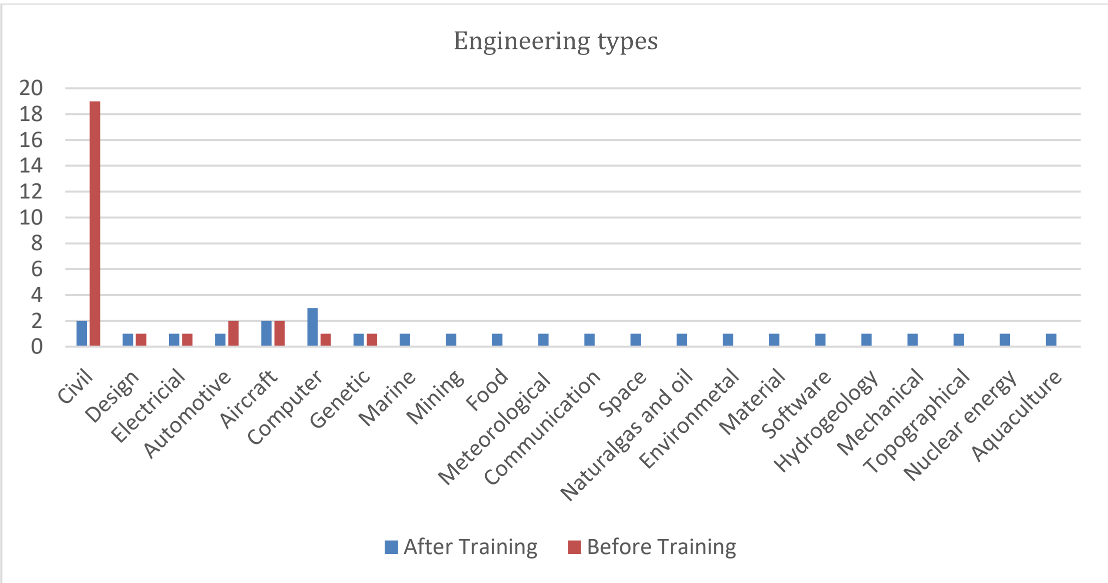


Figure 5. Engineering types in STEM-EE group's DAE data

Before the training, students were not aware of different fields of engineering. However, after the training, most probably owing to researching different fields of engineering and presenting what those engineers do, the students in the STEM-EE group seemed well informed both about those fields and their job descriptions. By contrast, DAE data collected from the other group showed that students mostly drew civil engineers in both administrations (Figure 6). Moreover, the types of engineering in the STEM-O group were not diverse.

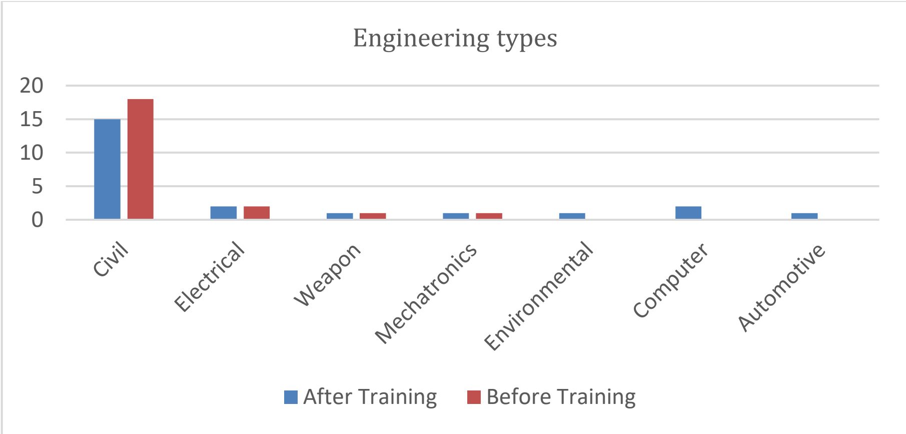
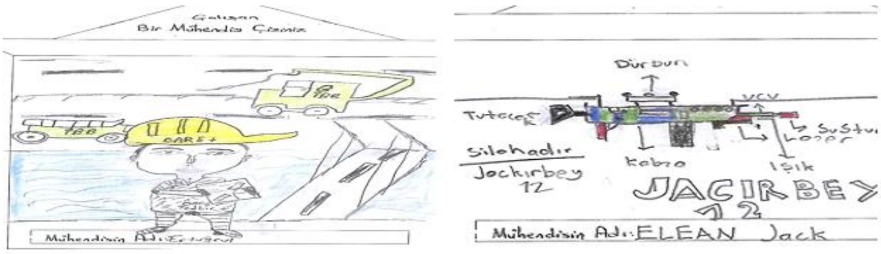


Figure 6. Engineering types in STEM-O group's DAE data

Although the students in the STEM-O group drew mostly civil engineers after the study and confused engineers with workers, there were some students (n=5) who drew and explained a civil engineer who was designing a bridge and calculating the load that the bridge would carry (Figure 7a). This showed that the confusion between engineer and worker does not exist anymore. Likewise, another student drew an engineer working on designing a new weapon with new properties (Figure 7b).



(a) "He builds bridges and calculates the load that they are able to carry." (STEM-O-8)

(b) "He works on weapons and designs defense systems." (STEM-O-17)

Figure 7. Drawings from STEM-O group after the training

However, the students who drew electrical engineers stated that they were fixing electronic goods, indicating the confusion still exists.

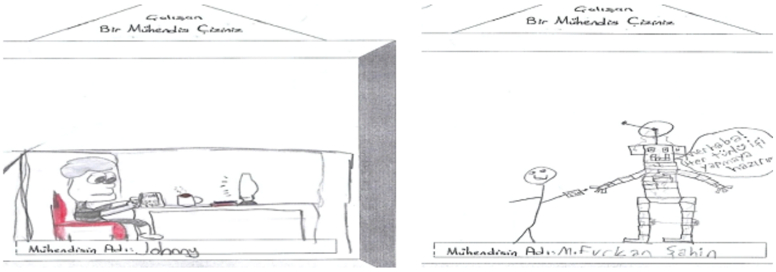
3.2.4. Objects

The objects included in the students' drawings are presented in Table 6.

Table 6.
Objects in Both Groups' Drawings

	STEM-EE		STEM-O	
	Before	**After**	**Before**	**After**
Computer	1	3	1	2
Robot	-	-	-	1
Passenger vehicles	2	1	-	2
Construction vehicles	1	2	3	-
Civil structures	19	3	18	14
Plane	-	2	-	-
Blueprints	9	2	11	12
Weapon	-	-	2	3
Writing objects	9	12	8	8
Building tools. hammer	15	2	18	15
Math symbols	1	-	-	-
Animals	-	1	-	-
Ship	-	1	-	-
Meteorology	-	1	-	-

Before training, students in both groups drew civil structures, building tools, blueprints, which are related to civil engineering (Table 6). After the training, the number of drawings of civil structures, building tools, and blueprints decreased significantly in the STEM-EE group whereas in the other group the decrease was small. It was also observed that the students in the STEM-EE group diversified the objects used by the engineers after the training. For example, ships, computers (Figure 8-a), meteorology, and aircraft were seen in post-DAE administration.



(a) "He is a computer engineer. Now, he is trying to find the best system for the computer and is designing the system. He is trying to design the best computer card [motherboard]''(STEM-EE-16)

(b) "My engineer designs robots and all types of electrical devices. Now, he is testing a long-awaited robot.''(STEM-O-13)

Figure 8. Objects in drawings after training

Students' drawings in the STEM-O group after the study mainly focused on civil engineering. However, some students drew different objects, for instance, robots and weapons (Figure 8-b).

3.3. The interpretation of quantitative and qualitative results together

Both quantitative and qualitative data analyzes presented results in favor of the STEM-EE group. Students' in the STEM-EE group had higher scores in the test when compared to the students in STEM-O group. Although students in both groups had difficulties in items related to EDP and its steps, STEM-EE group's performance was better than STEM-O group with a large effect size. Additionally, the drawings and explanations revealed by DAE analysis painted a similar picture. For example, students in STEM-EE group improved their views of engineers' action. After the study, they drew engineers experimenting, designing, and observing. However, many students from the STEM-O group still confused engineers with workers. Likewise, students in the STEM-EE group provided more details both in drawing and explanation part of the DAE. Students in STEM-EE group viewed the engineers as someone who design, test, conduct research, calculate, use and present data after the training. That development and enrichment were also parallel to the increase in the types of engineering mentioned after the training. When the quantitative and qualitative results were put together, it can be argued that integrated STEM implementation with explicit engineering emphasis is more useful for students to enrich their knowledge of engineering and the views of engineers.

Finally, to check the extent to which students in both groups were similar regarding knowing someone as an engineer or talking about engineers/engineering at home, which is an important factor explaining children's familiarity with engineering and engineers (Mitchell, et al., 2022), the data collected were examined. 15 and 12 students had engineer relatives in the STEM-EE and STEM-only groups, respectively. Students in both groups stated that they mostly do not talk about engineers/engineering with their parents. For instance, one student in the STEM-EE group stated that he does not know anybody who is an engineer and does not talk about engineering at home. He drew a civil engineer before the training and then drew a software engineer. Another student in this group (student-18, whose father is an agriculture engineer) drew a genetic engineer in both DAE administrations.

4. DISCUSSION AND RECOMMENDATIONS

This study focused on comparing and contrasting the contribution of STEM training with and without explicit engineering emphasis on 6th-grade students' knowledge and views of engineering after a four-week-long STEM training. With the recent integrated STEM movement, engineering has received explicit attention. However, assuming that students' knowledge and understanding of engineering, and what engineers do are acquired only through participation in integrated STEM activities raises some issues. A similar assumption was tested in NOS literature as well. NOS research has revealed that the implicit approach was not as successful as the explicit approach in augmenting students' NOS understanding (Lederman, 2007). This study showed that STEM activities with explicit emphasis on engineering, job description, and engineering types are necessary to ensure students' understanding of the profession.

Regarding EKMS results, although there was no significant statistical difference between the groups at the beginning, after the training, the STEM-EE group outperformed the STEM-O group. As Antink-Meyer and Brown (2019) and Pleasants and Olson (2019) argued, NOS is best learned through the explicit emphasis on NOS. Therefore, the engineering profession should be integrated into STEM lessons with explicit examples, cases, and historical events. Despite the differences between the groups in favor of STEM-EE group after the training, students in both groups had difficulties in answering the questions related to EDP. The possible reason of that result may be related to the inadequate emphasis on EDP and its steps. In other words, for a solid understanding of EDP and which steps that engineers go through EDP, more time and emphasis is required. Hence, the trainings should include more and explicit EDP focus in the future. Regarding the gender of the engineers drawn in the DAE instrument, the participants in this study showed an unexpected tendency by drawing many female engineers, which conflicts with previous literature. Capobianco et al. (2011), Fralick et al. (2009), and Mitchell et al. (2022) revealed that students generally drew male engineers. However, in this study, most of our participants do not have a view that engineering is a male profession. Additionally, students in both groups did not change the engineer's gender in the second administration (i.e., except one student). This showed that we did not make any changes to students' perceptions of engineers regarding gender. Although engineering is viewed as a male profession in Turkey (STEM Turkey Report, 2015), we think that our participants might prefer to imagine themselves as engineers. Through Constructivist lenses, this result can also be interpreted that students' perspectives about engineers can be resistant to change (Duit & Treagust, 2012). Similar resistance was reported by Hammack et al. (2015). Hence, that point in students' minds requires more attention and longer training to be changed.

Regarding the appearance of engineers, some of the students drew engineers with a helmet and laborer's clothing, which indicates that students confusing engineers with workers (Fralick et al., 2009). The area where the study was carried out had an earthquake disaster almost ten years ago. Hence, the students who participated in the study have seen many construction sites with many workers, which could explain why students confuse engineers with workers. In the construction sites, although there are engineers, the students may seem to view them as workers. Hence, the difference between workers and engineers, and their job descriptions should be done explicitly and intentionally to address the confusion. However, the results also revealed that not only civil engineers but also automotive engineers were also explained as workers or mechanics fixing cars. Similar results were reported by previous studies (e.g., Fralick et al., 2009; Knight & Cunningham, 2004). Students' inaccurate views of engineers and what they do ignore higher-level mental processes such as using scientific or mathematical knowledge in designing or experimenting (Fralick et al., 2009). In some of the DAE data, the details regarding actions were missing, especially before the study. Fralick et al. (2009) observed a similar situation and reported that although their students drew scientists in detail and explained what they do, the data for engineers were not rich. Accordingly, it is observed that students have not had enough opportunities to observe engineers working in daily life, and this results in the view of engineers being both incomplete and inaccurate. Finally, the problem may also be related to the students' difficulties in drawing those higher-level mental processes. Students may not know how to draw an engineer calculating or using scientific knowledge in the design process. As Karatas et al. (2011) mentioned, to acquire the participants' conception of engineers and engineering, the DAE instrument is not sufficient. The DAE data should be supported by interviews that let the participants explain her/his drawing regarding the location, process, work, and engineering type. To conclude, in light of the points raised, despite some problems discussed, introducing the engineering profession to students should be a part of STEM activities. As in our case, the 'Connect-the-Engineer activity' developed by (Lamar & Townsend, 2018), giving assignments about different types of engineering fields and their job descriptions, and students' presentation about what they learned would address students' limited recognition of the profession. Moreover, classroom immersion models that provide partnering and collaboration between teachers and engineering fellows (e.g., graduate engineering students) would be another great opportunity. Thompson and Lyons (2008) showed that students mentioned their experience with engineering fellows to explain what engineers do. Students' answers to questions in the interview also included their observation of the engineering fellow working in class.

Regarding location, before the study, students in both groups drew engineers working outside, especially working at construction sites with civil structures, which is consistent with their pre-instructional experience and observations. This is also in keeping with previous studies' results (Capobianco, et al., 2011; Knight & Cunningham, 2004). After the training, however, students who had a chance to research engineering types and their jobs, drew engineers in different locations such as offices, laboratories, ateliers/studios, and doing mental work. Moreover, those students drew engineers working outside in different locations (e.g., shipyards and mines). In addition, there were still some students drawing engineers at construction sites as if they were workers, indicating that to make changes in students' views of engineers and their work, the training given should be longer and include varying types of opportunities as mentioned above. Similar to the gender of engineering aspect, this point was also resistant to change, which requires more stress on the working environment of engineers (e.g., a video showing a biomedical engineer working on researching and developing an artificial organ in a laboratory or a marine engineer who is designing seagoing vessels and structures) and different examples of locations where engineers work to create cognitive conflict in students' minds. To help students change pre-instructional views, more examples showing different locations in which engineers work should be provided (e.g., videos, short documentaries about engineering, or interviews with engineers). Moreover, visits to the locations where engineers work would also be supportive for students to construct the idea that engineers not only work in civil structures but also in laboratories, offices, underwater, lands, and aircraft. Research on developing students' NOS understanding would shed light on how to design and enrich training for developing participants' views of engineering (Antink-Meyer & Brown, 2019). As reported in the NOS literature, the contribution of different types of support should be analyzed in future studies and evidence provided regarding how hybrid models can be implemented for participants with different backgrounds (e.g., regarding experience, socioeconomic status).

Regarding fields of engineering, students' knowledge was limited at the beginning of the study. However, later, the students in the STEM-EE group appeared to understand that there are many different fields of engineering. Moreover, the different engineering fields mentioned by the STEM-EE group students after the training were the ones that were included in their homework assignments, which is evidence for us to show the usefulness of explicit emphasis and assignments on students' learning about the fields of engineering. Students in the STEM-O group also mentioned more different types of engineering after training. However, the changes observed in the STEM-O group were not as rich as observed in the STEM-EE group. Pleasants and Olson (2019) and Hammack et al. (2015) argue that students' inaccurate or inadequate views and knowledge of engineering and its fields are one of the reasons that many students do not prefer engineering as a career to pursue. Therefore, focusing on the issue and addressing the problem is necessary for the success of the STEM movement.

Finally, studying with only two groups, short term training (i.e., one month, 16 class hours), and making emphasis through homework assignments, discussions, and presentation of the homework were the limitations of the study. In future research, emphasis on engineering by inviting engineers from different fields to class, interviewing engineers as assignments, and providing opportunities for students to observe engineers working in real contexts other than construction sites (e.g., genetic engineers in a laboratory) would provide useful results regarding how to enrich students' perceptions of engineers. In addition to that, new research by the use of modified version of Draw An Engineer test (mDAET) (i.e., developed by Thomas, Hawley, & DeVore-Wedding, 2020) that asks students how engineers use scientific and mathematical knowledge while doing engineering work would promise better results regarding students' conceptualization of engineers and their work. Last but not least, to assure all the suggested implications, it is necessary to train teachers who are knowledgeable about what engineers are and what they do. Hence, an elective Introduction to Engineering and Engineering Design Process course would be useful for pre-service teachers and professional development support for in-service teachers to understand engineering and EDP, which would reflect positively into their STEM implementation(Aydin-Gunbatar et al., 2020).

Research and Publication Ethics Statement

To address the ethical issues, permissions were obtained from the Institutional Review Board from Van-Yuzuncu Yil University with E-85157263-604.01.02-14496 document number. Moreover, to protect anonymity, the name of the participants were not used. Rather, the numbers were assigned to the participants from each group (e.g. STEM-O- 32 means student 32 from STEM-O group). No video recordings or photos of the students were taken.

Contribution Rates of Authors to the Article

The first author's contribution was about 55% (e.g., setting research questions, designing the research, data analysis, writing the paper in English). The second author's contribution was about 45% (e.g., implementation and data analysis).

Statement of Interest

The authors declare that they have no conflict of interest.

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