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Comparative Review of Science Teachers' and Prospective Science Teachers' Awareness, Efficacy and Attitudes and Opinions towards STEM[1]

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ABSTRACT This research aims to compare the awareness, efficacy and attitudes, and opinions of science teachers (STs) and prospective science teachers (PSTs) toward STEM. In this study, convergent parallel design from mixed methods was used. The study group consists of 45 STs and 177 PSTs. In the quantitative dimension of the study, "Teacher Efficacy and Attitudes Towards STEM Survey" and "STEM Awareness Scale " were applied to the study group, which was formed by sampling criteria and maximum diversity from purposeful sampling. In the qualitative dimension of the research, semi-structured interviews were conducted with 24 STs and 25 PSTs selected through maximum diversity sampling from purposeful sampling. As a result of the research, it was observed that although the STEM awareness, efficacy, and attitudes of STs and PSTs were similar, they had positive attitudes. However, most of the participants in both groups considered themselves inadequate in STEM, expressed their opinions about the adverse effects of STEM applications as well as their positive effects, and that STEM applications were effective in career selection and country development.

Keywords Attitudes, Awareness, Efficacy, Opinions, Prospective Science Teachers, Science Teachers, STEM

1. INTRODUCTION

In today's conditions, where technological innovations determine the economic development of countries, it is crucial to spread science and technology literacy and to train future engineers and science experts (Miaoulis, 2009). According to the results of recent studies on science education, it is clear that it is necessary to use the engineering design approach to improve science education (Kelly, 2010). Engineering integrates the principles of science and the foundations of mathematics, intending to meet social needs by connecting scientific and mathematical theory and the technology we use daily (Asunda, 2012). In engineering design-based science education, the design process is related to real-life situations, and students are taught that they have different options for the problems they face. Engineering design-based science education requires high-level thinking, using questioning skills, and collaborative work (Marulcu, 2010; National Research Council [NRC], 2012). In engineering design-based science education, students themselves participate in activities such as gathering information, identifying the problem, proposing solutions, modeling and testing the solutions they propose, generating creative ideas, evaluating and reviewing the solution, repeating the process as much as necessary (National Academy of Engineering & NRC, 2009; NRC, 2012; Next Generations Science Standards [NGSS], 2013).

STEM (Science, Technology, Engineering, and Mathematics) that comes to mind regarding engineering design-based education is an approach that integrates science, technology, engineering, and mathematics content and skills for learning and teaching (Çorlu, 2014). Although its origin is said to date back to 1958 (Daugherty, 2013), to the 1990s (Bybee, 2010; Tezel & Yaman, 2017) by some, and appeared in 2001 with Judith Ramaley (Breiner, Harkness, Johnson, & Koehler, 2012; Daugherty, 2013; Yıldırım & Altun, 2014), as a result of the emphasis on STEM in the "Next Generation Science Standards" published in the United States (USA) in 2013, studies on STEM education have accelerated (Yager & Brunkhorst, 2014). In the USA, with STEM education being a state policy, it is aimed to raise awareness in the choice of

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profession of students in science, technology, mathematics, and engineering fields with STEM schools and to increase the development of positive attitudes towards these areas (Akgündüz et al., 2015).

1.1 Why STEM?

Today, economics, science, and technology developments have changed how individuals live and work. To raise quality individuals to adapt to this change, countries have felt the need to fundamentally change their educational views (The Partnership for 21st Century Skills, 2002; Yıldırım & Selvi, 2016). Because individuals need to have 21st-century skills such as creative thinking, problem solving-critical thinking, teamwork-leadership, flexible thinking-adaptation, foresight-entrepreneurship, written-oral communication, and finding-analyzing information (Wagner, 2008), 21st-century individuals should be able to plan or improve on many things, such as a system, a product, a new object. In doing so, they should be able to reach the cheapest and best solutions by combining the necessary information and technologies to meet the requirements in the most appropriate ways in the face of the problems they encounter (Yuran & Taşgetiren, 2010). In this case, STEM education adopting 21st-century skills is noteworthy (Lacey & Wright, 2009; Yamak, Bulut, & Dundar, 2014; Altun & Yildirim, 2015; Chang, Ku, Yu, Wu, & Kuo, 2015).

By integrating skills and knowledge from science, technology, mathematics, and engineering, STEM education not only provides students with the skills and information to collaborate across disciplines, think systematically, think creatively, and solve problems in the most appropriate way (Bybee, 2013; Riechert & Post, 2010; Sanders & Wells, 2006; Tezel & Yaman, 2017), but also acts as a bridge between science, technology, mathematics and engineering fields (Hom, 2014; Meng, Idris, & Eu, 2014). Moreover, STEM education includes educational activities at all grade levels, from preschool to doctoral level, and in both formal and informal learning settings (Gonzalez & Kuenzi, 2012).

The fact that STEM education has a holistic approach allows individuals to understand the problems encountered in daily life and removes the barriers between the four areas of this education. In addition, STEM can integrate knowledge into a teaching and learning understanding (Lantz, 2009; Satchwell & Loepp, 2002). In their study, Elliot, Oty, McArthur, & Clark (2001) concluded that students who participated in STEM activities and activities integrating mathematics, science, technology, and engineering were able to make meaningful connections between these fields. Hartzler's (2000) research on the holistic teaching approach found that it increased the students' success, interest in the areas covered, and desire to learn in general. In their meta-analysis study, Becker and Park (2011) indicated that integrated STEM education positively affected learning and increased academic success. STEM education activities support STEM fields of students with low socio-economic status (Mohr-Schroeder et al., 2014). Studies in the field of STEM in Turkey (Şahin, Ayar, & Adıgüzel, 2014; Yamak et al., 2014) have reported that STEM activities support students' peer learning for STEM fields, improve scientific process skills and attitudes towards science.

Moore and Smith (2014) have emphasized that teachers who teach STEM education focus on traditional science and mathematics teaching because they need more knowledge about areas outside their fields, while they almost ignore the technology and engineering components. Teachers' lack of knowledge of the required field is one of the most significant obstacles to their teaching with an interdisciplinary approach (Harkness, Stinson, Stallworth, & Meyer, 2009). The increase in the success of STEM education is related to the excellent knowledge of the field, and the teaching methods and strategies teachers use while applying this education. In the study conducted by Han, Yalvaç, Capraro, and Capraro (2015) on the understanding and applications of STEM education based on project-based learning, it was concluded that teachers do not include project-based teaching in their lessons because they see implementing activities, supplying materials and collaborating with teachers in other disciplines as time-consuming tasks. In addition, the teachers participating in the research believe that the methods and practices that the students are not accustomed to will adversely affect the students' achievements.

Preparing an environment suitable for STEM applications allows students to establish the connection between these areas, to have the desire to learn, to increase their success in science and mathematics courses, including other subjects, and to reconcile STEM subjects with daily life (Gallant, 2010; Satchwell & Loepp, 2002). In this context, it is vital to review comparatively the awareness, efficacy, attitudes, and opinions of current and future practitioners of STEM, which is included in the education programs of developed countries and has a significant impact. This situation is valuable for the science curriculum, which started to be implemented in Turkey in 2018, in which the STEM approach is integrated. Because the equipment of STs, which is the essential component of STEM practices, can directly affect the program's success. The results from this research concern not only the STs and the curriculum but also the teacher training institutions. The situation of future STEM practitioner PSTs regarding the STEM approach may also require the teacher training programs to be reviewed. While studies on STEM are increasing in the literature, the number of studies in that STs and PSTs participate together is limited. Ültay, Balaban, and Ültay (2021) stated that only one of the 23 studies (Baran, Baran, Aslan Efe, & Maska, 2020) in which they examined the studies on the views of STs and PSTs on STEM through content analysis, was conducted with both STs and PSTs. In this study, the quantitative method was used. As a result of the same study, it was stated that out of 23 studies, 14 used quantitative, 7 qualitative, and 4 mixed research designs. This study, in which the mixed research design is adopted, is essential in obtaining richer and more in-depth results by making a methodological difference.

This study aims to review the awareness, efficacy, attitudes, and opinions of STs and PSTs towards STEM comparatively. In this study, answers to the following sub-problems were sought.

1) Is there a significant difference between the STEM awareness of STs and PSTs?

2) Is there a significant difference between the efficacy and attitudes of STs and PSTs toward STEM?

3) What are the opinions of STs and PSTs towards STEM?

2. METHOD

2.1 Research Design

In this study, convergent parallel design from mixed methods was used. The convergent parallel design is the application of quantitative and qualitative stages simultaneously, giving equal priority to the methods. These stages are kept separate during the analysis, and the results are combined when making general interpretations (Creswell & Clark, 2014). After the separate quantitative and qualitative data analysis, the convergence parallel pattern design was used because it was thought that combining and interpreting the findings would make the research more understandable and explanatory. In the quantitative dimension of the research, the survey model aims to describe an existing situation as it is. In the qualitative dimension of the research, the following interview questions were used to determine and compare STEM awareness, efficacy, and attitudes in depth.

1) What are your thoughts on STEM disciplines? Explain (awareness, attitude).

2) What are the positive aspects of STEM applications in learning and teaching? Explain (awareness, attitude).

3) What are the negative aspects of STEM applications in learning and teaching? Explain (awareness, attitude).

4) What do you think about the role of STEM applications in students' career choices? Explain (awareness).

5) What do you think about the role of students who made STEM applications in the country's development? Explain (awareness).

6) Do you feel competent in STEM? Explain (efficacy).

2.2 Study Group

In the quantitative dimension of the study, the study group consisted of STs working in Burdur and PSTs studying in the Department of Science Education of Mehmet Akif Ersoy University Faculty of Education through purposeful sampling. Accordingly, in selecting STs, attention was paid to the maximum diversity in terms of the school's location (village, city), gender, and seniority, along with the criterion of being taught in the 5th grade. In the selection of PSTs, attention was paid to the maximum diversity in terms of gender, grade level, and academic achievement, along with the criterion of being studying in the Department of Science Education, as well as stratification in the dimension of grade level (consistency of the grade level with the percentage of the whole department). In the research, criterion and maximum diversity sampling methods were chosen. STs are teaching 5th grade because the 2018 science lesson curriculum, in which STEM applications are integrated under the title of science, engineering, and entrepreneurship applications, started to be implemented gradually in 5th grades for the first time in the same year in Turkey. The maximum diversity sampling is chosen because it aims to address the current problem in a broader framework with STs and PSTs with different characteristics without generalization concerns. The study's quantitative data were collected from a total of 177 PSTs, 131 of whom were women, 46 of whom were men, 45 teachers, 29 of whom were women, and 16 of whom were men. In the qualitative dimension of the research, semi-structured interviews were conducted with 24 STs and 25 PSTs from the sample in which quantitative data were collected. STs were determined according to seniority, school work, and gender, and PSTs were determined according to academic achievement, class, and gender through maximum diversity sampling from purposeful sampling.

2.3 Data Collection Tools

The study "STEM Awareness Scale" developed by Buyruk and Korkmaz (2016), consists of 17 items, and "Teacher Efficacy and Attitudes Towards STEM Survey" adapted to Turkish by Taş, Yerdelen, and Kahraman (2016) and consists of 7 main items and 62 sub-items were used as quantitative data collection tools. The Croanboach's reliability coefficient of the "STEM Awareness Scale" for this study was calculated as .94, and the Croanboach's reliability coefficient for the "Teacher Efficacy and Attitudes Towards STEM Survey" was calculated as .95. Accordingly, both measuring tools are quite reliable.

In the qualitative dimension of the study, semi-structured interviews were conducted with 24 STs and 25 PSTs, with the interview form created by the researchers. Various measures have also been taken for the validity and reliability of qualitative data. Some precautions should be taken for internal and external reliability in qualitative research. In this study, some measures were taken for external reliability by clearly defining the researcher's position in the research process and the participants who are the data source and explaining the data collection and analysis methods in detail. For internal reliability, method triangulation (comparison and combining of data collected by both quantitative and qualitative methods) and source triangulation (examination of the same situation in both STs and PSTs) were performed. Direct quotations were also used for both internal reliability and validity (LeCompte & Goetz, 1982 as cited by Yıldırım & Şimşek, 2005). In addition, the reliability coefficient for consistency between encoders in qualitative data analysis was calculated as 0.80. The coding was done separately by the researcher and the expert and then worked on again and again until a consensus was reached.

2.4 Data Analysis

In the study, quantitative data were analyzed by applying descriptive analysis and ANOVA tests with the help of the SPSS statistical program. In addition, various tests have been made for the assumptions of ANOVA.

STEM Awareness Scores

In order to provide the assumptions of ANOVA, firstly, two tests for normal distribution were examined. The first of these is the skewness-kurtosis values. While the Skewness value was -1.591, the Kurtosis value was 3.731. The closer these two values are to zero, the more normal the data distribution is. The fact that the Kurtosis value is so far from zero causes the variance to result in smaller values for small samples, while this risk will decrease for large samples with 200 or more participants (Tabacknick & Fidell, 2013 as cited by Palant, 2017). For normality, the Kolmogorov-Smirnov value was also checked and found to be p = .000. Although it is seen that there is no normal distribution according to this value (p<.05), according to Palant (2017, p.227), this situation is frequently seen in large samples for parametric tests and does not cause any problems for samples with 30+ numbers. As a result, it was accepted that the data in this sample (N = 223) provided a normal distribution.

For homogeneity of variances, another assumption of ANOVA, Levene's test, was used and found as p = .077. Accordingly, since p>.05, it was accepted that the variances were homogeneously distributed.

Other assumptions of ANOVA; The assumptions that the scores of the dependent variable are at least in the interval scale and that the samples whose mean scores are to be compared are unrelated were also met. Because the data were collected with a Likert-type questionnaire from the interval scale type, the condition that the samples were not related to the fact that they were STs and PSTs, was provided.

Teacher Efficacy and Attitudes towards STEM Scores

As a result of the test for the normal distribution condition of the ANOVA, it was seen that both the skewness (.039) and kurtosis (.484) values were very close to zero, that is, the data were normally distributed. Normal distribution was also obtained in the Kolmogorov-Smirnov test (p=.06>.05). Levene's test was used for the homogeneity of the variances (p=.257>.05), and it was seen that the variances were homogeneously distributed. Other assumptions of ANOVA; The assumptions that the scores of the dependent variable were at least in the interval scale and that the samples whose mean scores were to be compared were unrelated were also met. Because the data were collected with a Likert-type questionnaire from the interval scale type, the condition that the samples were not related to the fact that they were STs and PSTs, was provided.

In the evaluation of arithmetic means; (Array width: Highest Value-Least Value = 5– 1= 4), (Array Spacing = Array width / Number of groups to be made = 4/5 = 0.80) formula was used, and the range width limits are determined (Karakuş & Hatuk, 2011) as in Table 1.

Table 1 Range of data

Value	Qualification	Limit
5	Absolutely yes	4.20-5.00
4	Yes	3.40-4.19
3	Undecided	2.60-3.39 (average)
2	No	1.80-2.59
1	Absolutely no	1.00-1.79

As for qualitative data analysis, content analysis was used. Inductive analysis, which includes discovering patterns, themes, and categories, was adopted while conducting content analysis (Patton, 2014, p.453). Teachers' interview forms were named in the form of "ST1, ST2, ST3..." while the interview forms for prospective teachers were named in the form "PST1, PST2, PST3...".

3. RESULT

The ANOVA results, which were made to test the difference between the STEM awareness of STs and PSTs, are shown in Table 2.

Table 2 Findings for the STEM Awareness Scale

STEM Avareness	N	X	SD	Source of variance	Sum of squares	df	Mean square	F	p	η 2	Power
PSTs	178	70.11	12.57	Between Groups	195.35	1	195.35	1.36	.24	.01	.21
STs	45	72.44	9.40	Within Groups	31836.86	221	144.06				
Total	223			Total	32032.21	222					

Table 3 Findings on Science Teachers' Efficacy and Attitude Scale

STEM Competence and Attitude	N	X	SS	Source of variance	Sum of squares	df	Mean square	F	p	η 2	Power
PSTs	178	242.73	26.75	Between Groups	1340.11	1	1340.11	1.99	.16	.01	.29
STs	45	236.62	22.33	Within Groups	148579.63	221	672.31				
Total	223			Total	149919.74	222					

Table 4 Codes related to understanding of science teachers and prospective science teachers' thoughts on STEM disciplines

	Codes	f	%	Participants
STs	Areas that support each other	23	62.16	ST1,ST2,ST3,ST4,ST5,ST6,ST7,ST8, ST9,ST10,ST11, ST12,ST13 ,ST14, ST15,ST16,ST17,ST18,ST20,ST21, ST22,ST23,ST24
	Numerical relationship	4	10.81	ST2,ST10,ST11,ST13
	Engineering dominant	3	8.11	ST3,ST11,ST23
	Common point is Mathematics	2	5.40	ST19,ST23
	Different points of view	2	5.40	ST8,ST9
	Intellectual process	2	5.40	ST4,ST10
	Compatible with everyday life	1	2.70	ST7
	Total	**37**	**100**	
PSTs	Areas that support each other	23	82.14	PST1,PST2,PST3,PST4,PST5,PST6,PST7,PST8,PST9,PST10,PST1 1, PST12,PST13, PST14,PST15,PST16,PST17,PST18,PST19, PST21, PST22,PST23,PST24
	Engineering dominant	3	10.71	PST2,PST18,PST22
	Common point is Mathematics	1	3.57	PST20
	Analytical thinking	1	3.57	PST25
	Total	**28**	**100**	

According to Table 2, there was no significant difference between the scores of STs and PSTs on the STEM awareness scale (F_{1-221} = 1.356; p>.05; η^2 = .006). Also, according to the results (70.11/17=4.12, 72.44/17=4.26), it is seen when we divide the averages of PSTs and STs by the number of questions in the questionnaire that the awareness of both groups is above average (see Table 1).

The ANOVA results, which were made to test the difference between the STEM efficacy and attitudes of STs and PSTs, are shown in Table 3.

According to Table 3, there was no significant difference between the scores of STs and PSTs on the STEM efficacy and attitude scale (F_{1-221} = 1.993; p>.05; η^2 = .009). In other words, there is no significant difference between the STEM efficacy and attitudes of STs and PSTs. However, when we divide the averages of PSTs and STs by the number of questions in the questionnaire (24.73/62=3.92, 236.62/62=3.82), it is seen that both groups are above the average score range (See Table 1). In other words, it can be said that STs and PSTs think positively about the efficacy and attitude toward STEM.

The findings obtained from interviews with STs and PSTs also support these results. For example, when Table 4 examined the opinions of the participants in both groups about STEM disciplines, it was seen that the majority of STs and PSTs expressed their opinions that the disciplines that makeup STEM were areas that supported each other. Other common thoughts of teachers and prospective science teachers are that mathematics is the common point and engineering is dominant. When we look at the different opinions of both groups, it is seen that the teachers indicated their opinions about the numerical relationship between STEM disciplines, the intellectual process, being compatible with daily life, and the prospective science teachers about analytical thinking.

Direct quotes on what STs and PSTs think about STEM disciplines can be seen below.

ST12: "*They are an inseparable whole... They are all related.*"

ST19: "*Each is a system in which both nature and human relations take place. In other words, both science and engineering are inspired by nature and use the two together. But at the core of them all is mathematics.*"

ST16: "*It is a complementary relationship, that is, one that is not independent of each other. Let's call one a union or a relationship that is not considered separate from the other .*"

PST5: "*... I think they are all interconnected. Anyway, I think science is in our lives and is related to science in engineering, so we know something in science and physics that we can apply in engineering.*"

PST18: "*... It's the same way in engineering, but when we think of science, we think of physics, chemistry, biology, and engineering is one of the most important things in physics. So, they are all interconnected things.*"

When the opinions of STs and PSTs on the positive aspects of STEM applications in learning-teaching are examined, it is seen that STs express their opinions about these practices being the most motivation, self-knowledge,

Table 5 Codes on the positive aspects of STEM applications in terms of learning-teaching

	Codes	F	%	Participants
STs	Motivation	7	21.21	ST2,ST3,ST11,ST12,ST20,ST21,ST23
	Student self-knowledge	6	18.18	ST9,ST14,ST15,ST17,ST19,ST23
	Being practical	4	12.12	ST1,ST8,ST11,ST21
	Development of thinking skills	3	9.09	ST10,ST13,ST14
	Development of the country	4	12.12	ST1,ST2,ST5,ST20
	Developing creative thinking	4	12.12	ST6,ST7, ST15,ST17
	Ensuring permanent learning	2	6.06	ST5, ST18
	Making sense of what has been learned	1	3.03	ST1
	Product release	1	3.03	ST4
	Career choice	1	3.03	ST24
	Development of technological skills	1	3.03	ST22
	Total	**33**	**100**	
PSTs	Development in every aspect	9	24.32	PST1,PST3,PST4,PST6,PST8,PST17,PST20,PST21,PST22
	Diversity of thought	6	16.22	PST1,PST7,PST12,PST17,PST23,PST24
	Being practical	6	16.22	PST5,PST9,PST13,PST14,PST18,PST25
	Developing life skills	6	16.22	PST1,PST2,PST10,PST16,PST19,PST23
	Creating a product	4	10.81	PST9,PST15,PST18,PST22
	Increase in psychomotor skills	2	5.40	PST19,PST20
	Development of self-confidence	2	5.40	PST1,PST14
	Making sense of what has been learned	1	2.70	PST24
	No idea	1	2.70	PST11
	Total	**37**	**100**	

being applied, developing thinking skills and creative thinking and being positive for the country. At the same time, PSTs mostly pose opinions on STEM applications, such as these applications developing every aspect, having a variety of thoughts, being applied, developing life skills, and producing products (Table 5). It is seen that STs give more detailed and precise answers than PSTs. For example, most PSTs said there would be an improvement in every aspect, but they did not open this concept.

Direct quotes on what STs and PSTs think about STEM applications in learning-teaching can be seen below.

ST11: *"The positive aspects are that children already love to learn by living by doing, they find it fun. ... they like the lesson more than it is enjoyable. ... they can also apply it to everyday life. It would be nice and more functional, obviously."*

ST15: *"Actually, we give the child the ability to think creatively , first of all, we make him discover that he can do something, that he can produce something . That's why it is important for the child to know himself."*

PST2: *"The positive aspects can produce practical solutions to problems in daily life more quickly. Individuals can solve the problems they face more quickly."*

PST25: *"... In other words, it has been better for the individual to be at work and practice than to keep things in words, and I think so..."*

Again, when the opinions of STs and PSTs on the negative aspects of STEM applications in terms of learning-teaching were examined (Table 6), it was seen that a close number of participants from both groups expressed their opinions about the problems in practice. In contrast, 3 STs and 14 PSTs expressed no negativity. Therefore, the PSTs think there is not the most negativity and point out the problems in the application as the closest to it can also be attributed to the fact that they are not in the application.

Direct quotes on what STs and PSTs think about negative aspects of STEM applications in terms of learning-teaching can be seen below.

ST14: *"Negatively, If a 5th class student does not use the environment and technology to think so systematically, he is narrow-minded, which restricts him. So, there can be a negativity of such an environment."*

ST17: *"The negative side is only the negative side is that we have less time and we are lacking in material terms..."*

ST10: *"Some concepts may not be appropriate for children's ages..."*

PST18: *"If the negative aspects are a little more complicated, it can be difficult for a student at the elementary or middle school level to understand."*

PST19: *"So the space and the environment may not be possible in the classroom environment..."*

The opinions of science teachers and prospective science teachers on STEM applications about students' career choices are given in Table 7. Accordingly, almost all STs and PSTs believed that STEM is effective in career choice. Furthermore, while two of the teachers stated that it was not effective, it was seen that there was no one among the prospective science teachers who thought that it needed to be more effective.

Table 6 Codes on the negative aspects of STEM applications in terms of learning-teaching

	Codes	f	%	Participants
STs	**Difficulties in application**	36	67.92	
	Lack of material	11	20.75	ST1, ST4, ST5, ST8, ST11, ST12, ST16, ST17, ST18, ST21, ST24
	Time	7	13.21	ST3, ST5, ST11, ST15, ST16, ST17, ST20
	Failure to cultivate curriculum	4	7.55	ST7, ST11, ST15, ST16
	Classroom management	4	7.55	ST1, ST11, ST17, ST20
	Lack of technology	3	5.66	ST12, ST14, ST22
	Lack of Stem lab	3	5.66	ST1, ST3, ST22
	School administration	3	5.66	ST7, ST8, ST20
	No application	1	1.89	ST13
	Student-related troubles	12	22.64	
	Lack of interest	6	11.32	ST2, ST7, ST9, ST12, ST15, ST18
	Feeling of failure	3	5.66	ST1, ST5, ST21
	Inability to think abstract	1	1.89	ST19
	Inability to think systematically	1	1.89	ST14
	Readiness problem	1	1.89	ST1
	No negativity	3	5.66	ST4, ST10, ST23
	Lack of in-service training	2	3.77	ST14, ST17
	Total	53	100	
PSTs	**No negativity**	14	53.85	PST3,PST4,PST6,PST7,PST8,PST9,PST11,PST12, PST13,PST14,PST17,PST20, PST22,PST25
	Difficulties in application	6	23.08	
	Time	2	7.69	PST2,PST5
	Lack of material	2	7.69	PST10, PST23
	Difficult to implement	2	7.69	PST16, PST23
	Student-related troubles	4	15.38	
	Feeling of failure	3	11.54	PST18, PST21, PST24
	Lack of interest	1	3.85	PST24
	Production of technological weapons	1	3.85	PST15
	Lack of in-service training	1	3.85	PST1
	Total	26	100	

Table 7 Codes for students' thoughts on their career choices

	Codes	**F**	**%**	**Participants**
STs	Effective	22	91.67	ST1,ST2,ST3,ST4,ST7,ST5,ST6,ST8,ST9,ST10,ST11,ST12, ST14,ST15,ST16,ST17,ST18,ST20,ST21,ST22,ST23,ST24
	Not effective	1	4.16	ST13
	Parents are more effective	1	4.16	ST19
	Total	**24**	**100**	
PSTs	Effective	24	96	PST1,PST2,PST3,PST4,PST5,PST7,PST8,PST9, PST10, PST11,PST12,PST13,PST14,PST15,PST16,PST17 PST18,PST19,PST20, PST21, PST22,PST23,PST24,PST25
	I have no idea	1	4	PST6
	Total	**25**	**100**	

Direct quotes on what STs and PSTs think about students' career choices concerning STEM applications can be seen below.

ST21: *"Engineering, so after all, since science and technology engineering mathematics are all intertwined, I think that the student will contribute a lot to the choice of profession..."*

PST1: *"I definitely think it would have a big impact... As he puts out a lot of products, he can say oh yes, I can do this and direct himself to engineering , or he can strive to be a scientist."*

PST16: *"... Students draw their own lives accordingly. They can also be more knowledgeable about what career they want to do ."*

PST18: *"I think it is a good thing. Engineers or those going to different departments learn what kind of work they will do in the future. It becomes easier to choose, to choose a profession.*

The opinions of STs and PSTs about the role of students who practice STEM in the country's development are given in Table 8. When Table 7 is examined, the opinions of both STs and PSTs that students who practice

Table 8 Codes for thinking about the role of students in STEM applications in the development of the country

	Codes	F	%	Participants
STs	21st century skills	11	32.35	ST6, ST7, ST10, ST11, ST12, ST16, ST18, ST19, ST20, ST21, TS24
	Productive	9	26.47	ST1, ST3, ST4, ST5, ST7, ST8, ST13, ST14, ST1
	Scientific and technological contribution	9	26.47	ST1, ST3, ST8, ST9, ST10, ST14, ST17, ST22, ST23
	Career awareness	3	8.82	ST6, ST15, ST21,
	Preventing brain drain	2	5.88	ST2, ST3
	Total	**34**	**100**	
	Productive	11	31.43	PST1, PST3, PST7, PST10, PST12, PST13, PST20, PST21, PST22, PST23, PST25
	21st century skills	10	28.57	PST2, PST5, PST8, PST10, PST11, PST18, PST19, PST21, PST22, PST23
	Scientific and technological contribution	8	22.86	PST5, PST9, PST13,PST15, PST17, PST18, PST20, PST24
	I Don't Know	4	11.43	PST4, PST6, PST14, PST16
	Preventing brain drain	2	5.71	PST1, PST24
	Total	**35**	**100**	

Table 9 Codes for whether or not they feel competent in STEM practice

	Codes	**F**	**%**	**Participants**
STs	Incompetent	13	51.17	ST1,ST2,ST3,ST5,ST6,ST7,ST8,ST9,ST10, ST11,ST12, T14, T22
	Competent	7	21.17	ST4, ST13, ST15, ST17, ST19, ST20,ST24
	Partially competent	4	16.17	ST16,ST18,ST21, ST23
	Total	**24**	**100**	
PSTs	Incompetent	20	80	PST1,PST2,PST3,PST4,PST5,PST6,PST8,PST9,PST11,PST12,PST13 PST14,PST15,PST16,PST17,PST18,PST20,PST21,PST23,PST24
	Partially competent	3	12	PST10,PST22,PST25
	Competent	2	8	PST7, PST19
	Total	**25**	**100**	

STEM applications will play a role in developing the country with 21st-century skills, productivity, and scientific and technological contribution come to the fore. Although teachers mostly point to 21st-century skills about the role of students who make STEM applications in the country's development, it is striking that prospective science teachers point to being productive the most. While it is seen that both teachers and prospective science teachers have a common view on scientific and technological development and brain drain at almost the same rates, it is seen that 3 teachers draw attention to career awareness, and 4 prospective science teachers have no idea about the subject.

Direct quotes from opinions of STs and PSTs about the role of students who practice STEM in the development of the country are given in Table 8.

ST3: *"First of all, the biggest benefit of this will be to research and development, and now one of the biggest problems in our country is that we are a country experiencing brain drain... But thanks to this STEM, I think that if we turn it a little more in this direction, Aselsan, especially Aselsan, will be a little more useful in this regard ..."*

ST6: *"... So it will be positive. Children, in other words, will become inquisitive, developing, curious and questioning people . They will use it in their job selection."*

PST2: *"Our students grow up to be individuals who are more entrepreneurial and able to produce more active creative ideas . That would be a very good result for our country."*

PST13: *"... As this application progresses further, we will try to approach other developed countries, whether we have our own special national robots or engines, these will be more, so we will be able to produce a technological product that we need, so we will be able to produce a technological product ourselves ."*

The opinions of STs and PSTs on whether they feel competent in STEM practices are seen in Table 9. According to Table 9, it is seen that both the teachers and most of the prospective science teachers consider themselves inadequate, this rate is the highest among the prospective science teachers, and the same number of participants from both groups consider themselves partially sufficient. In addition, while eight teachers see themselves as sufficient, none of the prospective science teachers see themselves as sufficient.

Direct quotes on what STs and PSTs think about their efficiency in STEM applications in learning-teaching can be seen below.

ST3: *"I do not feel like it, frankly, because we were not given this opportunity much at the university either, and our professors say it openly... I consider myself* inadequate"... "*I think the steps taken once are absolutely inadequate... You are doing this research, but both national education and students need to work more on this subject, especially teachers who need to be taken to a seminar on this subject.*"

ST6: *"No, I am not competent. I think I need to do more research ..."*

ST23: *"I try to improve myself every time. This is my 13th year, but I am still trying to improve myself. I try to go to courses and seminars. I mean, I consider myself competent, but I am still working."*

PST11: *"I don't feel quite competent in STEM..."*

PST13: *"So I don't think I am better in STEM. Because we do not find myself competent because we have not fully learned a learning by experimenting and observing in practice."*

PST1: "*Not for now, I need to improve". "I don't think enough information has been given".*

4. DISCUSSION

When the results of this study, which was conducted to review the STEM awareness, attitudes, and opinions of STs and PSTs towards STEM comparatively, are examined, there is no significant difference found between the awareness of STs and PSTs about STEM. Qualitative findings also support this conclusion. Accordingly, the vast majority of both STs and PSTs expressed their opinion that the disciplines that make up STEM are areas that support each other. When the opinions of STs and PSTs on the positive aspects of STEM applications in learning-teaching are examined, it is seen that STs express their opinions about these practices being the most motivation, self-knowledge, being applied, developing thinking skills, and being positive for the country. At the same time, PSTs mostly pose opinions on STEM applications, such as these applications developing every aspect, having a variety of thoughts, being applied, developing life skills, and producing products. It is seen that teachers give more detailed and precise answers than PSTs. For example, most PSTs said there would be an improvement in every aspect, but they did not open this concept. These results are in line with the results reported by Yıldırım and Altun (2014), Altun and Yıldırım (2015), Altan, Yamak, and Kırıkkaya (2016), Daymaz, 2019, Yılmaz and Pekbay (2017). For example, Yıldırım and Altun (2014) stated in their articles that they made a general evaluation of STEM that students actively participate in STEM studies and that they will make them more productive by organizing the information and experiences they learn in a meaningful way in their daily lives. Altun and Yıldırım (2015), who examined the effect of STEM education and engineering applications on the academic success of prospective science teachers, stated that they had a positive effect on the students' academic success as a result of their study.

Moreover, in a study where Altan et al. (2016) examined the effects of STEM education on the education of teachers and prospective teachers, they stated that the questioning skills, permanent learning, and motivation increased in science teachers and prospective teachers. Yılmaz and Pekbay (2017), in their work on the introduction of STEM education, stated that the training and activities of prospective teachers were fun, easy, and efficient in learning STEM education. Daymaz (2019), as a result of his study with seventh-grade students, found that STEM activities positively affected student motivations. In summary, the results of these studies in the literature regarding the positive effects of STEM applications on motivation, permanent learning, meaningful learning, associating with daily life, and questioning skills are consistent with our results.

When the opinions of STs and PSTs on the negative aspects of STEM applications in terms of learning-teaching were examined, it was seen that a close number of participants from both groups expressed their opinions about the problems in practice. In contrast, 3 STs and 14 PSTs expressed no negativity. The fact that the PSTs think that there is not the most negativity and point out the problems in the application as the closest to it can also be attributed to the fact that they are not in the application. Furthermore, some studies conducted in the literature on the problems encountered during STEM applications (Alagöz & Sözen, 2021; Çavaş & Çavaş, 2018; Günşen, Uyanık, & Akman, 2019; Hacıoğlu, 2020; Taktat Ateş, Saraçoğşlu, & Ateş, 2022) also point to the difficulties experienced by teachers during the implementation due to lack of tools, time shortage due to curriculum intensity and in-service training deficiencies.

It was also seen that almost all STs and PSTs were influential in STEM career choices. The participants in both groups expressed that the students who made STEM applications would play a role in developing the country with 21st-century skills, productivity, and scientific and technological contributions. Some studies are similar to these results. For example, it was found that students' attitudes towards STEM disciplines, STEM career perceptions, and STEM field occupational interests increased statistically significantly after problem-based STEM activities. This increase was especially in favor of engineering and technology-related professions. In addition, students who participated in the study stated that problem-based STEM education was influential in developing and learning 21st-century skills, made the course fun, increased their interest in the engineering profession, and helped them choose their future careers (Alıcı, 2018). Similarly, Daymaz (2019) stated that STEM activities positively affect and increase the interest of seventh-grade students in STEM professional fields, that there were positive developments in the students' views on technology and the concept of engineering, and that their engineering skills also improved and that they wanted the future career choices of the students in STEM fields. In summary, the results of Alıcı (2018) and Daymaz (2019) that STEM applications are effective in students' career choices seem to align with the results of our research.

Another result obtained in this study is that there is no significant difference between the competencies and attitudes of STs and PSTs about STEM. The opinions of both STs and PSTs about their competence in STEM applications support this result. The vast majority of participants in both groups do not consider themselves proficient in STEM practice. The reason for this is reported by STs and PSTs the fact that they should receive serious training about this practice and that experts should give this training. Considering the direct quotations of both STs and PSTs, it is seen that they have incomplete information about STEM applications. For example, according to primary school and even 5th-grade students, the view that these practices may be severe prevails. However, STEM activities should be planned according to the age of the children. That is because there are STEM activities even for preschool children. According to Williams (2011), the lack of sufficient studies showing how teachers will provide STEM education, and especially the integration of engineering education and classroom practices are not apparent enough in the studies (Katehi, Pearson, & Feder, 2009), have a significant impact on teachers' inadequacy in STEM education.

STs and PSTs who consider themselves competent think of the reason for their competence as their efforts. STs and PSTs who consider themselves partially competent have stated that they are competent in the field knowledge and professional knowledge section. However, they also need to be improved in STEM applications. These results follow the earlier findings from Çorlu, Adıgüzel, Ayar, Çorlu, & Özel (2012). Çorlu et al. (2012), in their studies of Turkey, stated that a small group of students in Turkey can get a good education and the remaining majority do not receive an adequate education in STEM subjects and that this will only be achieved by training qualified and qualified teachers who can provide STEM education. Again, Çorlu et al. (2012), in the same study, stated that the desired level of success is impossible due to the complex structure of teacher training and employment in Turkey and that individuals undergo the necessary and healthy education for today's competitive economic system, and that this can only be achieved with qualified teachers who have received STEM education. When the thoughts of science teachers and prospective teachers towards STEM are examined, it can be said that they have generally positive and similar attitudes. This result is in line with studies conducted by Hartzler (2000), Judson and Sawada (2000), Pinnell et al. (2013), Yılmaz and Pekbay (2017) and Altan et al. (2016). Hartzler (2000), Judson and Sawada (2000), and Pinnell et al. (2013) mentioned the benefits of STEM activities and practices in their studies. For example, Hartzler (2000), in his study on the effect of integrative teaching on student success in science and mathematics applications and engineering design, showed that integrative teaching improves student interest, desire to learn, success, and self-efficacy. Judson and Sawada (2000) have shown that integrating mathematics into science has positively affected students' success in their studies, examining the effect of integrating mathematics into science lessons. Pinnel et al. (2013), in their studies examining the effect of STEM education on the knowledge and skills of teachers and prospective teachers, revealed that engineering and design-based STEM education practices improve leadership skills and perceptions related to teaching competencies.

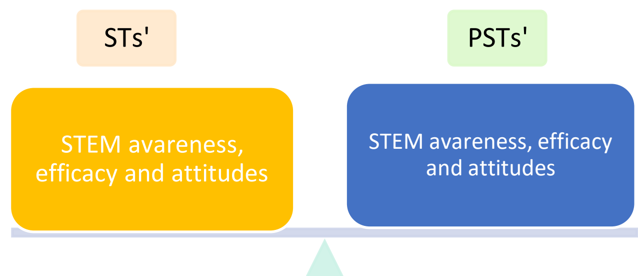

Figure 1 STEM awareness, efficacy and attitudes of PSTs and PSTs.

5. CONCLUSION

According to the results of this study, which was conducted to compare the STEM awareness, efficacy, and attitudes and opinions of STs and PSTs, there was no significant difference between science STs and PSTs' STEM awareness, efficacy, and attitudes towards STEM (Figure 1).

When the views of the participants about STEM are examined, it is seen that although they have similar views about STEM disciplines and the positive and negative aspects of STEM, the effect of STEM on career choice, and the contribution of STEM students to the development of the country, it is seen that STs gave more

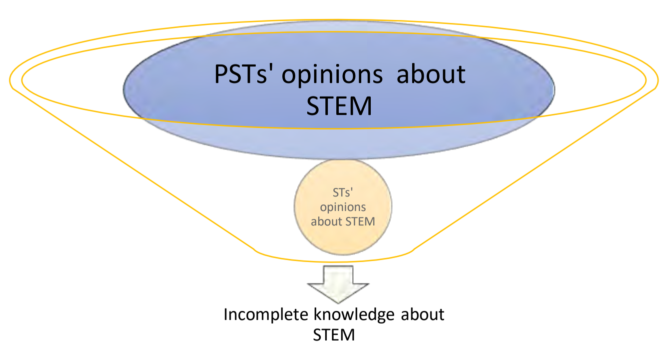

Figure 2 PSTs' and PSTs' opinions about STEM

precise and detailed information. This may be because PSTs have not yet made enough STEM applications. Considering the open views of STs and PSTs and the sentences they have made about STEM, they have incomplete information about STEM. As seen in Figure 2, if we filter the opinions of STs and PSTs, although the STs have more clear ideas, when the filtered ideas are examined, it is seen that both groups have insufficient information on STEM.

Since STEM education includes different disciplines and the relationship of these disciplines with each other, it will be a simple approach to give the required courses and think that teachers will be competent to provide the development of field knowledge and pedagogical field knowledge as in the usual science teacher education (Sanders, 2009). Therefore, "fundamentals of STEM education, pedagogy, curriculum, research, current issues addressed in each of the STEM fields, and new integrated STEM ideas, approaches, teaching materials, and curricula" (Sanders, 2009, pp. 20-26) should be considered. For teachers and prospective teachers to use STEM education effectively in their classrooms, they need to know the practical knowledge, infrastructure, and philosophical foundations of STEM education. For this, both pre-service and in-service training can be arranged. Teachers' STEM education should not remain theoretical but should be practical. Teachers should be informed through in-service training that there is no need for large budgets for STEM applications at all levels, and teachers should not have curriculum training anxiety and exam anxiety to make STEM applications more effective.

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