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Self-Efficacy Levels of Pre-Service Science Teachers Regarding STEM Practices

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ABSTRACT

The aim of this study is to investigate the self-efficacy levels of pre-service science teachers in relation to STEM practices. For this purpose, the research was conducted during the 2021–2022 academic year with 110 volunteer pre-service teachers enrolled in the third and fourth years of the Department of Science Education at a public university. In collecting the data, the general survey model, one of the quantitative research methods, was utilized. The data for the study were gathered through a convenience sampling method. As the data collection instrument, the "STEM Practices Self-Efficacy Scale" developed by Özdemir, Yaman, and Vural (2018) was employed. The scale consists of 18 items and is structured as a five-point Likert-type scale. The Cronbach's alpha internal consistency coefficient of the scale was calculated as .97. The data obtained from this study were analyzed using the SPSS 21 statistical analysis software. Overall, the findings of the study indicated that the pre-service teachers possessed an adequate level of self-efficacy regarding STEM practices. It is anticipated that the results of this study will provide guidance for program developers and teachers concerning the implementation of STEM education in Turkey.

Keywords: STEM education, pre-service science teacher, self-efficacy

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1. Introduction

In today's world, considerable efforts are being made across countries to restructure and reshape educational curricula (Tomte, Enochsson, Buskqvist, & Karstein, 2015). Current research explores how technology can support teaching and learning in various subjects and examines attempts to integrate technology throughout entire curricula (Tondeur et al., 2012). Within these efforts, establishing strong connections among STEM fields and promoting a holistic approach to teaching by developing skills, knowledge, and pedagogical beliefs related to these disciplines are of great importance (Merrill & Daugherty, 2009).

Technology is described as the integration of science and engineering to create new products (Dugger Jr., 2003; Günay, 2001). During the development of technological products, scientific methods are employed alongside technical knowledge and skills used in engineering. Engineering, in turn, addresses individuals' needs by combining scientific methods with mathematical theories within the framework of technological advancements (Asunda, 2012). Integrating all these disciplines, one of the innovative and supportive approaches that significantly contributes to the acquisition of 21st-century skills is STEM (Science, Technology, Engineering, Mathematics) education. The concept of STEM was

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first introduced by Dr. Judith Ramaley in 2001, deriving from the initials of the fields of Science, Technology, Engineering, and Mathematics (Yıldırım & Altun, 2015). In STEM education, the disciplines of science, technology, engineering, and mathematics function collaboratively to form an integrated whole (Gonzalez & Kuenzi, 2012). STEM is implemented by harmoniously combining the four domains within a particular framework without placing emphasis on any specific field (Moore, Stohlmann, Wang, Tank, & Roehrig, 2014). The STEM approach aims to develop students' engineering skills through the process of creating products related to science, mathematics, engineering, and technology (Bybee, 2010b; Yıldırım & Altun, 2015). It presents a holistic learning and teaching environment by integrating these disciplines through interdisciplinary connections (Bybee, 2010b; Smith & Karr-Kidwell, 2000). STEM education has emerged as a response to the need for a qualified workforce equipped with entrepreneurial, innovative, and creative skills to foster economic development in light of the rapid changes in science and technology (Martin-Páez et al., 2019). STEM education is becoming increasingly widespread, particularly in the United States, and in many other countries around the world (Akgündüz et al., 2015; Ünlü & Şenler, 2020).

In STEM education, applications in the fields of science and mathematics are simultaneously integrated with those in technology and engineering (Kang, Kim, & Kim, 2013). These practices not only encourage students to generate solutions to problems using their own knowledge but also enhance learning skills and promote meaningful learning (Wang, 2012). Today, STEM education practices are applied across all age groups, from early childhood to higher education (Berlin & Lee, 2005; Bryan, Moore, Johnson, & Roehrig, 2015; Bybee, 2010a; Moore & Richards, 2012). The literature emphasizes the contributions of STEM practices to students' acquisition of multiple perspectives, as well as the development of communication, problem-solving, creativity, and design skills (Berlin & White, 1994; Sanders, 2009; Şahin, Ayar, & Adıgüzel, 2014; Wai, Lubinski, & Benbow, 2010; Wang, 2012). Additionally, these practices are reported to positively affect students' higher-order thinking and critical thinking skills, thereby enhancing their motivation and academic achievement (Chesloff, 2013; Çavaş, Bulut, Holbrook, & Rannikmae, 2013; Hartzler, 2000; Herdem & Ünal, 2018; Elmalı & Balkan Kıyıcı, 2017; Morrison, 2006; Niess, 2005; Perkins, 1994; Yıldırım, 2016). STEM education fosters the development of critical perspectives towards real-life problems and promotes creative problem-solving through collaboration (Hernandez, 2014). Furthermore, students participating in STEM activities not only seek solutions to everyday life problems and needs but also develop an awareness of environmental and global issues (Soylu, 2016). Alongside the development of skills in STEM fields, students also engage with the processes of invention and discovery (Harkema, Jadrich, & Bruxvoort, 2009; Pekbay, 2017). STEM education effectively provides students with knowledge and skills applicable to real-world problems within a multidimensional learning environment (Soylu, 2016; Thomasian, 2011).

The inclusion of the engineering discipline in STEM activities contributes to the development of students' engineering design skills and enhances the quality and effectiveness of instruction through active student participation (Çavaş et al., 2013; MoNE [MEB], 2018; Wendell, 2008). Therefore, the implementation of STEM activities, in which different disciplines are used together, is considered essential in educational curricula and environments (Martinello, 2000; Özçelik, 2015). Consequently, it is crucial to equip students with the knowledge and skills necessary for adapting to contemporary conditions through the innovative approach offered by STEM education (Çorlu, Capraro, & Capraro, 2014). Teachers are the primary agents in imparting these skills, and thus it is imperative for both current and future teachers to possess a high level of competency regarding STEM (Ertmer & Ottenbreit-Leftwich, 2010). At this point, the concept of self-efficacy gains significance.

Self-efficacy is defined as an individual's belief in their personal ability to perform specific behaviors or actions (Bandura, 1997). In other words, it refers to an individual's self-assessment of their capability to organize and execute the courses of action required to attain designated goals (Bandura, 1997). Self-efficacy concerns an individual's capacity to cope with potential situations and the effectiveness with which they can carry out necessary behaviors. As emphasized by Bandura (1982), self-efficacy is regarded as a separate attribute from task feasibility, based on the individual's belief in their ability to succeed. Self-efficacy judgments can influence individuals' activity choices and environmental experiences (Bandura, 1982).

In this context, it is considered essential for pre-service teachers, who will practice the teaching profession in the future, to possess sufficient self-efficacy regarding STEM practices. A high level of self-efficacy not only influences the likelihood of implementing innovative practices such as STEM in real classroom settings but also shapes the attitudes, motivation, and persistence of future teachers in overcoming instructional challenges. Moreover, teachers with strong self-efficacy are more likely to experiment with interdisciplinary methods and encourage active learning environments. Given that the successful integration of STEM depends heavily on teachers' willingness and perceived competence, assessing and understanding pre-service teachers' self-efficacy can provide valuable insights into how well-prepared they are for modern educational demands. Therefore, investigating the self-efficacy levels of pre-service teachers concerning STEM practices is of critical importance. In line with this understanding, this study aims to determine the self-efficacy levels of pre-service teachers regarding STEM practices and to contribute to the development of evidence-based strategies for improving STEM education in teacher training programs.

2. Method

2.1. Research Model

This study was conducted within the framework of the general survey model, one of the quantitative research designs. General survey models are research approaches that aim to describe and depict an existing situation as it is, either in the past or present. The subject of this research involves a situation that is attempted to be defined within its own conditions and in its current state. The general survey model seeks to make a general assessment about a population through surveys conducted either on the entire population or a selected sample (Karasar, 2017).

2.2. Study Group

The study group of this research consisted of 110 volunteer pre-service science teachers who were enrolled in the third and fourth years of the Department of Science Education at a public university during the 2021–2022 academic year. The participants were determined using the convenience sampling method (Cohen, Manion, & Morrison, 2007). In this method, researchers select participants who are easily accessible and willing to participate in the study (Gravetter & Forzano, 2012). The participants consisted of 3rd and 4th year pre-service science teachers, as these students had already taken foundational courses and were more familiar with STEM-related practices compared to 1st and 2nd year students.

2.3. Data Collection Tool

The data collection tool used in this study was the STEM Applications Self-Efficacy Scale which includes items addressing various components of STEM application self-efficacy such as planning STEM activities, integrating multiple disciplines, problem-solving, and applying engineering and design processes in classroom settings developed by Özdemir, Yaman, and Vural (2018). This scale was designed to assess the STEM approach self-efficacy of teachers and pre-service teachers, initially comprising a pool of 55 items. The draft scale was administered to 219 pre-service teachers enrolled at the Faculty of Education of a public university located in the western region of Turkey, and validity and reliability analyses were conducted. The scale is structured on a 5-point Likert-type format. For the validation of the scale, both Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) were performed. The scale was determined to be unidimensional, explaining 68.2% of the total variance. As a result of the analyses, the scale was refined from 55 to 18 items. The Cronbach's Alpha internal consistency coefficient of the scale was calculated as .97. According to the results of the confirmatory factor analysis, the fit indices for the unidimensional structure of the scale were found to be at an excellent level.

2.4. Data Analysis

For the analysis of the data collected in this study, Microsoft Excel and the SPSS 21 statistical analysis software were utilized. The data were transferred to SPSS 21, where missing values were identified and necessary adjustments were made. The data were transferred to SPSS 21, where missing values were identified. Cases with missing or incomplete data were excluded from the analysis to ensure the integrity of the results Boone and Boone's (2012) method was employed to determine whether the data followed a normal distribution. Descriptive statistical techniques were used to assess whether the responses of the pre-service teachers exhibited a normal distribution, including measures of central tendency such as mode, standard deviation, median, and arithmetic mean. Additionally, measures of central dispersion, such as skewness and kurtosis values, standard deviation, and variance, were examined. During the data analysis, frequency and percentage distributions were used. All analyses were conducted considering a significance level of 5%.

3. Findings

The data for this study were collected using the STEM Applications Self-Efficacy Scale administered to pre-service teachers. In quantitative research, determining the appropriate method of data analysis requires an initial assessment of the normality of the data distribution (Boone & Boone, 2012). The use of parametric tests in the analysis of data obtained from the study is contingent upon the assumption that all collected data are normally distributed (Sim & Wright, 2002). In the present study, descriptive statistical indicators (mean, median, mode, kurtosis, and skewness) were utilized to examine the assumption of normality. The results related to the responses provided by pre-service science teachers on the scale are presented in Table 1 and Table 2.

Table 1. Descriptive Data on Scale Scores

Scale	N	M	Sd.	Mode	Median	Kurtosis	Skewness
STEM Applications Self-Efficacy Scale	110	66,81	11,46	69	67	-,24	,21

An examination of Table 1 reveals that the mean, mode, and median scores of the pre-service teachers are closely aligned. The proximity of these values is considered an indication of a normal distribution of the data (Köklü, Büyüköztürk, & Çokluk Bökeoğlu, 2006). Furthermore, Table 1 shows that the kurtosis and skewness values are also within acceptable ranges for a normal distribution. Specifically, kurtosis and skewness values falling within the range of -2 to +2 suggest that the data are normally distributed (George & Mallery, 2003). In addition, considering the maximum possible score on the scale (90 points), the relatively high mean score obtained by the pre-service science teachers is noteworthy.

Information regarding the percentage and frequency distribution of the responses given by the pre-service teachers to the items on the scale is presented in Table 2.

Table 2 presents the percentage and frequency distributions of the responses provided by pre-service teachers to the items on the STEM Applications Self-Efficacy Scale. The responses of the participants varied depending on the specific items of the scale. For example, regarding Item 1, 0.9% of the participants responded "Never," 40% "Sometimes," 17.3% "Often," and 17.3% "Always." For Item 2, 5.5% selected "Rarely," 41.8% "Sometimes," 39.1% "Often," and 13.6% "Always." For Item 3, 3.6% answered "Rarely," 36.4% "Sometimes," 41.8% "Often," and 18.2% "Always." In Item 4, 2.7% of the participants responded "Rarely," 37.3% "Sometimes," 46.4% "Often," and 13.6% "Always." Regarding Item 5, 0.9% chose "Never," 5.5% "Rarely," 25.5% "Sometimes," 50% "Often," and 18.2% "Always." For Item 6, responses included 13.6% "Rarely," 31.8% "Sometimes," 35.5% "Often," and 19.1% "Always." For Item 7, 5.5% of participants chose "Rarely," 36.4% "Sometimes," 42.7% "Often," and 15.5% "Always." In Item 8, 3.6% selected "Rarely," 25.5% "Sometimes," 50.9% "Often," and 20% "Always." Item 9 showed that 10% responded "Rarely," 40% "Sometimes," 32.7% "Often," and 17.3% "Always." Regarding Item 10, 3.6% answered "Rarely," 30% "Sometimes," 50.9% "Often," and 15.5% "Always." For

Item 11, responses were as follows: 0.9% "Never," 12.7% "Rarely," 40.9% "Sometimes," 28.2% "Often," and 17.3% "Always." For Item 12, 10.9% answered "Rarely," 39.1% "Sometimes," 40% "Often," and 10% "Always." In Item 13, 4.5% of the participants responded "Rarely," 27.3% "Sometimes," 52.7% "Often," and 15.5% "Always." For Item 14, 7.3% selected "Rarely," 30% "Sometimes," 50% "Often," and 12.7% "Always." Responses to Item 15 were 4.5% "Rarely," 25.5% "Sometimes," 46.4% "Often," and 23.6% "Always." For Item 16, 8.2% chose "Rarely," 31.8% "Sometimes," 40.9% "Often," and 19.1% "Always." In response to Item 17, 7.3% of the participants answered "Rarely," 35.5% "Sometimes," 40% "Often," and 19% "Always." Finally, in Item 18, 1.8% selected "Rarely," 26.4% "Sometimes," 43.6% "Often," and 28.2% "Always."

Table 2. Percentage-Frequency Distributions of Responses of Pre-Service Teachers to Items in the Scale

Scale items	Never		Rarely		Sometimes		Often		Always	
	%	f	%	f	%	f	%	f	%	f
Item 1	,9	1	0	0	40	44	17,3	46	17,3	19
Item 2	0	0	5,5	6	41,8	46	39,1	43	13,6	15
Item 3	0	0	3,6	4	36,4	40	41,8	46	18,2	20
Item 4	0	0	2,7	3	37,3	41	46,4	51	13,6	15
Item 5	,9	1	5,5	6	25,5	28	50	55	18,2	20
Item 6	0	0	13,6	15	31,8	35	35,5	39	19,1	21
Item 7	0	0	5,5	6	36,4	40	42,7	47	15,5	17
Item 8	0	0	3,6	4	25,5	28	50,9	56	20	22
Item 9	0	0	10	11	40	44	32,7	36	17,3	19
Item 10	0	0	3,6	4	30	33	50,9	56	15,5	17
Item 11	,9	1	12,7	14	40,9	45	28,2	31	17,3	19
Item 12	0	0	10,9	12	39,1	43	40	44	10	11
Item 13	0	0	4,5	5	27,3	30	52,7	58	15,5	17
Item 14	0	0	7,3	8	30	33	50	55	12,7	14
Item 15	0	0	4,5	5	25,5	28	46,4	51	23,6	26
Item 16	0	0	8,2	9	31,8	35	40,9	45	19,1	21
Item 17	0	0	7,3	8	35,5	39	40	44	19	19
Item 18	0	0	1,8	2	26,4	29	43,6	48	28,2	31

4. Results and Discussion

This study aimed to determine the STEM applications self-efficacy levels of 110 voluntary pre-service science teachers enrolled in the 3rd and 4th years of a state university's science education program. The findings revealed that the pre-service teachers' STEM self-efficacy level was 66.81 points. Considering that the maximum score obtainable from the scale is 90 points, this value is considered high. Based on the results, most pre-service science teachers reported feeling competent or proficient in implementing STEM activities. Therefore, it can be concluded that the candidates perceive themselves as competent in conducting STEM activities, based on their self-reported efficacy levels.

When examining the item-level responses, it was observed that certain items received notably high or low ratings. For instance, Item 5 and Item 8 showed high frequencies in the 'Often' and 'Always' categories, indicating that pre-service teachers feel confident in implementing interdisciplinary activities and integrating engineering concepts into teaching. On the other hand, Item 6 had relatively higher responses in the 'Rarely' category, which may point to difficulties in planning time-efficient STEM lessons. These results suggest that while candidates generally feel confident about most areas of STEM integration, they may need additional support or experience in certain practical dimensions of implementation.

A review of the literature shows similar findings. In a study conducted by Hacıoğlu, Yamak, Kavak, and (2016), the views of 58 physics, chemistry, biology, and science teachers regarding engineering design-based science education were investigated. The results indicated that although some teachers expressed negative opinions about the subject, the majority had positive attitudes. Despite their stated concerns, the teachers indicated a willingness to implement STEM activities in their science classrooms. Similarly, in another study by Hacıoğlu, Yamak, and Kavak (2017), the opinions of 42 pre-service science teachers regarding STEM education were examined, and it was found that they were willing to implement STEM activities once they became teachers. Likewise, a study conducted by Çevik, Danıştay, and Yağcı (2017) found that pre-service teachers' awareness of STEM was moderate and positive. In another study by Dadacan (2021), involving 315 pre-service teachers, the results revealed that the participants' self-efficacy perceptions regarding STEM applications were at a moderate level.

Other studies have also emphasized that the integration of STEM into lessons plays an important role in enhancing teachers' instructional capacities (Hacıömeroğlu, 2018; Nadelson, Seifert, Moll, & Coats, 2012; Sowell, Southerland, & Granger 2006; Watt, Richardson, & Pietsch, 2007).
Yıldırım and Türk (2018) also highlighted the positive effects of STEM activities on pre-service teachers in their study. According to their findings, pre-service science teachers generally demonstrated the ability to define the concept of STEM. In a study by Eroğlu and Bektaş (2016), teachers were asked to define STEM education, and it was observed that they typically incorporated at least one of the concepts of science, engineering, mathematics, or technology in their definitions. Similarly, in a study by Sungur-Gül and Marulcu (2014), pre-service teachers and in-service teachers indicated that they viewed engineering as a tool for transferring science subjects to daily life. Aslan Tutak, Akaygun and Tezsezen (2017) found that teachers defined STEM more often as an approach in which different disciplines are taught together in an integrated manner. Additionally, the study by Sarı and Yazıcı (2019) showed that teachers could relate science lessons to other disciplines such as engineering. These findings demonstrate that pre-service teachers possess knowledge about STEM-related topics.

As highlighted by researchers such as Koray (2003) and Yaman (2003), self-efficacy perception is critically important, particularly regarding the efforts individuals exert to successfully complete assigned tasks and the resilience they show when facing obstacles. Nowadays, just like in other fields, there is a growing emphasis on teachers' self-efficacy perceptions in science education (Dorman, 2001; Ritter, Boone, & Rubba, 2001). Therefore, it is considered crucial to assess and enhance the STEM self-efficacy perceptions of pre-service teachers during their undergraduate education processes. In light of the findings from this study, which indicate that pre-service teachers generally perceive themselves as competent in STEM practices, it is recommended that teacher education programs continue to incorporate and possibly expand STEM-based coursework and applied experiences. Particular attention should be given to areas where self-efficacy was relatively lower, such as lesson planning or time management in STEM contexts. Future research could examine STEM self-efficacy levels across different departments or with varying instructional methods. Furthermore, designing intervention-based programs, workshops, or peer-led projects targeting specific STEM competencies may help strengthen weaker areas and better prepare pre-service teachers for classroom implementation.

Ethical Statement

The research was conducted in accordance with the articles outlined in the Directive on Scientific Research and Publication Ethics of the Council of Higher Education. We declare that there is no case of ethical misconduct.

Declaration of Interest

We declare that there is no academic or financial conflict of interest regarding the publication of this study.

Informed Consent

Participants voluntarily took part in the study. We declare that informed consent forms were obtained from all participants.

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