

# Investigating STEM Semantics and Perceptions of Engineer Candidates and Pre-Service Teachers: A Mixed Method Study

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## KEYWORDS

Engineer candidates  
Pre-service teachers  
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## ABSTRACT

This research aims to investigate STEM (Science-Technology-Engineering-Mathematics) semantics of engineer candidates and pre-service teachers in depth in regard to different variables and identify their STEM perspectives. The study group consisted of 228 students enrolled in undergraduate programs in a state university in Central Anatolia in Turkey. Explanatory design was used as a mixed method strategy in the study. The survey model as the quantitative component and the case study as the qualitative component was carried out. According to findings obtained in the study, a statistically significant difference was observed between STEM semantics of the undergraduate students and their gender, department and high school types point averages. In the in-depth interviews, it was revealed that participants were partially differentiated in their STEM semantics and STEM perspectives. These differences in the participants' STEM semantics on their department basis appeared more clearly through VENN diagram in the STEM visualization part and several recommendations were introduced in order to increase STEM semantics positively.

## Introduction

STEM education is at forefront among multidisciplinary approaches in education. This new approach which is named as STEM and addresses science, technology, engineering and mathematics disciplines as a whole possesses an important ground in raising individuals with equipped with the 21st century skills to fulfil tasks in the actual world, in combining theory and practice and acquiring creative problem solving skills, with investigating and questioning skills, with the awareness of sustainable development, and who become lifelong learners and science literate.

STEM education is of great importance in terms of various objectives such as being able to take steps towards industrialization of the country, being able to have the promise of the global market, being able to gain economic advantage, as well as educating competent and qualified individuals in existing and future generations of business. Given the necessary importance to STEM education, this is why raising STEM literate students from kindergarten to university STEM education, employing these students with their individuals' competences especially in industry areas ought to be among important goals in terms of industrial and economic development of the countries.

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Recently research findings in science education highlighted the need to use the engineering design-based approach to improve science teaching (Kelley, 2010). Engineering integrates the principles of science and mathematics by providing a link between scientific and mathematical theory and technology we use in our daily life with the aim of meeting social needs (Asunda, 2012). STEM semantic differential of individuals who grow in STEM areas with multidisciplinary features.

It is stated in the literature that STEM education has two main goals (Thomasian, 2011). The first of these is to increase the number of students who would prefer professionals in STEM fields at higher education level, another is to increase students' readiness levels in STEM disciplines so that they make effective solutions to overcome the problems they face in daily life. Today technology production has a significant share in the development of countries and it is important to put the information into practice in a qualified manner and draw attention of individuals to these fields while they raise career awareness (Hacıömeroğlu & Bulut, 2016).

It is only feasible through educators and engineers who are equipped with the necessary competences in this field to enable students to acquire STEM achievements. In particular when considering that students of education faculties have potentials to become teachers of the future, in general undergraduate students - especially STEM field undergraduates - would be one of the key milestones that affect the future of the country. Therefore ought to be able to use innovative methods and techniques to educate individuals who meet the need of the age and their levels of STEM semantic differentials ought to be high.

Teachers are expected to follow professional organizations, conferences and scientific publications in order to stay up-to-date with education, technology and practices, encourage students for scientific research, and support them in developing a product and improving their analytical thinking skills. For this reason, teachers are asked to have features such as critical thinking, problem solving, cooperation, leadership, flexible thinking, adaptation, entrepreneurship, verbal and written communication, information accessibility and use, curiosity and imagination (Wagner, 2008), which are required by the concept of innovation and its action as well as to acquire basic achievements of the STEM approach. It can be said that enabling educators to gain the theoretical knowledge of science and mathematics course and applications of engineering and technology with an integrated approach has an important ground in the acquisition of all these skills. Structuring the reform agenda of recent years with the approach embracing integration of STEM disciplines ([National Academy of Engineering [NAE], 2010) is a noteworthy indicator of putting emphasis on these fields.

The first attempts on STEM were carried out in various universities in Turkey. These initiatives were introduced by Hacettepe University and İstanbul Aydın University. On the other hand, in 2014, the Ministry of National Education (MNE) General Directorate of Innovation and Educational Technology was included as a national support point for the Scientix Project run by the European School Network. Thus, it was get involved in this STEM-based formation. The 2015-2019 strategic plan of the MNE have goals to place importance on STEM education. The 2011-2016 Science and Technology Development Plan of TUBITAK (Scientific and Technological Research Council of Turkey) has some activities that support students' STEM education (Baran, Canbazoğlu-Bilici & Mesutoğlu, 2015). However, the studies on STEM education that have been already carried out in Turkey are still in the beginning stage comparing to the studies carried out in developed countries. In particular teachers and engineers graduated from the universities and again engineer candidates and pre-service teachers studying at the universities are required to be equipped with decent competences through STEM approach.

In order to integrate the holistic interdisciplinary approach introduced by STEM education into our education system, pre-service teachers are ought to be ensured with the STEM awareness when they are yet in the education faculties, and existing teachers are needing to be equipped with support training programs and in-service trainings. Similarly, engineers of 21st century are expected to embrace multi-disciplinary culture and be able to put the STEM approach into practice in every moment of life. Brophy, Klein, Portsmouth and Rogers (2008) describe the engineering process as learning something new, learning how it operates, using knowledge to create new stuff, and making it suitable for others. This situation, which is at the core of the STEM approach, is not only a design process but also the process of effectively solving the problems individuals face (Marulcu & Sungur, 2015). Engineer candidates also learn concepts related to science and technology while they improve their engineering skills through design-based learning (Kolodner, 2002). Engineering education forms an interactive learning environment that includes activities to solve problems faced in daily life. Students can only acquire engineering skills such as analysing the situation, identifying the problem, gathering the relevant information, introducing creative ideas, proposing solutions for the problems, designing the proposed solutions and testing, revising the solution by evaluating and iterating the process as needed by personally participating in engineering design activities (NRC, 2012).

Johnson (2013) defines STEM as a teaching approach; integrating teaching of science and mathematics disciplines through the implementation of scientific research and application methods of technological research. Given that even STEM specialists today consider STEM within similar ways, pre-service teachers and engineer candidates are expected to have different reasoning and application features in visualisation methods in STEM (Anderson et al., 2013; Cook, 2006). Radolff and Guzey (2006) highlights that numerous factors influence STEM field pre-service teachers' STEM visualisations. Furthermore, they point out that different drawings emerged from individuals in STEM visualisations. It is emphasized that drawings is a form of communication giving information about individual's intelligence, anxiety, attitude and so on that helps individuals to express their experiences about a particular subject without prejudice (Kearney & Hyle, 2004; Melanlıoğlu, 2015; Zians, 1997). From this point of view, drawings are important to

understand the main theme of the research. In the study of Pinnell et al., (2013) 10 teachers and 5 pre-service teachers involved in workshops and activities related to curriculum development, inquiry-based learning and the conceptual framework of STEM education in 6-week program designed to improve their knowledge and skills related to STEM education. Following this, t an engineer candidate studying in a engineering faculty, a lecturer from a engineering faculty and an engineer working in the industry were involved in the study. The researchers evaluating program outputs stated that participant teachers improved their STEM skills and continued to improve their skills by leading the implementation of STEM education in their schools.

No study appeared in the relevant literature to identify undergraduate students' STEM semantic differentials and perspectives. In this context, it is considered that exploring STEM semantics of undergraduate students with different variables, and comparing primary school mathematics education, engineering and classroom education undergraduate students' STEM semantics would contribute to the literature. In addition, it is considered that the study would be important to reveal reasons of high STEM semantics of participants in their branches and their STEM perspectives.

### Research Problems

Studies that examine STEM awareness of undergraduate students in STEM field seem to be limited in the national literature. In this study, opinions of pre-service teachers and engineer candidates that have a key role in spreading the STEM education awareness were focused. In line with this direction, it was aimed to explore awareness of students of engineering, mathematics education, and classroom education about STEM which emerges as a new teaching approach in the education recently. The following questions were explored in this direction:

Is there a difference between point averages of Education Faculty and Engineering Faculty undergraduate students for the whole scale and subscales?

1. Is there a significant difference between STEM semantics of pre-service teachers and engineer candidates by gender variable?
2. Is there a significant difference between STEM semantics of pre-service teachers and engineer candidates by department variable?
3. Is there a significant difference between STEM semantics of pre-service teachers and engineer candidates by graduated high school types?
4. What are the factors that affect STEM semantics and perspectives of the students with high STEM semantics difference?

### Method

This study was based on a mixed model in which quantitative and qualitative data tools were used to explore classroom teachers' STEM semantic variations and perspectives in-depth. The exploratory sequence design which is one of mixed methods was carried out in the study. Convenience sampling method which is one of non-random sampling methods was embraced for the study. In the qualitative stage, homogeneous sampling method which is one of purposive sampling from non-random samplings was used. The diagram prepared to describe the design of the research is presented in Figure 1 below.

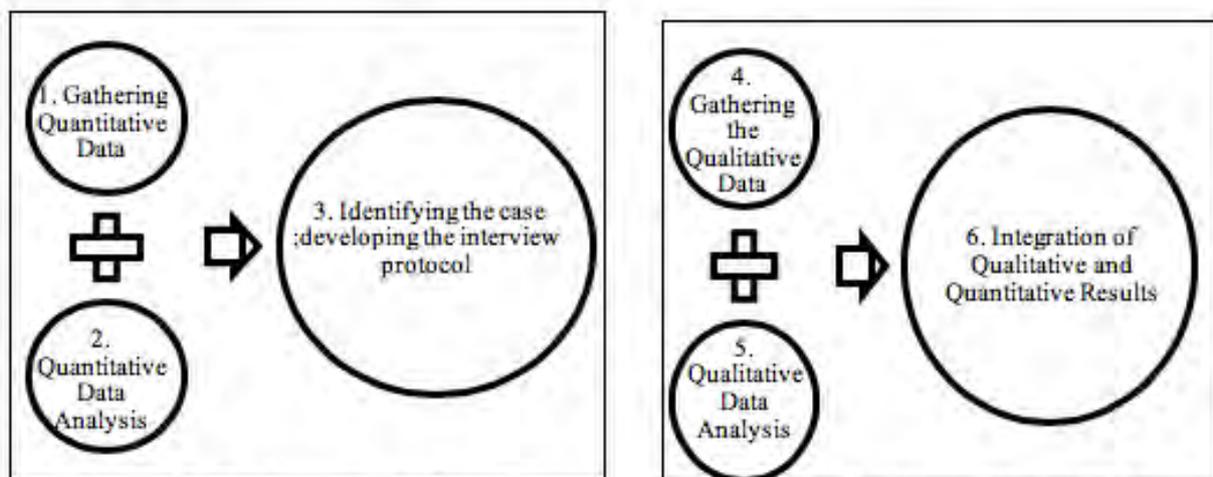


Figure 1. Exploratory design diagram source: Creswell & Plano Clark (2014).

### Study Group

An easily accessible sampling method was adopted from the purposeful sampling methods while the participant group of the research was being formed. In this context, the study group of the research consisted of 228 participants enrolled in engineering and education faculties of a university in Central

Anatolia in Turkey. The STEM Semantics Survey was administered to the participants and the second stage of the study was carried out with 45 participants who had 150 scores and more from the survey (ones with high STEM semantic variations). In this stage, interviews were conducted in order to identify reasons for participants' high STEM semantic variations and explore their STEM perspectives in-depth. Below are the distributions of the teachers who participated in the research by the demographic variables. The demographic information of the participants in the survey are as shown in Table 1.

Table 1.

*Demographic characteristics of participants*

Independent Variables	Groups	f	%
Gender	Female	122	53.5
	Male	106	46.5
High School Types	Anatolian High School (AHS)	138	60.5
	Vocational and Technical Anatolian (VTAS)	70	30.7
	Science High School (SHS)	20	8.8
Department	Classroom Teaching (CT)	80	35.1
	Primary Education Math Teaching (PEMT)	36	15.8
	Electrical-Electronic Engineering (EEE)	47	20.6
	Metallurgy and Materials Engineering (MME)	65	28.5
Total		<b>228</b>	<b>100</b>

As seen in Table 1, of the 228 participants, 122 (53.5%) were female and 106 (46.5%) were male. According to high school type graduated, 62 (27.2%) of the participants graduated from the private high school, 138 (60.5%) were from the Anatolian high school, and 8 (3.5%) were from the science high school. When examining departments of the participants, it is seen that 80 (35.1%) were in the classroom teaching, 36 (15.8%) in elementary school math teaching, 47 (20.6%) were in electrical and electronic engineering and 65 (28.5%) were in material engineering.

### Data Collection Instruments

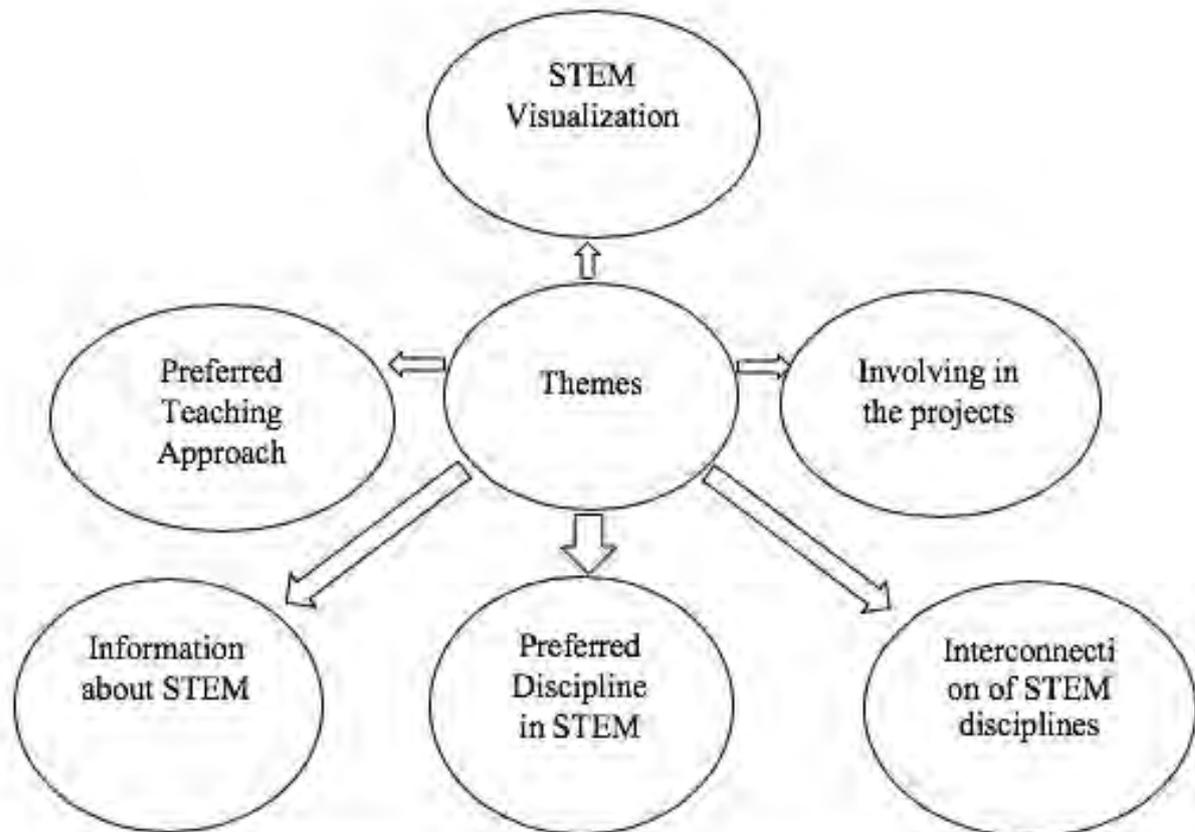
#### *The STEM semantics scale*

The "STEM Semantics Scale" developed by Knezek and Christensen (2008) and adapted to Turkish by Kizilay (2017) was used as the data collection instrument in the quantitative part of the research. In semantics scales, unlike likert scales, adjective pairs are used instead of expressions. These adjective pairs can be in the form of opposite adjective pairs or in the form of positive-negative adjective pairs (Şencan, 2005). The STEM Semantics Scale used in this study consists of 7 categories in which two opposite adjective categories were included (Kızıl, 2017). Validity and reliability of the study were carried out. The Cronbach alpha reliability coefficient was calculated as  $\alpha = .97$  for the whole scale. The reliability coefficients of the sub factors were respectively determined as science  $\alpha = .84$ , technology  $\alpha = .86$ , engineering  $\alpha = .96$ , mathematics  $\alpha = .88$  and career  $\alpha = .87$ . This value indicates that the scale has a very high level of reliability (Karasar, 2007). In addition to reliability analysis, exploratory factor analysis and confirmatory factor analysis were performed to determine the validity of the scale. The KMO (Keizer Meyer-Olkin) value and the Barlett's Test of sphericity were carried out to perform the exploratory factor analysis. Accordingly, the KMO value was 0.96 and Barlett's value was .00, ie,  $p < .05$ . These values are sufficient to proceed with descriptive factor analysis. As a result of the factor analysis, it was observed that the scale consists of 5 sub factors and the factors explain 85% of the total variance. The highest score that can be taken on a scale of 35 items is 245, the lowest score is 35.

#### *STEM semantic differences and perspectives interview form*

In the second stage of the research, an interview form consisting of 8 questions including 7 open-ended and 1 visualisation question was prepared to interview face-to-face with participants who had 150 scores or more on the scale. With questions in the form, the reasons for this high score in semantic differences of participants with high STEM semantic differences were explored in depth. In addition, the visualization fragment to determine what the STEM semantic differences in their minds constituted was another part of the form. The form of Radloff and Geothermal (2016) was inspired while this form was being developed. In the form prepared by taking the necessary permissions from the writers, the visualization question which was used to determine the perspectives of the participants was also used with reference to Bybee (2013). In the form created by the researcher, preparation principles (Yıldırım & Şimşek, 2016) was considered. The prepared questions were evaluated by 2 experts in the field of science, 2 experts in the field of mathematics, 1 expert in the field of classroom education, 1 expert in the field of measurement and 1 expert engineer and 2 questions were removed in the

direction of feedbacks and 2 questions were amended. The question of "What approach did you teach in your field? " was removed as it was not an appropriate question for engineer candidates. The themes related to the final form of the 6-question form are as shown in Figure 2.



*Figure 2. Questions about theme and subthemes in the interview form*

#### Data Analysis

SPSS 24.0 package program was used for analysis of quantitative data. The normality test was performed to determine the analysis methods to be used before analyzing the data collected in the study. The normality test was carried out by considering the demographic variables and the point averages of the data collection tool. It was observed that the data indicated normal distribution considering the skewness-kurtosis values, when Kolomogorov- Smirnow test was applied to the data, thus t-test, one-way variance analysis (ANOVA), Tukey HSD test and Pearson Correlation Coefficient to determine the source of difference were used for independent variables. 05 level of significance was adopted to interpret the results. In the analysis of the qualitative data, the content analysis method was adopted, and the answers given by the participants were coded and expressed in the forms of frequency and percentage. The data in the tables were interpreted just after the table was presented. Opinions of two different visual arts experts were taken and drawings of the participants in the visualization question were included and interpretations were made.

#### Findings

The results obtained from the collected data in accordance with the purpose of the research are given in tables and explanations. Interpretations based on these data were made. The normality test values in terms of variables related to the participants are given in Table 2.

Table 2.

*Normality test results of demographics of participants*

Independent Variables	S / K Skewness-Kurtosis	sd	Kolmogorov-Smirnov	Independent Variables	S / K Skewness-Kurtosis	sd	Kolmogorov-Smirnov
Female	.59/.77	122	.20	Anatolian H.	.13/.48	138	.20
Male	.06/.06	106	.52	Vocational H.	.49/.81	70	.20
CT	.18/.21	82	.20	Science H.	.59/.74	20	.20
PEMT	.95/.76	36	.20	1st Year	.42/.78	86	.20
EEE	.07/.43	45	.15	2nd Year	.11/.32	142	.20
MME	.43/.91	65	.05				

\*p<.05, sd: The number of participants, S-K: Skewness-Kurtosis Values, p: Significance value

CT: Classroom Teaching, PEMT: Primary Education Math Teaching, EEE Electricity-Electronic Engineering, MME: Metallurgy and Materials Engineering

In Table 2, the normality test for the whole scale was examined in terms of independent variables. The coefficients of skewness and kurtosis and Kolmogorov-Smirnov values in the test indicate that the distribution of the data is homogeneous in all variables. The fact that the coefficients of skewness and kurtosis are close to 0 within the limits of  $\pm 1$  are considered as evidence for the existence of the normal distribution in the literature (Tabachnick & Fidell, 2013; Huck, 2012). Furthermore, the fact that Kolmogorov-Smirnov p value is bigger than .05 can be stated that the scores of the scale are in normal distribution for the significance level (Büyüköztürk, 2011). In this regard, it is necessary to use parametric methods in data analysis which are normally distributed. For this reason, independent t-tests and analyzes such as Anova were performed.

Table 3.

*Undergraduate students of score distributions for the scale by department*

Faculties	Departments	N	$\bar{X}$	ss	Min	Max	Total
Education	CT	82	121.14	2.41	52	162	244.16
	PEMT	36	123.02	4.67	27	175	
Engineering	EEE	45	121.64	3,73	49	175	264.68
	MME	65	138.26	2,95	91	173	

CT: Classroom Teaching, PEMT: Primary Education Math Teaching, EEE Electricity-Electronic Engineering, MME: Metallurgy and Materials Engineering

As seen in Table 3, the average points of the respondents on the scale were 121.14 for classroom teachers, 123.02 for elementary mathematics, 121.64 for electrical and electronics engineering and 138.26 for metallurgy and material engineering. Thus, it can be said that metallurgy engineering students are with higher STEM semantics differences among departments. In addition, higher STEM semantic difference was observed in undergraduate students studying in engineering faculties ( $264.68 > 244.16$ ). Table 6 indicates the distribution of the scores for the sub-dimensions of the scale.

Table 4.

*Score distributions of faculties-based undergraduate students for the sub-dimensions of the scale*

Faculties	Sub Dimensions	N	$\bar{X}$	ss	Min	Max
Education	Science	118	22.01	7.58	5	35
	Mathematics	118	25.28	7.30	5	35
	Technology	118	28.65	6.76	5	35
	Engineering	118	20.95	8.45	0	35
	STEM Career	118	25.75	7.18	5	35
Engineering	Science	110	24.70	6.80	5	35
	Mathematics	110	24.15	6.98	5	35
	Technology	110	27.47	6.27	5	35
	Engineering	110	27.47	6.46	5	35
	STEM Career	110	26.16	7.15	2	35

As seen in Table 4, The mean of the semantic difference of science which was one of 5 sub-dimensions of the scale was observed as 22.01 in students of the education faculty and 24.70 in students of the engineering faculty. Considering that points of sub-dimensions between min 5 and max 35, it can be said that the semantic difference of the participants is high. The mean score of engineering students is higher than the mean score of pre-service teachers. In the mathematics sub-dimension, mean score of the pre-service teachers was 25.28, while those of the engineers was observed as 24.15, meaning that their semantic differences were lower in the field of mathematics. In the technology sub-dimension, mean score of the pre-service teachers was 28.65, and the mean score of the engineer candidates was 27.47, so it was revealed that the semantic differences of the pre-service teachers in the field of technology are higher than those of the engineer candidates. In the engineer sub-dimension, the mean score of the pre-service teachers was 20.95 and the mean score of the engineer candidates was 27.47. This indicates that engineer candidates have high semantic differences in their engineering profession. The mean score of the semantic differences for STEM career, the last sub-dimension of the scale, was 25.75 in pre-service teachers and 26.16 in engineer candidates. Therefore, engineer candidates said that making a career in the field of STEM would be more meaningful for them. The results of the t-Test are given in Table 5 for independent groups by gender in the scores of STEM semantic differences of undergraduate students participating in the survey.

Table 5.

*T-test results for independent groups by gender in the scores of stem semantic differences of undergraduate students*

Sub-dimensions	Gender	N	X	ss	sd	t	p
Science	Female	122	23.79	6,45	228	.57	.56
	Male	106	23.24	8,03			
Technology	Female	122	28.38	5,98	228	.12	.89
	Male	106	28.37	7,13			
Engineering	Female	122	23.07	7,81	228	-2.44	.01*
	Male	106	25.70	8,42			
Mathematics	Female	122	24.21	7,38	228	.83	.40
	Male	106	25.03	7,58			
STEM Career	Female	122	25.79	6,92	228	.31	.75
	Male	106	25.49	7,87			
The Whole Scale	Female	122	125	23,21	228	-.74	.45
	Male	106	127	27,21			

\* $p < .05$

As seen in Table 5, no significant difference was observed between the male and female participants on the whole scale ( $t [226] \text{ whole scale} = .74, p > .05$ ). Similarly, no significant difference was observed in science, technology, mathematics and STEM career sub-dimensions by gender of the participants. However, a significant difference was observed in the engineering field semantic differences between female and male. This difference is in favor of male.

Table 6.

Anova test results of scores of undergraduate students stem semantic differences by department

Sub-dimensions	Department	N	X	ss	sd	f	p	Tukey-HSD Test	Levene F Test
Science	CT	82	22.53	6.58	227	4.39	.00*	CT - MME PEMT - MME	$p < .05$ , $F_{sci} = 2.64$ , $sd = 227$ , $p = .05$
	PEMT	36	21.50	8.58					
	EEE	45	23.31	6.58					
	MME	65	26.09	7.03					
Technology	CT	82	29.75	5.25	227	7.82	.00*	CT - PEMT CT - EEE PEMT - MME EEE - MME	$p < .05$ , $F_{technology} = 5.89$ , $sd = 227$ , $p = .05$ ;
	PEMT	36	26.38	8.27					
	EEE	45	25.11	7.05					
	MME	65	29.84	5.50					
Engineering	CT	82	21.43	8.13	227	15.30	.00*	CT - MME CT - EEE PEMT - EEE	$p < .05$ , $F_{engineering} = 2.11$ , $sd = 227$ , $p = .09$ ;
	PEMT	36	20.47	8.78					
	EEE	45	26.35	6.26					
	MME	65	28.60	6.67					
Mathematics	CT	82	23.65	7.93	227	4.56	.00*	PEMT - EEE EEE - MME	$p < .05$ , $F_{mathematics} = 1.32$ , $sd = 227$ , $p = .26$ ;
	PEMT	36	26.91	6.68					
	EEE	45	22.06	6.97					
	MME	65	26.24	7.00					
STEM Career	CT	82	23.75	7.31	227	4.51	.00*	CT - PEMT CT - MME	$p < .05$ , $F_{stemcareer} = .08$ , $sd = 227$ , $p = .96$
	PEMT	36	27.75	7.05					
	EEE	45	24.80	7.18					
	MME	65	27.47	7.13					
The Whole Scale	CT	82	121.14	21.91	227	7.34	.00*	CT - MME PEMT - MME EEE - MME	$p < .05$ , $F_{total} = .89$ , $sd = 227$ , $p = .44$ .
	PEMT	36	123.02	28.07					
	EEE	45	121.64	25.08					
	MME	65	138.26	23.82					

CT: Classroom Teaching, PEMT: Primary Education Math Teaching, EEE: Electricity-Electronic Engineering, MME: Metallurgy and Materials Engineering

As seen in Table 6, STEM semantic differences of undergraduates differ by the departments. The ANOVA test was performed to determine whether this difference was significant. The Tukey-HSD test was carried out to determine the direction of this difference. As a result of the test, it was found that there was a statistically significant difference between CT and PEMT departments and MME in the science sub-dimension of the scale ( $F(3,224)_{science} = 2.64$ ,  $p < .05$ ). Similarly, in the technology sub-dimension, it was observed that there was a statistically difference between PEMT and EEE departments and CT in favor of CT, between PEMT and MME in favor of PEMT, between EEE and MME in favor of EEE ( $F(3,224)_{technology} = 5.89$ ,  $p < .05$ ). In the engineering sub-dimension, a significant difference was observed between pre-service teachers and other engineering (CT-MME, CT-EEE and PEMT-EEE) in favor of engineering departments ( $F(3,224)_{engineering} = 2.11$ ,  $p < .05$ ). In mathematics sub-dimension, there was a significant difference between PEMT and MME departments in favor of PEMT as well as between EEE and MME in favor of MME ( $F(3,224)_{mathematics} = 1.32$ ,  $p < .05$ ). In the STEM career sub-dimension, the last dimension of the scale, a significant difference was observed between CT and PEMT in favour of PEMT as well as between CT and MME in favour of MME department ( $F(3,224)_{STEM\ career} = .08$ ,  $p < .05$ ). As a result of the test, a significant difference was observed between CT, PEMT and EEE departments and MME in favour of MME on the whole scale ( $F(3,224)_{overall} = .89$ ,  $p < .05$ ). Findings related to STEM semantics difference scores of undergraduate students by high school types graduated are given in Table 7.

Table 7.

Anova test results of scores of undergraduate students stem semantic differences by high school types

Sub-Dimensions	Department	N	X	ss	sd	f	p	Tukey-HSD Test	Levene F Test
Science	VTAS	70	23.02	6.27	227	4.51	.01*	VTAS - SH AHS - SHS	p<.05, F <sub>science</sub> =3.11, sd=227, p=.05
	AHS	138	23.13	7.45					
	SHS	20	28.10	7.41					
Technology	VTAS	70	26.42	6.96	227	4.67	.01*	VTAS - AH	p<.05, F <sub>technology</sub> =1.92, sd=227, p=.14
	AHS	138	29.04	6.27					
	SHS	20	30.10	5.34					
Engineering	VTAS	70	24.71	6.88	227	2.68	.07		
	AHS	138	23.55	8.52					
	SHS	20	27.95	9.27					
Mathematics	VTAS	70	23.32	6.85	227	2.71	.06		
	AHS	138	24.80	7.60					
	SHS	20	27.60	7.98					
STEM Career	VTAS	70	25.38	6.61	227	.59	.55		
	AHS	138	25.54	7.39					
	SHS	20	27.35	9.54					
The Whole Scale	VTAS	70	122.88	22.94	227	4.23	.01*	VTAS - SH AHS - SHS	p<.05 F <sub>overall</sub> =.76, sd=227, p=.46
	AHS	138	126.08	25.24					
	SHS	20	141.10	27.55					

VTAS: Vocational and Technical Anatolian School, AHS: Anatolian High School, SHS: Science High School

As seen in Table 7, STEM semantic differences of undergraduate students vary by high school types they graduated. The ANOVA test was performed to determine whether this difference was significant. The Tukey-HSD test was conducted to determine the direction of this difference. As a result of the test, a statistically significant difference was observed between VTAS and AHS and SHS in favor of SHS in the science sub-dimension ( $F(2,225)_{science}=3.11, p<.05$ ). Again, a statistically significant difference was seen between VTAS and AHS in favor of AHS in the technology sub-dimension ( $F(2,225)_{technology}=1.92, p<.05$ ). No statistically significant difference between high school types and engineering ( $F(2,225)_{engineering}=1.87, p>.05$ ), mathematics ( $F(2,225)_{mathematics}=2.16, p>.05$ ) and career ( $F(2,225)_{STEM\ career}=2.44, p>.05$ ). As a result of the test, a significant difference was seen between VTAS and SHS in favor of SHS ( $F(2,225)_{overall}=.76, p<.05$ ). The second stage of the research was applied then to reveal in-depth the factors affecting STEM semantic differences and perspectives of undergraduate students with high STEM semantics scores. For this, face-to-face interviews with participants with a score of 150 points or more ( $f=45$ ) were carried out and voice recording was taken.

### Demographic Characteristics of Participants in Qualitative Research

Table 8.

*Demographic characteristics of participants*

	Groups	f	%
Gender	Female	20	44.44
	Male	25	55.56
Department	CT	10	22.22
	PEMT	5	11.11
	EEE	7	15.56
	MME	23	51.11
Age Range	17-27	45	100
Total		45	100

CT: Classroom Teaching, PEMT: Primary Education Math Teaching, EEE Electricity-Electronic Engineering, MME: Metallurgy and Materials Engineering

20 (44.44%) were female, 25 (55.56%) were male of 40 participants who scored 150 or more on the scale. 10% (22.22%) of the participants enrolled in classroom teaching, 5% (11.11%) were primary education math teaching, 7 (15.56%) electrical and electronics engineering and 23 (51.11%) metallurgy and materials engineering departments. It is seen here that the participants who scored high on the scale were mainly from the faculty of engineering ( $f=30$ ) rather than from the faculty of education ( $f=15$ ). When the age range of the participants is examined, it is seen that 45 (100%) participants are involved in the age range of 17-27 years.

### *Participants' preference in STEM discipline in a STEM application*

The answers to the question of what disciplinary base the practitioner would like to have had opportunities to participate in a STEM application were shown in Table 9.

Table 9

*Participants' preference in STEM discipline in a STEM application*

	Groups	STEM Fields	f	%
What Area Will Be Centralized at STEM Activities	Engineer Candidates	Science	4	13.33
		Technology	14	46.66
		Engineering	10	33.34
		Mathematics	2	6.67
		Total	30	100
	Pre-Service Teachers	Science	1	6.67
		Technology	8	53.33
		Mathematics	5	33.33
		Social	1	6.67
		Total	15	100

As seen in Table 9, among the participants who responded given to the question of if you had the chance to participate in a STEM activity, what kind of discipline you would like to be based on, 4 (13.33%) indicated science, 12 (46.66%) indicated technology, 10 (33.34%) indicated engineering and 2 (6.67%) indicated mathematics. This result also explains the fact that engineer candidates have the highest point average on technology and engineering sub-dimensions in Table 4. Similarly, this is consistent with the results of relationships among sub-dimensions by department type in Table 6. Because it was revealed that participants in engineering departments are more interested in technology and engineering sub-dimensions. The reason that engineer candidates desire to be involved in a technology and engineering-focused STEM activity might be due to their departments. Of the pre-service teachers, 8 (53.33%) responded as technology, 5 (33.33%) responded as mathematics, 1 (6.67%) responded as science and 1 (6.67) responded as social. When Table 10 is examined, it can be seen that the answers given by the pre-service teachers shown in Table 4 are reasonable considering that they have the average points in the technology and mathematics sub-dimensions. In the analysis carried out with ANOVA in Table 8, it is seen that there are significant differences in terms of classroom teaching and primary education math teaching pre-service teachers for technology and mathematics sub-dimensions. This is consistent with the findings obtained by the interviews. The reason that one of the participants desired to involve in a social-focused STEM activity might be due to the courses taken in their department lead to the idea of implementing the STEM approach into social discipline.

Approaches participants will use in any activity. The participants involved in the interviews were asked how their approaches would be in activities such as a task/project/course. The responses given by engineer candidates are indicated in Table 10.

Table 10.

*Approaches that participants' preferences in activities*

Activity Approach	Groups	Approach	f	%
Teacher Centered	Engineer Candidates	Totally	2	6.66
		Partly	7	23.33
		None	0	0
		Total	10	33.33
	Pre-service Teachers	Totally	12	40
		Partly	8	26.64
		None	1	3.33
		Total	20	66.67
Student Centered	Engineer Candidates	Totally	0	0
		Partly	2	13.33
		None	3	20
		Total	5	33,33
	Pre-service Teachers	Totally	7	46.67
		Partly	3	20
		None	0	
		Total	10	66.67

As seen in Table 10, 20 (66.67%) of the engineer candidates who participated in the interviews stated that they would perform activities with a student-centered approach. In addition, it is seen that 10 (33.33%) engineer candidates are with teacher centered approach. This result is also an indication of how well STEM education is understood based on a constructivist approach that incorporates a student-centered approach. The student-centered approach of the engineer candidates participating in the interview is an indication of the proper understanding of STEM. The fact that engineer candidates have a higher average point than pre-service teachers in average points of STEM Semantics Scale is also in line with this result (Table 3).

The majority of pre-service teachers taking part in the interviews stated that they would embrace a student-centered approach in an activity they would practice. 7 (46.67%) were those who completely use student-centered the approach and 3 (20%) were those who did not use the teacher-centered approach at all. Therefore, 10 (75%) of pre-service teachers participating in the interviews consider performing student-centered activities. This result in an indication of proper semantic differences of pre-service teachers as well as engineer candidates.

### *Participants' experiences and information source about the STEM approach*

Table 11.

*Participants' experiences and information source about the STEM approach*

	Groups	Source	f	%
Experiences and Information Source about the STEM Approach	Engineer Candidates	Teachers	8	26.67
		Hearing	3	10
		Reading	10	33.33
		Conference	2	6.66
		Practice	7	23.34
		No experience		
		Total	30	100
	Pre-Service Teachers	Teachers	7	46.67
		Reading	2	13.33
		Science Fair	1	6.67
		Conference	1	6.67
		Practice	4	26.66
		No experience		
		Total	15	100

As seen in Table 11, of the engineer candidates participated in the interviews, 8 (26.67%) pointed out teachers, 3 (6.67%) pointed out hearing, 10 (33.33%) pointed out readings, 2 (6.67%) pointed out conferences and 7 (23.34%) pointed out having no practical experience in any STEM activities, as a source of information on the STEM approach. It can be said that the STEM semantic differences of engineer candidates are caused by the theoretical factors as practical experiences are insufficient.

Of the pre-service teachers involved in the interviews, 7 (46.7%) pointed out teachers, 2 (13.33%) pointed out reading, 1 (6.67%) pointed out science fair, 1 (6.67%) pointed out conferences and 4 (26.66%) pointed out having no practical experience, as a source of information about the STEM approach. The most important factor that constitutes the STEM semantic differences of the pre-service teachers participating in the interviews is due to it is theoretically known.

### *Participants' opinions regarding interrelationships between STEM disciplines*

The opinions of engineer candidates and pre-service teachers involved in the interviews on the extent to which the STEM disciplines are related to one another in practice and to what extent they were integrated to product design are given in Table 12.

Table 12.

Participants' opinions regarding interrelationships between STEM disciplines

	Groups	Relationship Status	f	%
Interrelationships between STEM disciplines	Engineer Candidates	Mostly Related	12	40
		Related	16	53.33
		Somewhat Related	2	6.67
		Not Related	0	0
		Total	30	100
	Pre-Service Teachers	Mostly Related	6	40
		Related	4	26.67
		Somewhat Related	5	33.33
		Not Related	0	0
		Total	15	100

As seen in Table 12, of the engineer candidates, 6 (31.57%) described interrelationships between STEM disciplines as mostly related, 9 (47.36%) described as related, and 4 (21%) described as related. Similarly, of the pre-service teachers, 6 (40%) described interrelationships between STEM disciplines as mostly related, 4 (26.67%) as related, and 5 (33.33%) described as related.

### *Project experiences of engineer candidates*

Table 13.

Findings related to project experiences of engineer candidates

	Groups	Experience	High School Type	f	%
Project Experience	Engineer Candidates	Available	VTAS	2	6.67
			AHS	10	33.32
			SHS	8	26.67
		Not Available	VTAS	8	26.67
			AHS	2	6.67
			SHS	0	
	Total		30	100	
	Pre-Service Teachers	Available	VTAS	0	0
			AHS	5	33.33
			SHS	4	26.67
		Not Available	VTAS	3	20
			AHS	3	20
SHS			0	0	
Total		15	100		

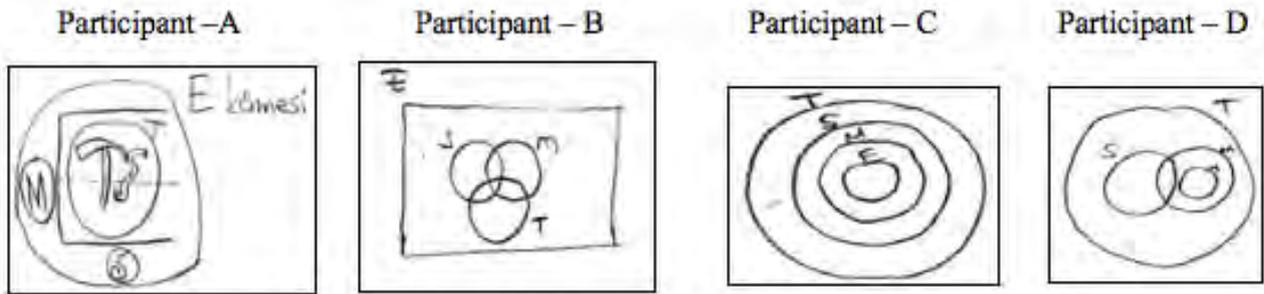
VTAS: Vocational and Technical Anatolian High School, AHS: Anatolian High School, SHS: Science High School

As seen in Table 13, 20 (66.66%) of the engineer candidates who participated in the interviews in stated that they had already had a project activity in their high school years and 10 (33.34%) stated that they have not yet been involved in any project activity. Of the engineer candidates involved in the projects, 2 (6.67%) graduated from, VTAS, 10 (33.32%) graduated from SHS and 8 (26.67%) graduated from SHS. This indicates that students graduated from science high schools or Anatolian high schools are more likely to participate in the projects than the students graduated from the other high schools, and therefore have a better background for STEM activities. As given in Table 7, it is noteworthy that there is a significant difference in the STEM semantic differences especially in the fields of science and technology in favour of science high schools and Anatolian high schools graduates. Furthermore, it can be considered that the participants are with a high-level STEM semantic differences as they study an area where project are carried out in abundance. This is because the STEM approach, which is parallel to project-based learning in many ways, may be effective in helping individuals understand STEM and enable STEM practices more effective and product-oriented. of the engineer candidates who were not involved in any project activity, 8 (26.67%) graduated from VTAS and 2 (6.67%) graduated from AHS. Inadequate project-based learning especially in the Vocational and Technical Anatolian high Schools, which are considered as suppliers of engineering, is likely to affect negatively in many ways as well as on STEM in the following years.

While 9 (60%) of the pre-service teachers said they already had a project activity in their high school years, 6 (40%) stated that they were not yet involved in any project activity. Of the pre-service teachers involved in the projects, 5 (33.33%) graduated from ASH, 4 (26.67%) graduated from SHS. Of the pre-service teachers who were not involved in any project activity, 3 (20%) graduated from VTAS, and 3 (20%) graduated from AHS. It can be said that students, as in engineer candidates, graduated from science and Anatolian high school are more likely to participate in the projects than other high school students, and therefore have a better background for STEM activities. On the contrary, not being involved in project-based activities in high schools such as VTAS explains why point differences between schools are not towards in favor of VTAS as indicated in Table 7.

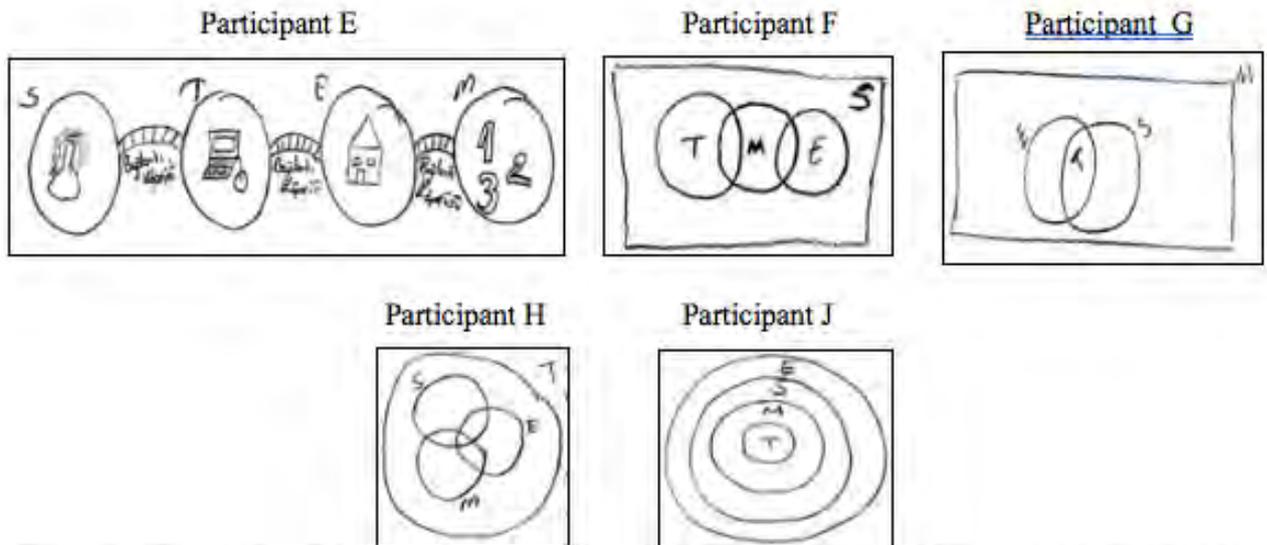
**Visualization of Participants’ STEM Approach**

Participants were asked to describe the STEM approach with the venn diagram technique to reveal their STEM perspectives and to support the quantitative data. In this regard, visualization pieces drawn by the students from each department are given below and interpretations were made.



**Figure 3. Visualization of STEM approach by EEE candidate participants**

Drawings of participant A and participant B in STEM visualization practices of engineer candidates in the EEE department indicates that engineering discipline covers or includes all other disciplines. Again, the participant C and participant D’s diagrams indicates that technology covers all other STEM fields. This is directly related to STEM semantic differences as far as the participant’s branch is concerned. Because, the fact that the point difference between EEE department students and other department students is in favor of EEE students is in line with visualization practices in Table 6. Information given Table 12 also in consistent with the opinions of engineer candidates regarding interrelationships between STEM disciplines.



**Figure 4. STEM visualization of participants in MME (metallurgy and materials engineering)**

In the visualization practices of MME candidates in Figure 4, Participant E made a drawing emphasizing that each STEM discipline is related to each other. This supports the fact that the majority of engineer candidates consider that STEM disciplines are related to each other in Table 6. Participant F visualized that science covers the other disciplines whereas participant G visualized that mathematics did. This can also explain the significant point difference in favour of MME in science and mathematics sub-dimensions in Table 12. Visualizations of participant H and participant J, which again

visualize that technology and engineering cover other disciplines can be related to the significant point difference in favor of MME in technology and engineering sub-dimensions in Table 6. This is also in line with their preference to focus on technology and engineering in an activity related to STEM in Table 9. In addition, drawings of participant H and participant J are in parallel to their expressions about interrelationships between STEM disciplines in Table 12.

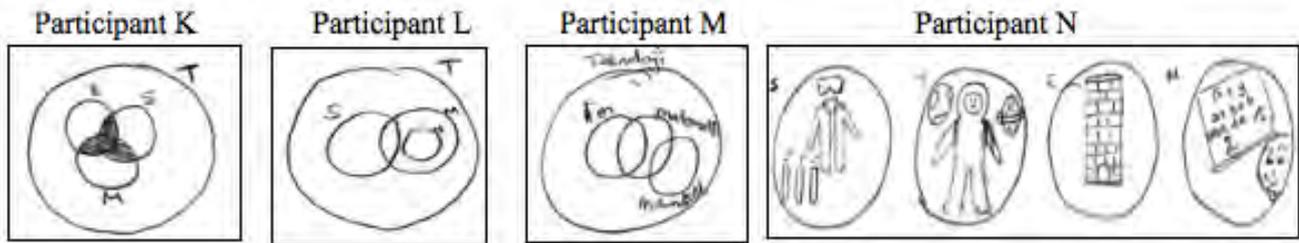


Figure 5. Visualizations of STEM approach by pre-service teachers in ct (classroom teaching)

Of the CT candidates participating in the interview, participant K, L and M visualized that technology field covered other STEM disciplines. This approach is consistent with the fact that the point difference in the science sub-dimension of STEM semantic differences in Table 6 is significant and in favour of CT. This is also parallel to the fact that they desire to participate in a technology-focused STEM activity in Table 10. High point average of pre-service teachers in technology field in Table 4 is another finding parallel to this finding. Visualization practice of Participant N is the expression with symbols that STEM disciplines form STEM independently. This is consistent with the tendency of pre-service teachers in Table 12 that STEM disciplines are partially related to each other.

Of the PEMT candidates participating in the interviews, Participant O, P and R visualized the mathematics discipline as the center of other disciplines in STEM visualization practices. This is consistent with the fact that the point difference of mathematics sub-dimension of the STEM semantics difference in Table 6 is significant. This is also in line with the finding that they desire to participate in a mathematical based STEM activity in Table 10. Drawing of STEM disciplines independently in the visualization practice of Participant S is parallel to the fact that pre-service teachers are tend to relate STEM disciplines partially with each other in Table 12.

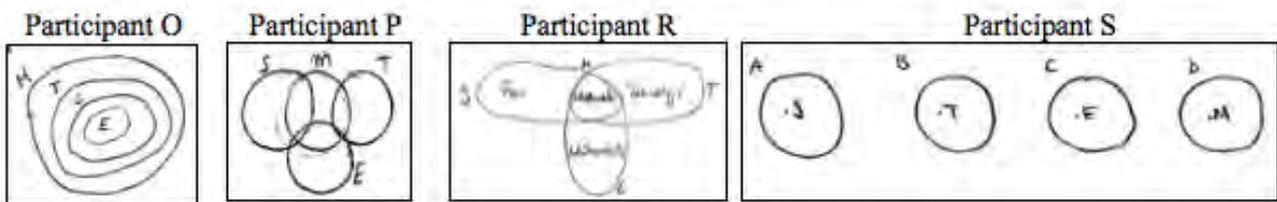


Figure 6. PEMT (primary education math teaching) pre-service teachers' STEM approach visualization

**Conclusion and Discussion**

In this section, research questions explored in the research were discussed one by one based upon the data and findings were compared with the results of other studies in the literature. The study involved 2nd year pre-service teachers of classroom teaching and primary education math teaching departments in the education faculty and 2nd year engineer candidates of electricity-electronic engineering and metallurgy and material engineering departments in the engineering faculty. In order to realize the main purpose of the study, the researcher had a mixed design to identify undergraduate students' STEM semantic differences and to introduce a holistic perspective on how these semantic differences were shaped. In this regard, it was identified that the STEM semantic differences of the undergraduate students involved in the research were positive on the whole scale. This result is consistent with many studies in the literature (Adams, Miller, Saul & Pegg, 2014; Akaygun & Aslan-Tutak, 2016; Çorlu, Capraro & Capraro 2014; Hacıömeroğlu, 2017). However, it was revealed that the engineer candidates participating in the research had higher point averages than the pre-service teachers did. In terms of sub-dimensions, it was observed that pre-service teachers had a high point average in technology and mathematics, whereas engineer candidates had a high point average in technology, engineering and STEM career.

No significant difference in the STEM semantic differences of the undergraduate students by gender variable in the study. Various studies indicating parallel results appear in the literature (Buschor, Berweger, Frei & Kappler, 2014; Hacıömeroğlu, 2017; Karakaya & Avcı, 2016; Simon, Wagner & Killion, 2017; Saucerman & Vasquez, 2014; Shapiro & Williams, 2012; Yenilmez & Balbağ, 2016). However, a significant difference was observed in favour of male in the engineering sub-dimension. This result was also obtained in the study of Karakaya and Avcı (2016) and Yenilmez and Balbağ (2016).

The third objective of the study was to identify the relationship between the departments of the participants and point averages of STEM semantic difference and a significant difference was observed on the whole scale in favor of MME department. NSF (National Science Foundation) reported in the study published in 2018 that metallurgy and material engineering is an integral part of the STEM. Furthermore, in the sub-dimensions of the STEM semantic differences, a significant difference was observed in the science sub-dimension in favor of MME, in the technology sub-dimension in favor of CT, PEMT and EEE, in the engineering sub-dimension in favor of EEE and MME, in the mathematics sub-dimension in favor of PEMT and MME and lastly in the STEM career sub-dimension in favor of PEMT and MME departments.

As a result of the study aimed at the fourth objective of the research, it was revealed that there was a significant difference between pre-service teachers and engineer candidates in terms of STEM semantic differences by high school type they graduated. While a significant difference was observed on the whole scale of STEM semantic difference in favor of participants who graduated from Science high schools, a significant difference was found in the science sub-dimension in favor of Science high school graduates. In the technology sub-dimension, a significant difference was observed in favour of both Science high school and Anatolian high school. It is inevitable that STEM semantic differences of these high school graduates are lower due to insufficient practices and activities for STEM disciplines and lack of interest for disciplines such as science and mathematics in VTAS (Yavuz, Gülmez & Özkara, 2016; Yavuz Mumcu, Mumcu & Cansız Aktaş, 2012). Especially reducing science class hours from the 10th grade in Turkey (MEGEP The Curriculum of Vocational and Technical Education, 2018) or the absence of these courses may lead them to become distant from the STEM fields (Çevik, 2018). Especially considering that mathematics knowledge is the basis for many important disciplines and professions, mathematically competent individuals with high numbers would inevitably have serious impacts on both national and global scale (Martin et al., 2012). It was emphasized in the literature that the positive STEM experience acquired at earlier ages increased the students' interests on STEM (Maltese & Tai, 2010).

In the second phase of this mixed-design study, face-to-face interviews were conducted with 45 undergraduate students with 150 scores or more on the STEM semantics scale and voice recordings were taken. Considering that a maximum score of 245 points and a minimum score of 35 points can be obtained on the scale, the score taken as a criterion included individuals with high STEM semantic differences. The intent here is to deeply analyze the factors of these high STEM semantic differences of the individuals and illuminate parameters to increase low STEM semantic differences. In this regard, of the 45 participants, 20 were female, 25 were male and 30 of them were engineer candidates and 15 of them were pre-service teachers. This ratio is consistent with the ratio of the results of STEM semantic differences.

In the interviews, engineer candidates pointed out technology and engineering and pre-service teachers pointed out technology and mathematics when asked "Which discipline-based approach would you like to participate in a STEM practice?" It is obvious that the participants are influenced by the departments in which they are studying. For instance, courses such as computer I and II, science laboratory practices I and II, instructional technologies and material development, mathematics I and II, mathematics teaching in the classroom teaching department influenced students' STEM semantic differences towards technology and mathematics. This result is consistent with the results of studies of Hacıömeroğlu (2018) and Yenilmez and Balbağ (2016). Similarly this is the case for the participants in the engineering field. As both engineer candidates and pre-service teachers mostly stated that they would prefer a student-centered approach, it can be said that this is a good indicator of their proper understanding of STEM, which bases the constructivist student-centered approach (Bransford, Brown, & Cocking, 2000), when asked "What approach would you rather to adopt in an activity?"

The majority of undergraduates stated that they heard about STEM by their teachers, by reading, or by a conference or science fair. Both engineer candidates and pre-service teachers stated that the STEM disciplines have a close relationship with each other. When quantitative data was examined deeply, it is feasible to recognize the tendency of the engineer candidates to relate STEM disciplines to each other more. As noted in the literature, STEM has a multi-disciplinary approach and is an integrated approach to science-technology-engineering-mathematics disciplines (Çorlu, 2013; NRC, 2012; Roberts, 2012, Şahin, Ayar & Adıgüzel, 2014). It can be said that the STEM semantic differences of the undergraduate students participating in the interview are accurate. As noted by Bybee (2013), although the STEM disciplines are sometimes given as integrated, there is an understanding of delivering disciplines as independent.

The students from the Science and the Anatolian high schools answered positively, and especially VTAS graduates stated that they did not participate when asked whether they were involved in a project during their high school years. One of the important and distinguished characteristics of STEM education compared to other disciplines is that it enables to improve practical skills (Chang, Ku, Yu, Wu & Kuo 2015).

In fact, most of the learning experiences advocated in STEM teaching approaches are similar to the basic principles of project-based learning (Siew, Amir & Chong, 2015). In this context, project experience may have affected the participants' STEM semantic differences to be high. The final question of the interviews, the visualization practice, is important as it provides clues about how participants shape STEM semantic differences in their minds. Because the STEM concept is defined in different ways in the literature (Breiner et al., 2012). Radolff and Goth (2016) emphasized in their study that many factors influence pre-service teachers' STEM visualizations. Again, in STEM visualizations, they pointed out that very different drawings emerged from

individuals. However, they emphasized that there were also common points. Bybee (2013), identified 9 figures in STEM visualization. Examples of each department student's drawings were included in the interviews, and the way to relate the findings to the both quantitative and qualitative findings was done. It is understood from the drawings that one of the most important factors affecting STEM semantic differences of participants was the department in which they studied. Because it is recognized that one discipline covers the diagrams, and this discipline covering is the department of the participant. In addition, STEM disciplines were expressed separately from each other, especially in the drawings of pre-service teachers. Engineer candidates, on the other hand, seemed to consider that these disciplines intertwined more. It was also noticed that pre-service teachers used shapes in diagrams. This is the case at the center of the STEM argument that even STEM experts would express STEM differently, while in STEM visualization method (Anderson et al., 2013; Cook 2006), both engineer candidates and pre-service teachers are expected to have a visualization competence in the context of different teaching methods.

### Recommendations

4 departments were preferred within the scope of the study as these departments were available in the university, which was the study field. Therefore, it was assumed that these departments within the STEM disciplines carry sufficient representation. Including different departments in the study may reveal different results. In addition, including the family parameter into the factors that affect the participants' STEM semantic differences in the interview may present a different perspective to explore reasons of participants' STEM semantic differences. This is because Blustein et al. (2013), state that if families have a positive attitude towards STEM and believe their children would be successful in these areas, families would give them more supports. Therefore, the awareness of the family in this regard may influence students positively. Furthermore, in future studies, the visualization practices may be further developed to achieve different results through techniques such as mind or concept mapping. The department of metallurgy and materials engineering, which had the highest STEM semantic differences in the research need to consider K-12 STEM teaching as a profession and encourage students studying in STEM fields to develop extra skills and knowledge to become perfect engineers. The engineering faculties should consider engineer training as an important part of their responsibilities and work with the education faculties in harmony to encourage their own students to consider K-12 education career in science and mathematics. In the training of STEM field teachers, education faculties should make more efforts and integrate STEM, integrate courses with STEM content into their undergraduate and postgraduate education programs.

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