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Examination of Pedagogical Content Knowledge of Pre-Service Primary School Teachers towards STEM

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ABSTRACT This study examines the pedagogical content knowledge of pre-service primary school teachers towards STEM. The research's study group consists of 202 pre-service primary school teachers studying at the faculty of education of two universities in the 2021-2022 academic year. The mixed method was used in the study. The survey model was used in the quantitative dimension of the study, and the case study was used in the qualitative dimension. The study's data were collected using the "STEM Pedagogical Content Knowledge Scale" and the "semi-structured interview form" developed by the researcher. A statistics program was used to analyze quantitative data, and content analysis was used to analyze qualitative data. According to the quantitative results of the study, the pedagogical content knowledge of pre-service primary school teachers towards STEM did not show the difference in terms of the variables of graduated high school, science proficiency, and desire to receive STEM education. In addition, differences were observed between the gender and technology sub-dimension, grade level and science and mathematics sub-dimension, having STEM knowledge and science sub-dimension, STEM competence and mathematics sub-dimension. According to the qualitative results of the study, it was determined that pre-service primary school teachers' perspectives toward STEM education were positive. However, they considered themselves inadequate because they did not receive training.

Keywords Pedagogical Content Knowledge, Pre-Service Primary School Teachers, STEM

1. INTRODUCTION

In our era, there is a need to increase students' readiness to overcome real-life problems and to raise individuals with qualifications that can contribute to the needs of society. Due to the development of science and technology day by day, curricula, one of the essential elements of education, have been updated. Accordingly, the need for countries to develop learning in line with the demands of the information society has emerged (Organization for Economic Co-operation and Development [OECD], 2015). Studies have also been carried out in our country to adapt to the changing and developing world and raise individuals according to age requirements. In this context, it is seen that there is an update in the Turkey Ministry of National Education (2018), and a new program was created. While scientific process and life skills are mentioned similarly in both programs, engineering, and design skills differ in the Turkey Ministry of National Education (2018) program. In the Turkey Ministry of National Education (2018) program, the fact that engineering and design skills, which are included under the title of field-specific skills, aim to integrate four different disciplines is an indication that the STEM approach, which has been frequently included in the educational planning and programs of countries in recent years, has also been adopted in our country.

STEM education is an approach that integrates science, technology, engineering, and mathematics and has especially brought innovation to science education (Bybee, 2013). STEM is an educational approach that focuses on the engineering design of the knowledge and skills of science, technology, mathematics, and engineering fields and aims to provide students with the integration of disciplines, open communication, ethical values, research, productivity, creativity, and problem-solving skills (Karakaya, Yantırı, Yılmaz, & Yılmaz, 2019). STEM creates an integrated model by bringing different disciplines together. It enables students to find creative solutions to problems by looking at them from a broad perspective. This approach aims to solve the problem that the student

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realizes by combining the knowledge learned in science and mathematics courses and combining it with technology and engineering skills (Polat & Bardak, 2019). Thus, STEM education has become the main focus of 21st-century education programs (National Academy of Engineering [NAE] & National Research Council [NRC], 2009; NRC, 2012). Defined as a learning-teaching approach based on interdisciplinary integration, which requires the use of 21st-century skills (Bybee, 2010; United States Department of Education, 2016; Honey, Pearson, & Schweingruber, 2014), the primary purpose of STEM education is to raise innovative generations (Rahman et al., 2022).

STEM education aims not only for students but also for teachers. It aims to increase teachers' content and pedagogical content knowledge as well. Teachers need to learn how to teach the skills gained through STEM education and what can be done for teaching (Crane et al., 2003). Teachers' experiences and knowledge about STEM education are of great importance in achieving the goals of STEM education. Teachers are expected to guide students in this process and their integral role. It is thought that incorrect or incomplete guidance may cause students to develop negative attitudes toward STEM. For teachers to use STEM education correctly in their classrooms, they need to learn the philosophical foundations, theoretical background, and application knowledge of STEM education very well (Yıldırım, 2018). Preparing teachers with the knowledge and skills needed to incorporate the content and develop abilities aligned with the goals of integrated STEM education is a critical step in advancing STEM education (Guzey, Caskurlu, & Kozan, 2020).

Shulman defines PCK as a "special amalgam of content and pedagogy that is uniquely the province of teachers, their special form of professional understanding" (Shulman, 1987). According to Shulman, several domains affect how teachers teach: knowledge of content, pedagogic knowledge (e.g., knowledge of classroom management strategies), knowledge of curriculum, PCK, and student learning interests. Grossman (1990) analyzed PCK in four categories: knowledge about individuals' understanding of the subject matter, knowledge of the curriculum, knowledge of teaching methods, and knowledge about the purpose of teaching. PCK is a concept related to teachers' knowledge, what they do with their knowledge, and why they do what they do (Baxter & Lederman, 1999).

The concept of pedagogical content knowledge (PCK), which is expressed as the presentation of knowledge to students by making it teachable, was first defined by Shulman as follows; the most useful form of knowledge is the knowledge of making the subject most appropriate for others to understand by formulating strong descriptions, animations, examples, explanations and concepts, presentation methods and topics (Bal & Karademir, 2013).

Pedagogical content knowledge is essential in implementing the STEM education approach. A teacher's ability to use the STEM education approach in his/her lessons to plan and manage the process depends on his/her pedagogical content knowledge. In this context, it is possible to say that STEM educators should have pedagogical content knowledge, integrated curriculum knowledge, and content knowledge competencies (Şahin, 2019). In order to practice STEM learning in the classroom as expected, it is crucial to develop teachers' PCK skills in STEM learning. Improving teacher efficacy in STEM learning is vital to prepare students to face the challenges in the 21st century. There are several ways to improve teachers' PCK skills, one of which is training. Many recent studies have revealed the benefits of developing PCK in education (Duschl & Bybee, 2014). Therefore, teacher training is necessary to develop the PCK of pre-service teachers. STEM education can reach the desired level of teachers who include this approach in their classrooms, perform their practices in a qualified way, and have STEM knowledge (Çayak, 2019).

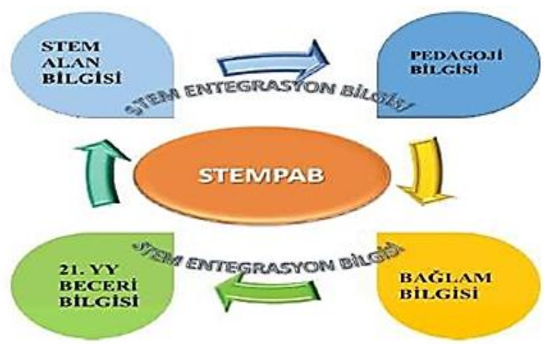

Figure 1 STEM PCK model (Yıldırım, 2018)

When Figure 1 is examined, it is seen that the teacher who will implement STEM education in the classroom and be a guide in this process should have STEM content knowledge, pedagogy knowledge, 21st-century skills knowledge, context knowledge, and integration knowledge (Eckman, Williams, & Silver-Thorn, 2016; Chai, 2019; Eilks & Markic, 2011; Epstein & Miller, 2011; Yıldırım & Şahin-Topalcengiz, 2018). The context knowledge mentioned here includes the establishment of the connection of STEM education with the environment; 21st-century skills knowledge includes "Life and Professional Skills", "Learning and Renewal Skills," and "Information, Media and Technology Skills" (Partnership for 21st Century Skills, 2009), while integration knowledge includes the knowledge required to provide all other knowledge together (Yıldırım, 2018). In light of this information, STEM education should be added to the courses of pre-service teachers studying in faculties of education (Yıldırım, 2018).

In this context, it is important to examine the pedagogical content knowledge of pre-service teachers, who are the future architects of education who will implement STEM applications in primary education. With this study, it is expected that the deficiencies of STEM education in teacher education will be identified, teacher education will be improved, and future STEM applications will be developed. When the literature is examined, Çayak (2019) aims to examine the pedagogical content knowledge of science teachers towards STEM; Güngör (2021) aims to determine the knowledge dimensions and self-efficacy of teachers and pre-service primary school teachers (science, elementary mathematics, computer, and instructional technologies) towards integrated STEM education in terms of technological pedagogical content knowledge; Ceran (2021) aimed to examine the pedagogical content knowledge, pedagogical beliefs and classroom practices of classroom teachers in the processes of participating in a professional development course and implementing STEM (science, technology, engineering, mathematics) teaching in their classrooms; Boyraz and Bilican (2020) aimed to examine their conceptual and pedagogical knowledge about STEM. Faikhamta, Lertdechapat, & Prasoblarb (2020) examined the effects of a PCK-based STEM professional development program on science teachers and concluded that it positively affected science teachers' attitudes toward STEM education. In addition, some studies have been conducted on teachers' STEM PCK competence (Hasanah, Permanasari, & Riandi, 2021) and Supporting PCK and CK Development of pre-service primary school teachers through a STEM program (Correia & Baptista, 2022). Since there are few studies in the literature, further research on STEM and PCK needs to be developed (Hasanah, Riandi, Kaniawati, & Permanasari, 2022).

This study aimed to examine the pedagogical content knowledge of pre-service primary school teachers toward STEM. When the literature is examined, the fact that there is no such study in terms of content and study group increases the importance of this study in terms of contributing to the literature. This adds to the novelty of the study. Additionally, in the study, some variables (gender, grade, high school of graduation, having STEM knowledge, and STEM competence) that are thought to be related to the STEM pedagogical content knowledge of pre-service primary school teachers and their views on STEM pedagogical content knowledge were examined in detail, which provided a more in-depth investigation of the subject and contribution to the field.

STEM education is included in the 2018 Science and Technology curriculum starting from the 4th grade. Since the foundation of STEM education will be laid from the 4th grade, providing an effective and efficient STEM education at this level is crucial. However, the lack of STEM education at the undergraduate level for pre-service classroom teachers, who are the future teachers, and the fact that pre-service teachers start their teaching profession without STEM knowledge and STEM PCK competence, results in a significant gap in terms of practicing STEM education. In this context, this study will bring innovation to the literature by revealing the level of pre-service classroom teachers' abilities, to what extent they can use these abilities, and their opinions while fulfilling the responsibility of practicing STEM education as a primary school teacher.

1.1 Sub-Problem Status

The main problem of the research is to investigate the pedagogical content knowledge of pre-service primary school teachers towards STEM. Depending on this problem, answers to sub-problems were sought.

a) Is there a relationship between pre-service primary school teachers' gender, grade level, graduated high school, STEM knowledge, STEM competence, and STEM pedagogical content knowledge?
b) What are the opinions of pre-service primary school teachers about their STEM pedagogical content knowledge?

2. METHOD

2.1 Research Model

This study used a mixed research design that combines quantitative and qualitative research designs. According to Creswell and Creswell (2017), mixed methods research is a type in which the researcher integrates quantitative and qualitative data collected to explain the research problems and draws conclusions with the advantage of combining these two data sets. There are basic designs that researchers can use with the mixed pattern. In this study, a sequential explanatory design was used. In sequential explanatory design, qualitative data are collected following the collection and analysis of quantitative data. Then the analysis of qualitative data is added (Dadacan, 2021). Finally, the data analyses are interconnected, and the process is completed by combining the data in the interpretation and discussion sections (Baki & Gökçek, 2012).

In the first part of the study, quantitative data were collected using the survey model. In the second part of the study, qualitative data were collected through semi-structured interviews using the case study model.

2.2 Working Group

The study group the research consists of pre-service classroom teachers studying at two different state universities in the Eastern Black Sea region in the 2021-2022 academic year. 202 pre-service teachers studying in the 1st, 2nd, 3rd, and 4th grades participated in the study based on volunteerism. Table 1 shows the gender distribution of the pre-service teachers participating in the study.

2.3 Data Collection Tools

In this study, STEM Pedagogical Content Knowledge Scale developed by Yıldırım and Şahin-Topalcengiz (2018) and semi-structured interview questions developed by the

Table 1 Distribution of pre-service primary school teachers by grade level and gender

Grade	Gender	Frequency
1st-grade	female	30
	male	15
Total		45
2nd-grade	female	36
	male	13
Total		49
3rd-grade	female	45
	male	6
Total		51
4th-grade	female	45
	male	12
Total		57

researcher were used to determine the pedagogical content knowledge of pre-service primary school teachers towards STEM education.

STEM Pedagogical Content Knowledge Scale (STEMPCK)

STEM Pedagogical Content Knowledge Scale was used as a data collection tool to examine the pedagogical content knowledge of pre-service primary school teachers towards STEM. The scale was developed by Yıldırım and Şahin-Topalcengiz (2018), and Cronbach's Alpha value was calculated as 0.95. The scale consists of 6 sub-dimensions (pedagogical knowledge, science knowledge, technology knowledge, engineering knowledge, mathematics knowledge, and 21st-century skills knowledge) and a total of 56 items. When the sub-dimensions of the scale items are considered in terms of the number of items, there are 12 items for pedagogical knowledge, eight items for science knowledge, seven items for technical knowledge, seven items for engineering knowledge, eight items for mathematics knowledge, and 14 items for 21st-century skills knowledge.

The study's quantitative data were collected using the STEM Pedagogical Content Knowledge Scale. The STEM Pedagogical Content Knowledge Scale was administered to pre-service teachers via Google Form and face-to-face application. In the first part of the form, the purpose of the study was briefly mentioned. The second part contains demographic information questions consisting of 11 titles (gender, age, grade level, graduated high school, STEM education knowledge, STEM teaching competence). In the third section, instructions on how to conduct the scale were given. Finally, the last part of the form contains the scale items. There is no time limit for completing the form. However, the researcher informed the participants that it is essential for the validity and reliability of the research that they fill in the scale items carefully. Two hundred two pre-service classroom teachers completed the scale.

Semi-structured Interview Questions

The researcher developed the semi-structured interview questions for the study. Semi-structured interview questions were prepared in parallel with the dimensions of pedagogical knowledge, 21st-century skills knowledge, mathematical knowledge, science knowledge, technology knowledge, and engineering knowledge, which are the sub-dimensions of the STEM Pedagogical Content Knowledge Scale. A total of 29 open-ended interview questions were prepared. The prepared questions were sent to one expert in the science education field. This other expert developed the STEM Pedagogical Content Knowledge Scale, and two expert opinions were taken and finalized. Due to the ethics of the research, pre-service classroom teachers were given codes as (teacher candidates), TC1(1), TC2(1), and TC1(2)...

Qualitative data were collected through semi-structured interviews. Face-to-face interviews were conducted with 14 pre-service teachers. The interviews lasted 25-30 minutes. The researcher asked open-ended interview questions to the pre-service teachers, and the answers were recorded using voice recordings. The interviews conducted in the school environment were conducted separately with each pre-service teacher. The researcher told the participants about the importance of their responses in terms of the validity and reliability of the study and asked them to show the necessary sensitivity.

2.4 Quantitative Data Analysis

In order to determine the data analysis methods for examining the STEM pedagogical content knowledge of pre-service primary school teachers in terms of various variables, a normality analysis of the data in the current study was conducted. In statistical analyses, Kolmogorov-Smirnov and Shapiro-Wilk tests are used to examine the normality distribution of the data. Kolmogorov-Smirnov test is used when the number of data in the group is more than 29, and the Shapiro-Wilk test is used when the number of data in the group is less than 29 (Şeref, 2008). If the significance value is greater than .05 as a result of the analysis, the test distribution is considered normal (Şeref, 2008). In this study, since the number of data in the group was greater than 29, the distribution was examined using the Kolmogorov-Smirnov test. As a result of normality analyses, it was decided to apply parametric data analysis methods (t-test, ANOVA) to those with normal distribution and nonparametric data analysis methods (Mann Whitney U Test, Kruskall Wallis Test) to those without normal distribution.

2.5 Qualitative Data Analysis

The content analysis method was used to analyze qualitative data in the study. Data were collected through semi-structured interview questions. Codes and themes were created. Different experts checked these codes and themes. The data obtained were explained statistically in tables using frequency (f).

3. RESULT AND DISCUSSION

3.1 Quantitative Data

The minimum value obtained from the STEM-PCK scale is 56, and the maximum is 280. Accordingly, the results of pre-service primary school teachers' STEM-PCK scores are given in Table 2. When Table 2 is examined, according to STEM-PCK scores, the highest mean value was 60.46 in the 21st-century sub-dimension.

Results Related to the Gender of Pre-service Primary School Teachers in Terms of STEM-PCK Subdimensions

When Table 3 is examined, according to the results of the Kolmogorov-Smirnov test, it is seen that the 21st-century skills sub-dimension and overall total values related to the gender variable ($p>0.05$) show normal distribution within a 95% confidence interval, while the pedagogy, science, technology, engineering and mathematics sub-dimension values ($p<0.05$) do not show normal distribution within 95% confidence interval. Table 4 found

Table 2 Results related to STEM-PCK scores of pre-service primary school teachers

Sub-Dimensions	$\bar{x}$	V	Std. Deviation	Skewness	Kurtosis	Min	Max
Pedagogy	50.4257	32.803	5.72738	-.843	3.368	21.00	60.00
Science	27.7822	27.037	5.19970	-.379	.462	12.00	40.00
Teknology	25.5743	23.350	4.83220	-.003	.018	12.00	35.00
Engineering	22.3564	20.260	4.50115	-.044	-.240	11.00	34.00
Maths	30.8416	27.428	5.23713	-.244	-.003	15.00	40.00
21st century	60.4604	38.429	6.19909	-.334	-.269	42.00	70.00
Total	217.4406	438.467	20.93959	-.069	.185	151.00	273.00

Table 3 Normality test results of STEM-PCK subscales regarding gender

Sub-Dimensions	Cinsiyet	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Pedagogy	Female	.095	156	.002	.951	156	.000
	Male	.137	46	.031	.869	46	.000
Science	Female	.117	156	.000	.967	156	.001
	Male	.129	46	.054	.968	46	.242
Technology	Female	.088	156	.005	.981	156	.027
	Male	.127	46	.062	.948	46	.038
Engineering	Female	.090	156	.004	.978	156	.013
	Male	.106	46	.200*	.978	46	.514
Maths	Female	.116	156	.000	.965	156	.001
	Male	.115	46	.154	.956	46	.080
21st century	Female	.070	156	.061	.966	156	.001
	Male	.109	46	.200*	.958	46	.095
Total	Female	.046	156	.200*	.990	156	.302
	Male	.092	46	.200*	.974	46	.398

Table 4 Mann Whitney U Test results of STEM-PCK sub-dimensions by gender

Sub-Dimensions	Groups	N	Rank Average	Rank Total	U	p
Pedagogy	Female	156	103.56	16155	3267	.355
	Male	46	94.52	4348		
Science	Female	156	100.74	15715	3469	.732
	Male	46	104.09	4788		
Teknology	Female	156	94.23	14700.5	2454.5	.001
	Male	46	126.14	5802.5		
Engineering	Female	156	99.64	15544.5	3298.5	.405
	Male	46	107.79	4958.5		
Maths	Female	156	100.94	15747	3501	.802
	Male	46	103.39	4756		

Table 5 T-test results regarding gender in terms of STEM-PCK subscales

Sub-Dimensions	Groups	N	$\bar{x}$	S	sd	t	p
21st century	Female	156	60.3013	6.29328	200	-.671	.503
	Male	46	61.0000	5.90292			
Total	Female	156	216.5577	19.93028	200	-1.104	.271
	Male	46	220.4348	24.05055			

Table 6 Normality test results regarding class levels in terms of STEM-PCK subscales

Kolmogorov-Smirnov	Shapiro-Wilk						
Sub-Dimensions	Class level	Statistic	df	Sig.	Statistic	df	Sig.
Pedagogy	1	.130	45	.054	.930	45	.009
	2	.145	49	.012	.842	49	.000
	3	.151	51	.005	.958	51	.066
	4	.150	57	.003	.950	57	.020
Science	1	.100	45	.200*	.976	45	.478
	2	.119	49	.079	.967	49	.189
	3	.094	51	.200*	.974	51	.328
	4	.119	57	.045	.979	57	.425
Technology	1	.094	45	.200*	.953	45	.068
	2	.096	49	.200*	.960	49	.093
	3	.102	51	.200*	.969	51	.211
	4	.129	57	.019	.972	57	.205
Engineering	1	.122	45	.089	.979	45	.567
	2	.114	49	.126	.979	49	.538
	3	.120	51	.066	.962	51	.097
	4	.110	57	.084	.974	57	.247
Maths	1	.108	45	.200*	.951	45	.055
	2	.113	49	.152	.959	49	.084
	3	.112	51	.153	.979	51	.483
	4	.133	57	.014	.947	57	.015
21st century	1	.083	45	.200*	.956	45	.089
	2	.084	49	.200*	.956	49	.066
	3	.100	51	.200*	.971	51	.239
	4	.080	57	.200*	.965	57	.101
Total	1	.099	45	.200*	.973	45	.381
	2	.082	49	.200*	.971	49	.257
	3	.090	51	.200*	.979	51	.497
	4	.082	57	.200*	.982	57	.550

a statistically significant difference between gender and technology sub-dimension ($p<0.05$).

In Table 5, within the scope of the 21st-century skills sub-dimension, it was determined that there was no significant difference between the mean value of the 21st-century skills knowledge test scores of female pre-service teachers ($\bar{x}$ = 60.30) and the test scores of male pre-service teachers ($\bar{x}$ = 61.00) (t (200) = -.671; p > 0.05). When it was examined whether the STEM PCK differed according to gender, it was determined that there was no significant difference between the mean value of the general total test scores of female pre-service teachers ($\bar{x}$ = 216.55) and male pre-service teachers ($\bar{x}$ = 220.43) (t(200) = -1.104; p>0.05).

Results Related to Pre-service Primary School Teachers' Grade Levels in Terms of STEM-PCK

When Table 6 is examined, according to the results of the Kolmogorov-Smirnov test, it is seen that the engineering, 21st-century skills sub-dimension, and general total values related to the grade level ($p>0.05$) show normal distribution within a 95% confidence interval, while the pedagogy, science, technology, and mathematics sub-dimension values ($p<0.05$) do not show normal distribution.

When the Kruskall Wallis Test results according to the grade level given in Table 7 are analyzed, there is no significant difference between the pedagogy sub-dimension and the grade level ($x^2(3)$ = 3.20, p>0.05), there is a

Table 7 Kruskall Wallis Test results regarding class levels in terms of STEM-PCK subscales

Sub-Dimensions	Groups	N	Rank Average	Sd	x^2	p
Pedagogy	1	45	96.30	3	3.208	.361
	2	49	109.40			
	3	51	91.94			
	4	57	107.37			
Science	1	45	107.77	3	18.882	.000
	2	49	85.18			
	3	51	84.25			
	4	57	126.01			
Technology	1	45	100.89	3	1.390	.708
	2	49	109.59			
	3	51	96.52			
	4	57	99.48			
Math	1	45	99.13	3	7.951	.047
	2	49	108.32			
	3	51	83.64			
	4	57	113.49			

Table 8 ANOVA test results by grade level in terms of STEM-PCK subscales

Sub-Dimensions	Source of Variance	Sum of Squares	sd	Mean Squares	F	p
Engineering	Between Groups	48.712	3	16.237	.799	.496
	Within Groups	4023.624	198	20.321		
	Total	4072.337	201			
21st century	Between Groups	161.858	3	53.953	1.413	.240
	Within Groups	7562.325	198	38.194		
	Total	7724.183	201			
Total	Between Groups	1852.975	3	617.658	1.417	.239
	Within Groups	86278.812	198	435.752		
	Total	88131.787	201			

significant difference between the science sub-dimension and the grade level ($x^2(3) = 18.88$, $p<0.05$), there is no significant difference between the technology sub-dimension and the grade level ($x^2(3) = 1.39$, $p>0.05$), there is a significant difference between the mathematics sub-dimension and the grade level ($x^2(3) = 7.95$, $p<0.05$). In order to determine which group was in favor of this difference, the Tukey test, one of the post hoc tests, was used. As a result of the multiple comparisons made in this context, it was determined that the difference between the science sub-dimension and the grade level was between the 1st-2nd grade (p.039), 2nd-4th grade (p.001) and 3rd-4th grade (p.006). As a result of the multiple comparisons between the mathematics sub-dimension and grade level, no significant data were obtained in favor of any group.

When the results of the ANOVA test related to the grade levels in terms of the STEM-PCK Subdimensions given in Table 8 are examined, the mean scores of the engineering subdimension for the grade level were found as 1st grade ($\bar{x} = 22.53$), 2nd grade ($\bar{x} = 21.51$), 3rd grade ($\bar{x} = 22.52$) and 4th grade ($\bar{x} = 22.78$) and there was no significant difference between the groups ($p>0.05$). The mean scores of the 21st-century skills sub-dimension for the grade level were found as 1st grade ($\bar{x} = 61.11$), 2nd grade ($\bar{x} = 61.63$), 3rd grade ($\bar{x} = 59.41$) and 4th grade ($\bar{x} = 59.87$) and there was no significant difference between the groups ($p>0.05$). The mean scores for the overall total and grade level were found as 1st grade ($\bar{x} = 218.93$), 2nd grade ($\bar{x} = 217.34$), 3rd grade ($\bar{x} = 212.64$), and 4th grade ($\bar{x} = 220.63$) and no significant difference was observed between the groups ($p>0.05$).

Results Related to the High School Graduated from in Terms of STEM- PCK

When Table 9 is examined, according to the results of the Kolmogorov-Smirnov test, it is seen that the technology, 21st-century skills sub-dimension, and general total ($p>0.05$) values related to the high school graduates show normal distribution within 95% confidence interval. In contrast, the values of the pedagogy, science, engineering, and mathematics sub-dimension ($p<0.05$) do not show normal distribution.

When the Kruskall Wallis Test results are analyzed in Table 10, pedagogy sub-dimension and graduated high school ($x^2(4) = .791$, $p>0.05$), science sub-dimension

Table 9 Normality test results regarding the high school graduates' STEM-PCK subscales

Sub-Dimensions	Graduated High School	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Pedagogy	General High School	.132	25	.200*	.876	25	.006
	Anatolian Technical and Vocational High School	.151	29	.088	.927	29	.047
	Science Anatolian high school	.104	119	.003	.910	119	.000
	Teacher High School	.114	15	.200*	.968	15	.832
	Other	.212	14	.090	.901	14	.117
Science	General High School	.137	25	.200*	.954	25	.302
	Anatolian Technical and Vocational High School	.101	29	.200*	.974	29	.658
	Science Anatolian high school	.093	119	.013	.983	119	.141
	Teacher High School	.194	15	.134	.922	15	.203
	Other	.185	14	.200*	.955	14	.642
Technology	General High School	.124	25	.200*	.976	25	.801
	Anatolian Technical and Vocational High School	.096	29	.200*	.951	29	.189
	Science Anatolian high school	.078	119	.070	.976	119	.031
	Teacher High School	.148	15	.200*	.911	15	.138
	Other	.111	14	.200*	.916	14	.193
Engineering	General High School	.166	25	.075	.952	25	.284
	Anatolian Technical and Vocational High School	.098	29	.200*	.979	29	.814
	Science Anatolian high school	.106	119	.002	.987	119	.311
	Teacher High School	.166	15	.200*	.960	15	.691
	Other	.130	14	.200*	.945	14	.481
Math	General High School	.155	25	.124	.931	25	.091
	Anatolian Technical and Vocational High School	.136	29	.183	.956	29	.268
	Science Anatolian high school	.122	119	.000	.959	119	.001
	Teacher High School	.176	15	.200*	.958	15	.653
	Other	.316	14	.000	.846	14	.020
21st century	General High School	.157	25	.113	.960	25	.416
	Anatolian Technical and Vocational High School	.137	29	.176	.946	29	.142
	Science Anatolian high school	.068	119	.200*	.968	119	.006
	Teacher High School	.145	15	.200*	.940	15	.386
	Other	.182	14	.200*	.919	14	.216
Total	General High School	.079	25	.200*	.991	25	.998
	Anatolian Technical and Vocational High School	.107	29	.200*	.974	29	.674
	Science Anatolian high school	.084	119	.039	.989	119	.428
	Teacher High School	.150	15	.200*	.956	15	.617
	Other	.140	14	.200*	.951	14	.582

and graduated high school ($x^2(4) = 2.635$, $p>0.05$), engineering sub-dimension and graduated high school ($x^2(4) = 9.167$, $p>0.05$)0.05), between the mathematics sub-dimension and the high school graduated from ($x^2(4) = .025$, $p>0.05$), and between the overall total and the high school graduated from ($x^2(4) = .883$, $p>0.05$).

In Table 11, the mean scores of the Technology sub-dimension for the high school graduated from were found as General High School ($\bar{x} = 25.40$), Anatolian Technical and Vocational High School ($\bar{x} = 26.03$), Science, Anatolian and YDAL ($\bar{x} = 25.53$), Teacher High School ($\bar{x} = 24.46$), Other ($\bar{x} = 26.42$) and there was no significant difference between the groups ($p>0.05$).

The mean scores of the 21st-century skills sub-dimension for the high school graduated from were found as general high school ($\bar{x} = 58.76$), Anatolian Technical and Vocational High School ($\bar{x} = 60.65$), Science, Anatolian and YDAL ($\bar{x} = 60.89$), Teacher High School ($\bar{x} = 61.06$)

Table 10 Kruskal-Wallis test results regarding the high school graduated from in terms of STEM-PCK subscales

Sub-Dimensions	Groups	N	Rank Average	sd	X^2	p
Pedagogy	General High School	25	99.40	4	.791	.940
	Anatolian Technical and Vocational High School	29	99.98			
	Science Anatolian high school	119	102.99			
	Teacher High School	15	106.77			
	Other	14	90.07			
Science	General High School	25	104.80	4	2.635	.621
	Anatolian Technical and Vocational High School	29	86.86			
	Science Anatolian high school	119	102.91			
	Teacher High School	15	101.33			
	Other	14	114.14			
Engineering	General High School	25	105.08	4	9.167	.057
	Anatolian Technical and Vocational High School	29	121.40			
	Science Anatolian high school	119	96.61			
	Teacher High School	15	121.43			
	Other	14	74.07			
Math	General High School	25	100.24	4	.025	1.000
	Anatolian Technical and Vocational High School	29	101.76			
	Science Anatolian high school	119	101.88			
	Teacher High School	15	101.40			
	Other	14	100.11			
Total	General High School	25	94.98	4	.883	.927
	Anatolian Technical and Vocational High School	29	106.76			
	Science Anatolian high school	119	102.00			
	Teacher High School	15	105.57			
	Other	14	93.61			

Table 11 ANOVA test results regarding the high school graduated from in terms of STEM-PCK subscales

Sub-Dimensions	Source of Variance	Sum of Squares	sd	Mean Squares	F	p
Technology	Between groups	35.679	4	8.920	.377	.825
	within groups	4657.707	197	23.643		
	Total	4693.386	201			
21^{st}-century skills	Between groups	144.491	4	36.123	.939	.442
	within groups	7579.692	197	38.476		
	Total	7724.183	201			

Table 12 Normality test results regarding STEM knowledge in terms of STEM-PCK subscales

Sub-Dimensions	STEM knowledge	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Pedagogy	Yes	.122	<83	.004	.957	83	.007
	No	.095	119	.010	.918	119	.000
Science	Yes	.135	83	.001	.973	83	.077
	No	.067	119	.200*	.986	119	.280
Technology	Yes	.077	83	.200*	.977	83	.152
	No	.090	119	.020	.971	119	.012
Engineering	Yes	.103	83	.029	.980	83	.216
	No	.101	119	.004	.989	119	.422
Math	Yes	.142	83	.000	.959	83	.009
	No	.090	119	.019	.968	119	.007
21st-century skills	Yes	.071	83	.200*	.959	83	.010
	No	.094	119	.011	.970	119	.009
Total	Yes	.065	83	.200*	.986	83	.512
	No	.065	119	.200*	.992	119	.752

Table 13 Mann Whitney U test results for STEM knowledge in terms of STEM-PCK subscales

Sub-Dimensions	Groups	N	Rank Average	Rank Total	U	p
Pedagogy	Yes	83	106.83	8867	4496	.278
	No	119	97.78	11636		
Science	Yes	83	114.99	9544.5	3818.5	.006
	No	119	92.09	10958.5		
Technology	Yes	83	108.24	8984	4379	.170
	No	119	96.80	11519		
Engineering	Yes	83	110.67	9186	4177	.062
	No	119	95.10	11317		
Math	Yes	83	105.20	8731.5	4631.5	.451
	No	119	98.92	11771.5		
21st-century skills	Yes	83	106.86	8869	4494	.276
	No	119	97.76	11634		

Table 14 T-Test Results for STEM Knowledge in Terms of STEM-PCK Sub-Dimensions

Sub-Dimensions	Groups	N	$\bar{x}$	S	sd	t	p
Total	Yes	83	221.2651	18.07106	200	2.188	.030
	No	119	214.7731	22.41611			

and other ($\bar{x}$ = 58.71). There was no significant difference between the groups (p>0.05).

Results Related to Pre-service Primary School Teachers' STEM Knowledge in terms of STEM-PCK

In Table 12, according to the results of the Kolmogorov-Smirnov test, it is seen that the overall total values (p>0.05) for STEM knowledge status show normal distribution within a 95% confidence interval, while the values of pedagogy, science, technology, engineering, mathematics and 21st-century skills sub-dimensions (p<0.05) do not show normal distribution.

When Table 13 is examined, a statistically significant difference was found between STEM knowledge and the science sub-dimension (p<0.05). In Table 14, when examining whether the total differs according to STEM knowledge, it is determined that there is a significant difference between the mean value ($\bar{x}$ = 221.26) of the total test scores of the "yes" answer and the mean value ($\bar{x}$ = 214.77), of the total test scores of the "no" answer (t(200) = 2.188; p<0.05).

Results Regarding the STEM Competence of Pre-service Primary School Teachers in terms of STEM-PCK

When Table 15 is examined, according to the results of the Kolmogorov-Smirnov test, it is seen that the 21st-century skills sub-dimension and the overall total (p>0.05) related to STEM knowledge status show normal distribution at a 95% confidence interval, while the

Table 15 Normality test results regarding STEM competence in terms of STEM-PCK sub-dimensions

Sub-Dimensions	STEM Competence	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Pedagogy	Yes	.161	51	.002	.949	51	.028
	No	.099	151	.001	.926	151	.000
Science	Yes	.143	51	.011	.972	51	.262
	No	.107	151	.000	.973	151	.005
Technology	Yes	.093	51	.200*	.981	51	.599
	No	.087	151	.008	.972	151	.003
Engineering	Yes	.187	51	.000	.953	51	.044
	No	.069	151	.075	.990	151	.399
Math	Yes	.122	51	.057	.955	51	.051
	No	.106	151	.000	.973	151	.005
21st-century skills	Yes	.100	51	.200*	.943	51	.016
	No	.059	151	.200*	.973	151	.005
Total	Yes	.077	51	.200*	.990	51	.933
	No	.060	151	.200*	.991	151	.470

Table 16 Mann Whitney U test results regarding STEM competence in terms of STEM- PCK sub-dimensions

Sub-Dimensions	Groups	N	Rank Average	Rank Sum	U	p
Pedagogy	Yes	51	109.48	5583.50	3443.500	.258
	No	151	98.80	14919.50		
Science	Yes	51	110.30	5625.50	3401.5	.212
	No	151	98.53	14877.50		
Technology	Yes	51	108.93	5555.50	3471.500	.292
	No	151	98.99	14947.50		
Engineering	Yes	51	112.10	5717.00	3310.000	.133
	No	151	97.92	14786.00		
Math	Yes	51	119.12	6075.00	2952.000	.013
	No	151	95.55	14428.00		

Table 17 T-test results for STEM competence in terms of STEM-PCK sub-dimensions

Sub-Dimensions	Groups	N	$\bar{x}$	S	sd	t	p
21st-century skills	Yes	51	61.0392	6.18372	200	.770	.442
	No	151	60.2649	6.21257			
Total	Yes	51	222.8235	19.19448	200	2.142	.033
	No	151	215.6225	21.24986			

pedagogy, science, technology, engineering, and mathematics sub-dimension values ($p<0.05$) do not show normal distribution.

Table 16 shows a statistically significant difference between STEM competence and the mathematics sub-dimension ($p<0.05$). In Table 17, when it was examined whether the 21st-century skills sub-dimension differed according to STEM proficiency, it was determined that there was no significant difference between the mean value of the test scores of the yes answer ($\bar{x}$ = 61.03) and the mean value of the test scores of the no answer ($\bar{x}$ = 60.26) ($t(200)$ = .0770; $p>0.05$). However, when it was examined whether the overall total differed according to STEM proficiency, it was determined that there was a significant difference between the mean value of the test scores of the yes answer ($\bar{x}$ = 222.82) and the mean value of the overall total test scores of the no answer ($\bar{x}$ = 215.62) ($t(200)$ = 2.142; $p< 0.05$).

3.2 Qualitative Data

Results Related to Pre-service Primary School Teachers' Views on Pedagogical Content Knowledge

In Table 18, it is seen that eight themes and 16 codes were identified as a result of the analysis of the responses, and the most common theme was "interdisciplinary." In Table 19, it is seen that six themes and 13 codes were determined as a result of the analysis of the answers, and most opinions were expressed about the "content" theme. Table 20 shows that one theme and six codes were determined, and the answer was mostly, “I do not know”.

In Table 21, it is seen that eight themes and 17 codes were identified, and the answers "should know technology

Table 18 "*What is STEM education according to you? Can you explain?*"; results obtained for the question

Theme	Codes	f	Opinion
Interdisciplinary	Science, technology, engineering	2	TC2(3): STEM education combines science, math, and technology.
	Math, Science	2	
	Engineering, math, and technology	1	TC2(2): I had not heard this before but learned that technology and lessons are intertwined.
	Science, math, technology	1	
	Mathematics, physics, biology	1	
	Intertwining technology and lessons	1	
Discipline	Science	1	TC1(2): I think STEM is an education that is predominantly used in science.
	Leveraging technology	2	TC3(1): In my opinion, STEM education is to explain the subject to students by using technology to explain the subject better.
Process	Practical training	1	
Objective	Creating lasting knowledge	1	TC2(1): STEM education creates more permanent knowledge for the child...
	Explaining the topic better	1	
	Ensuring better learning	1	
Content	Delivering information in a more organized way	1	TC2(1): ...to be able to provide sufficient information in a more organized way.
Method	A project-based education system	1	TC1(4): STEM education, in my opinion, is to create education like a project-based education system, which has settled with the developing world in today's conditions...
Approach	Innovative	1	TC1(4): ...situations where students carry out innovative actions in areas such as mathematics, physics, and biology in order to complete their projects so that students can learn better
No Information	I do not know	3	TC1(3): I do not know. I have no information

Table 19 "*What aspects distinguish the STEM education approach from other approaches?*"; results of the question

Theme	Codes	f	Opinion
Student	Building better projects	3	
	Ensuring permanent learning	1	TC2(1): It teaches more permanently. Education that is more organized than simplification and can make it easier for the child to perceive is necessary.
	Use your imagination	1	
Contents	Leveraging technology	3	TC3(4): Since the concept of technology is mentioned in it, I think there is a distinction about technology.
	Close to math	2	
	Being numeric	1	
	Close to scientific/contain scientific information	1	TC4(4): The STEM approach comes to my mind as an approach that takes others together, giving importance to mathematics and scientific knowledge rather than science.
	Being with pictures	1	
Interdisciplinary	Including more than one discipline	2	TC 4(2): What separates it, I think, is that it combines several branches of science and presents it.
Method	Problem-solving	1	TC 3(2): I think it is mainly focused on mathematics; it is a system closer to solving problems.
Teacher	Requires expertise and equipment	1	TC3(3): It requires more expertise, equipment, and knowledge. It requires skill.
	Be talented	1	
No information	I do not know	3	TC 1(3): I do not know.

Table 20 *"What do you understand when you say STEM pedagogical content knowledge?"*; results of the question

Theme	Codes	f	Opinion
STEM Pedagogical Knowledge	I do not know	9	TC 3(1): I have no information.
	Education on how to treat children	1	TC 3(2): An education we will receive about how to treat children.
	Teacher's knowledge	1	TC 2(3I understands it as the knowledge of the teacher.
	Education on how to apply STEM to children	1	
	Transferring the information learned in the lessons with STEM	1	
	Adapting engineering skills to education	1	TC 3(3): I think of applying these engineering skills to education.

Table 21 *"In your opinion, which pedagogical knowledge should a classroom teacher who wants to use STEM education practices in their lessons have? Why?"*; question and the results obtained for the question

Theme	Codes	f	Opinion
Field Knowledge	Must know technology well	3	TC 2(2): They should have a good command of technological devices, computers, telephones, hardware, and software. If he does not know these, it means he does not know anything about technology. Therefore, it would be difficult for him to use it in his lesson.
	Discipline knowledge	2	
	Science and engineering knowledge	1	TC4(2): They need to know science knowledge well, also in practical terms. I think he/she should also know the engineering field because it is a combination of these fields, so he/she should know these fields so that he/she can explain them to the students.
	Engineering knowledge	1	
Method-Process Knowledge	How to present information	1	TC4(4): ...They should choose their topics to suit the lesson. Students should be active.
	Making it fun	1	
	Students are active	1	
Content	Must have a good command of the subject	1	TC2(3): First of all, he/she should have a good command of the subject. According to which subject he/she is teaching. I mean, he/she cannot transfer this to a student without mastering it himself/herself. First of all, the student does not take the teacher seriously. It would not be convincing
	Topic selection	1	
Undergraduate Courses	Teaching principles and methods	1	TC1(4): In teaching principles and methods courses, in these teaching material development courses, etc., they need to have an excellent undergraduate education about this
	Material development	1	
Out-of-School Learning	Robotic coding-certificates	1	TC1(4): ... ...robotic coding, coding, etc. certificates, they also need to have developed themselves.
Student	Know the level of the student	1	TC4(4): Should pay attention to the level of the student...
	Student's field of interest	1	
Personal Feature	Must have good diction	1	TC3(1): ...should have good diction...
	He must have improved himself	1	
No Information	I do not know	3	TC1(3): I do not know.

Table 22 *"Which methods and techniques should be utilized when implementing STEM education in lessons? Why do you think so?"*

Theme	Codes	f	Opinion
Methods- Techniques	Technology-enabled	4	TC2(1): As I said, some tools and materials are things for visual memory after technology.
	Research-study	3	
	Narration	3	
	Tool-material supported	2	
	Path of invention	2	TC3(3): It can be a way of invention. The invention can be utilized. The station technique can be used as a technique. Because when using this STEM method, I think that the class should be fused. I think that students should discover something in the way of invention.
	Question and answer	2	
	Demonstration	2	
	Play dough	1	
	The Game	1	
	Image-slide	1	
	Video	1	
	Case study	1	
	Discussion	1	
	Station	1	
	Brainstorming	1	

Table 23 Results obtained for the question, *"Do you consider yourself competent in implementing STEM education in your teaching life? Why?"*

Theme	Codes	f	Opinion
Not enough	Lack of subject knowledge	3	TC2(4): No. As I said, I do not know whether I am adequate in this subject since I do not have complete knowledge or did not know it at the beginning.
	Lack of STEM education	2	
	Failure to use technology	2	
	Especially when it comes to computers	2	
	Prejudice about mathematics	1	
	Distance education	1	TC3(2): No, because I am not good with technology. I am prejudiced against mathematics. I look at it negatively, so no.
	Not receiving detailed science education	1	
	Willingness to receive training	1	
	Lack of practical application of the subject	1	
	Since I do not have a numerical interest	1	TC1(1): I do not consider it sufficient because I do not have such a numerical interest at the moment, but I will be sufficient if I receive training.
Adequate	Not knowing how to support	1	TC2(3): I see it, but I am afraid. I explain it, but if a child insists on not understanding it, I do not know how to support it.

well" and "disciplinary knowledge" were mainly given. Table 22 shows that one theme and 15 codes were identified, and the most common answer was "technology supported".

In Table 23, 2 themes and 11 codes were identified. Mostly they answered "lack of subject knowledge". In Table 24, 3 themes and eight codes were identified. It was observed that the answers "training should be provided" and "courses should be added" were mostly given.

Results Related to Pre-service Primary School Teachers' Science Knowledge

Table 25 shows that two themes and 15 codes were identified, and the answer "research examination" was mostly given. In Table 26, 2 themes and 14 codes were identified. They mostly answered "better teaching" and "if I learn, I research". In Table 27, 4 themes and eight codes were identified. It is seen that the answer "I do not know" was mostly given.

Results Related to Pre-service Primary School Teachers' Technology Knowledge

In Table 28, 2 themes and 18 codes were identified. Mostly the answer "making our lives easier" was given. When Table 29 was analyzed, two themes and nine codes were identified. It is seen that the answer "STEM is technology-relevant" was given the most. In Table 30, 2 themes and 14 codes were identified. Mostly, the answer "I do not know" was given. In Table 31, 1 theme and 3 codes were identified. Mostly, they answered, "I am competent" in technology. In Table 32, 2 themes and 8 codes were identified. Mostly, the answers were "if I get a good education - if I have knowledge" and "I don't know". In

Table 24 Results obtained for the question, *"What are your suggestions on providing STEM pedagogical content knowledge for pre-service classroom teachers?"*

Theme	Codes	f	Opinion
Positive	Training should be provided	5	TC2(1): This education can start from the first grade.
	The lesson should be added	5	TC2(2): They need to teach us technology more. Last year, for example, we took the technology course through distance education, but it is better to face to face this year.
	Teachers should be informed	1	TC3(3): I think courses related to this field should be added to the curriculum.
	Technology must be taught	1	
	More training should be provided at the undergraduate level	1	
	Robotic coding	1	TC3(2): As far as I know, science courses were divided in the previous system. That are physics, chemistry, and biology. Now they are all combined, and very superficial information is given. STEM education is almost like nothing this time.
Negative	Inadequate science education	1	
No Information	I do not know	3	TC3(2): ...I do not know about teachers

Table 25 *"Which techniques and methods should be used in STEM education in Science courses? Why do you think so?"*

Theme	Codes	f	Opinion
Methods-Techniques	Research-study	4	TC1(1): It can be an experiment, a model, or even showing something the child likes. Visual intelligence or application is simpler and more memorable.
	Show and do not tell	3	
	Experiment	2	
	Observation	1	
	Modeling (making a model)	1	TC4(4): It should be research, investigation, and student-centered. It should be suitable for the student level. Because I think learning does not take place when we do not take into account the level of the student. When the student is not active, no learning takes place when we only give them information. So we should involve students in the process.
	Trial and error	1	
	Science center trip	1	
	Path of invention	1	
	Case study	1	
	Question and answer	1	
	Discussion	1	
	Narration	1	
	Visuals-slides	1	
	Problem-solving	1	
No Information	I do not know	3	

Table 26 *"Would you benefit from STEM Education in science courses in your teaching life? Why?"*

Theme	Codes	f	Opinion
I will benefit	Better teaching	2	TC1(1): I get hurt. Because it's something we already need. And maximally all of us also need to know in the children we teach.
	I will investigate if I find out	2	
	Need	1	
	Children need to know	1	TC2(2): Yes, I do. Because it is easier to teach students something by using visuals, using technology.
	To ensure learning by doing- living	1	
	Using visuals	1	
	Using technology	1	TC3(2): Yes, I will. Because I don't know much about the use of technology, I think it can help because it is a system that combines technology with mathematics and engineering.
	Permanent effective learning	1	

Table 26 *"Would you benefit from STEM Education in science courses in your teaching life? Why?"* (Continued)

Theme	Codes	f	Opinion
I will benefit	Bringing technology- mathematics- engineering together	1	TC1(4): Of course, I would like to benefit, but if I do a research about it and get support from an expert.
	Providing versatile thinking	1	
	Research-study	1	
	Question and answer	1	
	Not always, but sometimes	1	
Undecided	Undecided	1	

Table 27 Results obtained for the question, "*How do you integrate science into STEM education?*"

Theme	Codes	f	Opinion
Application	Keeping children active	2	
	Screening	1	
	Observation	1	
Content	Experiments	2	TC3(1): I intertwine the subject of science with STEM. I explain it together with it.
	Intertwining science and STEM education	1	TC4(2): I think it would be more appropriate in the applied parts of science. It can be used in those aspects. For example, in the experiment parts.
	Electric circuit-microscope	1	
Environment	Suitable environment and conditions	1	TC1(4): Of course, there must be a suitable environment and conditions for this. The material and the student profile should be suitable for this so that I can apply them
No Information	I do not know	7	TC2(4): So there is science in it as science. Again, I do not have an entirely correct answer to this because I do not actually know.

Table 28 *"What is technology according to you? Is it necessary to use it in science lessons? Why?"*

Theme	Codes	f	Opinion
Technology Knowledge	Making our lives easier	4	TC1(1): In my opinion, I am a person who is afraid of technology. Because it is spread everywhere now, even in our pockets, a small world is actually dangerous. However, when used properly, it benefits us and makes our lives much easier.
	Development innovation modernization	3	
	Most of our needs	2	
	A necessity of the 21st century	2	
	Possibility to make use of everything – visual slide animation	1	TC2(3): Technology development innovation. Sure. I mean, everything is already in technology. So we can see everything more easily from there and reach more easily.
	Everything about informatics	1	
	All the tools and equipment we use are of great importance in our lives	1	
	Easy access to information	1	
Use in Science Lessons	Permanent learning	2	TC3(3):.... Yes, it is necessary. For example, an experiment video can be watched on a computer if you do not have the opportunity at that moment, children realize effective permanent learning.
	Modeling in hard-to-reach situations	1	
	Teaching by telling students	1	
	With technology, we can reach and see everything more easily	1	
	Increased efficiency of the course	1	
	Already in use (Smartboard, microscope)	1	

Table 28 *"What is technology according to you? Is it necessary to use it in science lessons? Why?"* (Continued)

Theme	Codes	f	Opinion
Use in Science Lessons	Children growing up in the age of technology	1	TC2(4): ...It is necessary, of course, if we go from technology and science to technology, for example, when I give you information, you may forget it after a while. However, by experimenting and using technology, for example, we cannot reach an experiment. We are in a village school. We can watch a video on the internet. Those children will have learned. So it appeals more to the visual.
	Addressing gaps in implementation	1	
	For tangible learning (seeing, trying, etc.)	1	
	In cases where it is not possible (video screening)	1	

Table 29 *"What is the relationship between STEM education and technology? Can you explain it by giving examples?"*

Theme	Codes	f	Opinion
Relationship dimension	STEM is technology - it is related	5	TC2(1): With technology, it provides more permanent learning with slides and animations by being illustrated more. TC4(4): For example, when I taught a topic in science class, I opened a video on the board or gave an example of a microscope. It becomes a mediator in transferring information to the students.
	Providing permanent learning	2	
	Inability to provide education without technology	1	
	With picture slide animation	1	
	Making an application	1	
	Doing better things with technology	1	
	Transfer of knowledge	1	
	STEM to be passed in	1	
No information	I do not know	4	

Table 30 *"Which methods and techniques should be utilized when using technology in STEM education? Why do you think so?"*

Theme	Codes	f	Opinion
Methods-Techniques	Show and do not tell	2	TC1(1): I mean, I think it should be used in a continuous interactive way. It would be nice if technology is used, so both sides are active on a teacher-student basis. / I think from the child's point of view. It can be difficult for the child to get up and memorize or to teach them something in writing. But it is easier for him/her to chat with a peer as if he/she is in front of him/her and learn that way. TC1(4): When using technology, again in the same way, showing and doing, brainstorming, etc., question and answer. TC2(3): Learning by doing and experiencing. It is more permanent.
	Research-study	2	
	Interactive	1	
	Animation	1	
	Music	1	
	Video	1	
	Path of invention	1	
	Discussion	1	
	Question and answer	1	
	Brainstorming	1	
	Station	1	
	Case study	1	
	Learning by doing and experiencing	1	
No Information	I do not know	5	

Table 31 Results obtained for the question *"Do you think you have sufficient knowledge about technology?"*

Theme	Codes	f	Opinion
Qualification	I have enough	7	TC3(3): Yes, I think... TC2(2): Moderate
	Moderate - partially	5	
	Not enough	2	

Table 32 *"Would you benefit from STEM education while using technology in your teaching life? Why do you think so?"*

Theme	Codes	f	Opinion
Positive	If I get a good education - if I have knowledge	3	TC1(1): We have to use it anyway. Technology has entered every aspect of our lives.
	Better teaching and learning	2	TC1(4):.... I would like to benefit from STEM education, of course, if I receive this education.
	Because it is in every aspect of our lives	2	TC1(2): ...I will probably benefit from it in my teaching life. I prefer to be an innovative teacher rather than a traditional teacher. Technology is also innovation. Therefore, I use it with children. I also encourage children to use technology.
	Creating lasting knowledge	1	
	Providing a good education	1	
	Being an innovative teacher	1	
Negative	I do not know the topic	3	
	I am not aware of all technological developments	1	

Table 33 Results obtained for the question *"How do you integrate technology into STEM education?"*

Theme	Codes	f	Opinion
Technology Integration	Presentation-	2	TC2(1): To prepare a presentation for the children, maybe the students can watch a movie. TV series, movies...
	slide	2	
	Video	1	
	TV series-	1	TC2(3): We can do it by showing technology, for example, computers, slides, and projections.
	film	1	
	Visual Animation Smartboard	1	TC1(4): How can I integrate technology into STEM education? Since it is project-based, I can carry out these projects more internet-based and technology-based.
	Projection	1	
	Computer- Internet	1	
	Product creation	1	
	Transferring an innovation	1	
No Information	I do not know	4	

Table 33, 2 themes and 11 codes were identified. Mostly, the answer "I don't know" was given.

Results Related to Pre-service Primary School Teachers' Views on Engineering Knowledge

In Table 34, 3 themes and 25 codes were identified. In Table 35, 3 themes and ten codes were identified. Most of the answers were "I don't know". In Table 36, 2 themes and five codes were identified. Mostly the answer "I have no information" was given.

Results Related to Pre-service Primary School Teachers' Views on Mathematics Knowledge

In Table 37, 2 themes and ten codes were identified. Mostly, it is seen that the answer "I do not know" was given. In Table 38, 2 themes and 11 codes were identified. Mostly, the answer "I don't know" was given. In Table 39, 3 themes and 13 codes were identified. Mostly, the response was "class level - children being small". In Table 40, 2 themes and five codes were identified. Mostly, they answered, "I do not know".

Results Related to Pre-service Primary School Teachers' Views on 21st-Century Skills

In Table 41, 2 themes and ten codes were identified. The most common response was technology. In Table 42, 2 themes and 12 codes were identified. Mostly, the answer "I don't know" was given. In Table 43, 2 themes and four codes were identified. Again, most of the answers were "I am competent" and "I am moderately competent". In Table 44, 2 themes and seven codes were identified. Mostly, they answered "technology".

In STEM-PAB and its sub-dimensions, it was determined that there was no difference in terms of gender in the other sub-dimensions except for the technology sub-dimension. However, on the technology sub-dimension, it was determined that male pre-service teachers had higher mean scores than female pre-service teachers, and there was a difference. In his study, Çayak (2019) concluded that the mean scores of male teachers on the STEM-TPACK sub-dimensions of the gender variable were higher and differentiated than female teachers. Similarly, Gedik, Sönmez, and Yeşiltaş (2019) concluded that pre-service primary school teachers' technological pedagogical content knowledge competencies differed in favor of male pre-

Table 34 *"What is engineering according to you? Is it necessary to use it in science lessons? Why?"*

Theme	Codes	f	Opinion
Engineering	Electric-electronics	2	TC1(1): In my opinion, engineering is the people who deal with electrical and electronics or construction and prepare the infrastructure for these. It is used. A shape is made, something is made, and ultimately it enters engineering in simpler modeling. It is easier.
	Construction	2	
	Conducting deep investigations in their field	2	
	Making, developing, and creating something	2	
	Enabling the formation of structures (houses, buildings, etc.)	2	TC3(4): When I think of engineering, I think of structures or electrical and electronic engineers. I can explain it as the people involved in the construction of these or a part of life that enables them to be formed. So again, it can be done when we think on a unit basis. I think it can be used through a material made in force and motion.
	Interrelated	2	
	Embodiment	2	
	Things that children make themselves	1	
	Working on nature	1	
	Using science, technology, and mathematics	1	
	Meeting human needs	1	
	Craft demonstration	1	
	The functioning of a mechanism-physics	1	
	Simple modeling	1	
	Permanent learning	1	
	Experiential learning	1	TC1(2): I do not know because science is at a very low level in my department, but I think it should be used in the future.
	In advanced classes	1	
	Making things, testing things	1	
	The foundation of science	1	
	Better learning	1	
	Using materials	1	
	On some issues	1	
	Inviting a layperson	1	
No Information Required	I do not know	3	
	Science should be used in engineering	1	

Table 35 *"Which techniques and methods should be utilized when using engineering in STEM education? Why do you think so?"*

Theme	Codes	f	Opinion
Methods and techniques	Research-study	3	TC4(2): Invention, presentation, again, demonstration, case study. I do not know if lecturing will do much. I think these areas are not practical because they are more practice-oriented. More applied techniques should be used.
	Straight narration	2	
	Show and do not tell	2	
	Invention	1	
	Presentation	1	
	Experiment-	1	TC3(4): Again, I will say research and investigation because I think it can be something that both the teacher and the student can do together.
	Observation Case study	1	
Materials	Play dough	1	TC2(1): For example, logos and ropes can be used
	Logo-Rope	1	
No Information	I do not know	7	

Table 36 Results obtained for the question *"How do you integrate engineering into STEM education?"*

Theme	Codes	f	Opinion
Engineering Integrated Knowledge	Using visuals (model-play dough-slide)	2	TC2(1): Again, supporting them with tools and materials.
	Inclusion of science and technology	2	TC4(4): It makes sense to make models and make them that way.
	Using materials	1	
	Supporting with math and technology	1	
No Information	I do not know	8	TC1(4): I do not know how to integrate engineering into STEM education.

Table 37 Results obtained for the question *"Can you explain the relationship between STEM education approach and Mathematics?"*

Theme	Codes	f	Opinion
Engineering Integrated Knowledge	Inclusion of engineering, science, and technology	2	TC1(4): Since this is a project-based thing, mathematical data includes mathematical operations, and the observation is related to mathematics because there are bears, etc. TC2(2): It could be problem-solving or something like that. These came to my mind right now, such as analyzing.
	Using visuals	2	
	Making calculations-operations	2	
	Expressing numbers with symbols	1	
	Problem-solving	1	
	Analysis	1	
	Measurement	1	
	Project-based-observation process numbers	1	
	Materials	1	
No Information	I do not know	6	

Table 38 *"Which methods and techniques should be used when teaching mathematics in STEM education? Why do you think so?"*

Theme	Codes	f	Opinion
Methods and Techniques	Show and do not tell	4	TC1(3): When I use it in mathematics, I think a little bit in mathematics. I do not know. It can be a demonstration. Again, lectures and discussions can be these. TC4(4): Again, we can do student-centered collaborative teaching with the student's active participation. I think they will learn better by working in a group.
	Symbols- visuals	2	
	Technology	1	
	Path ofinvention	1	
	Way of presentation	1	
	Narration	1	
	Discussion	1	
	Product creation	1	
	Research- study	1	
	Cooperative teaching	1	
No Information	I do not know	5	

Table 39 Results obtained for the question *"Do you think you have the necessary qualifications and skills for teaching mathematics? Why?"*

Theme	Codes	f	Opinion
Adequate	Class level - small children	3	TC2(2): Right now, yes. Because we explain at a superficial level, I think I have enough knowledge for this. I can explain by using materials. TC3(3): Yes. Because I know that I can teach children, I can make it concrete. I can prepare activities for them to understand.
	Training for a long time	2	
	Information holder	2	
	Subject matter expert	1	
	Embodiment	1	
	Using materials	1	
	Preparing an activity	1	
	I was able to do the internship	1	

Table 39 Results obtained for the question *"Do you think you have the necessary qualifications and skills for teaching mathematics? Why?"* (Continued)

Theme	Codes	f	Opinion
Not Sufficient	Content at a basic level	2	TC3(4): I do not think much because it was a course I took online. I mean, theoretically, we learned something, but when we started the internship and entered the classroom environment, we saw that the theory was not very important. That is why.
	I took the course online	2	
	I did not take the course	1	
	My knowledge is not enough	1	
No Information	I do not know	2	

Table 40 Results obtained for the question *"How do you integrate mathematics into STEM education?"*

Theme	Codes	f	Opinion
Mathematics Integrated Knowledge	Shapes	1	TC4(2): Here, the cost of the operations we use when creating something can be used in these aspects. For example, when making something, mathematics can be used to measure the quantity. TC3(3): I can explain mathematics by making small-scale mechanisms within the activities.
	Associating with daily life	1	
	Cost-measure-quantity	1	
	With small-scale mechanisms	1	
No Information	I do not know	10	

Table 41 *"What are 21st-century skills? Can you give an example?"*

Theme	Codes	f	Opinion
Skill Knowledge	Technology	6	TC3(4): I would say it is technology because it is a part of our lives. I can say that technology skills are involved. TC3(3): Research reading exploring problem-solving these. TC1(4): The skills of the 21st century can be a skill that fits the requirements of the age, knows the technology, and gives more importance to saving...
	Problem-solving	2	
	Innovation	1	
	Contact	1	
	Research	1	
	Reading, exploring	1	
	Active learning	1	
	Student self-expression	1	
	Savings	1	
No Information	I do not know	5	

Table 42 *"Which methods and techniques should be utilized when using 21st century skills in STEM education? Why do you think so?"*

Theme	Codes	f	Opinion
Methods-Techniques	5 E	2	TC2(2): I can only think of the 5E method now.
	Research-study	2	
	Path of invention	1	TC3(3): Problem-solving should be used. Research, research is necessary. Because I think STEM is something that requires knowledge. Therefore, it is necessary to do research.
	Way of presentation	1	
	Problem-solving	1	
	Show and do not tell	1	
	Multiple intelligences	1	
	Narration	1	
	Demonstration	1	
	Cooperative learning	1	
	Using technology	1	
No Information	I do not know	3	

Table 43 Results obtained for the question *"Do you feel adequate in teaching 21st century skills to your students?"*

Theme	Codes	f	Opinion
Positive	Adequate Moderately sufficient	5 5	TC 3(4): I think I can give it at the primary school level. they were born at the age of technology, but as young people of this age, I think I can give it to them. TC3(1): At the middle level.
Negative	Inadequate I do not want to win	3 1	TC4(2): I cannot say that I see it as sufficient. Because I think it is because of the grade level, I feel like I am always incomplete now because there is a road ahead of me.

Table 44 *"Do you think there is a relationship between 21st century skills and STEM education? Why do you think so?"*

Theme	Codes	f	Opinion
Relationship Size	Technology STEM-the necessity of the age Innovative Science-critical thinking Cooperation-communication STEM- numerical	8 2 2 1 1 1	TC4(2): Since there is technology in STEM education, technology also covers 21st-century skills. Critical thinking is already used in science. So there is a relationship. They are interconnected. It is like one cannot exist without the other. TC1(1): Yes. It is an innovative thing anyway. It is actually a challenging and beautiful thing to integrate things again or to explain them in an integrated way.
No Information	I do not know	1	TC1(3): I do not know STEM education, so I will not comment.

service teachers. Rahman, Rosli, & Rambley (2021), on the other hand, concluded that the mean score of female teachers was higher than the mean score of male teachers regarding gender in mathematics teachers' knowledge of STEM-based education, while Hiğde et al. (2020) concluded that the STEM teaching orientations of teachers and pre-service teachers and their attitudes towards STEM fields did not differ according to gender. Furthermore, unlike Rahman et al. (2022), their study with secondary school teachers concluded that non-parametric analysis did not show a difference in STEMPCK scores based on gender, educational qualification, and teaching experience.

In STEM-PAB and its sub-dimensions, it was determined that there was no differentiation in grade levels in pedagogy, technology, engineering, and 21st-century skills sub-dimensions. Similarly, Gedik et al. (2019) concluded that pre-service primary school teachers' technological pedagogical content knowledge differed according to the grade level. It was concluded that as the grade level increased, technological pedagogical content knowledge competencies increased positively. The group with the highest technological pedagogical content knowledge competencies comprised pre-service teachers at the 4th-grade level.

When the knowledge of pre-service primary school teachers about STEM education is examined, it was concluded that there was no difference in pedagogy, technology, engineering, mathematics, 21st-century skills sub-dimensions in terms of STEM-PCK and its sub-dimensions according to Rahman et al. (2022), it has been determined that teachers have very positive perceptions about STEMPCK regarding the components of pedagogical knowledge and 21st-century skill knowledge, but not to those of STEM knowledge.

In terms of STEM information, if we look at the qualitative results, it was determined that pre-service primary school teachers' generally perceived STEM education as an interdisciplinary education but could not explain it as the integration of four disciplines (science, mathematics, technology, and engineering). In her study, İmir (2019) concluded that classroom teachers, as a different sample, expressed STEM education as an interdisciplinary approach. Faikhamta et al. (2020), as a result of their studies, shows that the professional development program has a positive effect on science teachers' attitudes towards STEM education, on their knowledge and practices.

Let us look at the pre-service primary school teachers' views regarding the aspects that distinguish the STEM education approach from other approaches. It can be said that with the view of creating a project, they think that a product emerges as a result of STEM education and that it involves a process; regarding the utilization of technology, it can be said that they are aware that it involves more technology and is interdisciplinary compared to other approaches. These results are similar to the answers (creativity/imagination, problem-solving) given by Yıldırım and Türk (2018) in their study examining the views of pre-service primary school teachers toward STEM education.

It was concluded that most pre-service primary school teachers did not express their opinions on STEM pedagogical content knowledge. This result is similar to Correia & Baptista (2022), which identified various scientific misconceptions and weaknesses in the participants' PCK.

The pedagogical knowledge that classroom teachers who want to use STEM applications in their lessons should have mainly was given as "they should know technology well" and "they do not have any knowledge". However, in his study, Çayak (2019), as a different sample, it is seen that he reached the results of mastering field knowledge, following technology, being open to innovations, being inquisitive, internalizing STEM, and having pedagogical knowledge about the competencies that science teachers who will provide STEM education in schools should have. In this direction, it is seen that similar results have been reached.

Pre-service primary school teachers' mainly stated that the methods and techniques used in STEM education should be supported by technology and that they should be sufficient in terms of technology in STEM education. Similarly, Yıldırım (2018) found that the strategies, methods, and techniques used by science and mathematics teachers during STEM applications were problem-based learning, project-based learning, lecture, learning through a presentation, question-answer, learning through research and investigation; Arslan and Yıldırım (2020) concluded that pre-service teachers would use the invention, presentation, research, experiment, 5E, computer-assisted instruction, discussion, lecture, question and answer, six-hat thinking technique, brainstorming, and simulation technique while preparing STEM lesson plans.

Pre-service primary school teachers' views on their competencies to implement STEM education were examined, and it was determined that they mostly saw themselves as inadequate. Hasanah et al. (2021), determined that online professional development is very useful for teachers and can develop their skills in implementing STEM learning during distance learning. Apart from low-cost, online PD can be an alternative way to improve teachers' STEM PCK competence.

The pre-service primary school teachers' opinions about using STEM education in science courses in their teaching life were that although they do not have information about STEM education, it has been determined that they think its use in lessons will produce good results. Similarly, Sümen, Özçakır, and Çalışıcı (2016) concluded in their study that pre-service teachers want to use STEM activities in their professional lives. In the same way, Faikhamta et al. (2020) examined the effects of a PCK-based STEM professional development program on science teachers and concluded that it had a positive effect on science teachers' attitudes toward STEM education.

Pre-Service primary school teachers do not have sufficient knowledge about engineering and engineering education. In STEM education, it has been determined that they mostly do not know the methods and techniques that can be used in engineering education. In Yıldırım's (2018) study, the fact that teachers stated that they were most deficient in engineering education in STEM education is similar to the result of the study. Furthermore, Correia & Baptista's (2022) results for participants' PCK revealed that problem/inquiry-based learning and collaborative work are present in all lesson plans, while design-based learning received little attention.

In terms of overall results, it is possible to say that pre-service primary school teachers' pedagogical content knowledge about STEM education is partially sufficient. However, STEM is gradually developing as a discipline and requires solid educational practices based on teacher PCK (Rahman et al., 2022).

4. CONCLUSION

4.1 Quantitative Conclusions

When the gender dimension is examined, it has been determined that there is no difference in other sub-dimensions except for the technology sub-dimension in terms of STEM-PCB and its sub-dimensions. On the technology sub-dimension, it was determined that male pre-service teachers had higher mean scores than female pre-service teachers, and there was a difference. This result can be interpreted as the fact that male pre-service teachers are more interested in and use technology daily than female pre-service teachers. During the interviews, male pre-service teachers stated that technology facilitates human life, saves time, and is a part of life, supporting the study's quantitative result.

It was determined that there was no difference in grade levels in the pedagogy, technology, engineering, and 21st-century skills sub-dimensions of STEM-PCB and sub-dimensions. However, in science and mathematics sub-dimensions, it was determined that pre-service primary school teachers studying in the 4th grade had higher averages. This result can be explained by the fact that 4th-grade pre-service teachers transform their theoretical knowledge into practice in science and mathematics applications in the teaching practice course and actively participate in the process. In the qualitative results, most pre-service primary school teachers stated that they wanted to benefit from STEM education in the Science course in their teaching life but were insufficient. Regarding the integration of STEM education into the science course, the pre-service teachers stated that they would ensure that the students would be active and that they would use experiments, which can be explained as not having sufficient knowledge in terms of integration.

It was concluded that the type of high school graduate did not affect STEM PCK and its sub-dimensions. This situation can be explained by the lack of STEM education practices in secondary education programs and high schools' similar conditions and opportunities.

It was concluded that there was no difference in pedagogy, technology, engineering, mathematics, and 21st-century skills sub-dimensions in terms of STEM-PCK and its sub-dimensions according to pre-service primary school teachers' knowledge of STEM education. In the science sub-dimension, it was determined that STEM education knowledge had an effect. This result can be explained by the fact that STEM education is included in the Elementary Science Curriculum and is suitable to be applied in science subjects. It was seen that pre-service teachers mostly answered undergraduate education as the source of STEM knowledge. In the qualitative results, it was seen that they mostly answered interdisciplinarily. However, they did not specify four disciplines as science, technology, engineering, and mathematics together, and one pre-service teacher associated it only with the science course. From this point of view, it is possible to say that they have partial knowledge.

In terms of STEM-PCK sub-dimensions of pre-service primary school teachers' science efficacy, the result that there is no effect on pedagogy, science, technology, engineering, mathematics, and 21st-century skills sub-dimension can be said to be effective due to the fact that pre-service teachers did not receive training on STEM education during their undergraduate education and the subject was not included in the curriculum.

Regarding STEM-PCK and sub-dimensions of STEM efficacy of pre-service primary school teachers, no difference was found in the pedagogy, science, technology, engineering, and 21st-century skills sub-dimensions. In terms of the mathematics sub-dimension, it was determined that STEM competence had an effect. When the pre-service teachers' answers to the interview questions are analyzed, it is seen that they state that they consider themselves competent in teaching mathematics. This result can be explained by the fact that the class in which mathematics teaching will be done is at the primary school level and that they have improved themselves in this subject in the teaching practice course. However, in the qualitative results, pre-service teachers stated that they did not have the subject knowledge, did not receive STEM education, and were inadequate in using technology and computers. This can be said that pre-service teachers mainly associate STEM education with technology and content knowledge competence.

4.2 Qualitative Conclusions

When the opinions of pre-service primary school teachers about their knowledge of STEM education were examined, it was seen that they mostly stated that they did not know science, technology, engineering integration, mathematics, science integration, utilization of technology, and lack of knowledge. Furthermore, it was determined that pre-service teachers generally perceived STEM education as an interdisciplinary education but could not explain it as the integration of four disciplines (science, mathematics, technology, and engineering). In addition, the fact that they mostly agree on the use of technology can be said that they think of STEM education as more technology-oriented and have perceptions that it is used in teaching. Finally, it was observed that pre-service teachers' knowledge about STEM education was insufficient, and there were deficiencies in the definitions of STEM education. This can be explained by the fact that they did not receive any training in STEM education during their undergraduate education.

When the pre-service teachers' opinions about the aspects that distinguish the STEM education approach from other approaches were examined, it was seen that most of the pre-service teachers gave answers about utilizing technology, creating better projects, including more than one discipline, and lack of knowledge. From this point of view, it can be said that with the view of creating a project, they think that a product emerges as a result of STEM education and that it involves a process; regarding the utilization of technology, it can be said that they are aware that it involves more technology and is interdisciplinary compared to other approaches.

It is seen that most of the pre-service teachers did not express an opinion on STEM pedagogical content knowledge. Other opinions are teacher's knowledge, training on how to treat children and how to apply STEM to children, transferring the knowledge learned in the lessons with STEM, and adapting engineering skills to education. When the results are examined, it is possible to say that they are primarily associated with the way they treat children, and from this point of view, it is possible to say that their knowledge about pedagogical content knowledge is insufficient.

The pedagogical knowledge that classroom teachers who want to use STEM applications in their lessons should have mainly was given as "they should know technology well" and "they do not have any knowledge". Therefore, it can be said that pre-service teachers see technology as a part of STEM education.

The pre-service teachers mostly gave technology-supported answers to the methods and techniques that can be used in STEM education, and in general, they emphasized the need to be sufficient in terms of technology in STEM education. In this framework, the STEM-technology relationship is thought to be more critical.

When the pre-service teachers' views on their competencies to implement STEM education were examined, it was determined that except for one pre-service teacher, the other pre-service teachers considered themselves inadequate. It is possible to say that their lack of knowledge about STEM education caused them to see themselves as inadequate. Only one of the pre-service teachers stated that he considered himself sufficient, but he did not know how to support the subject at the point that the student did not understand.

The most common answers given as suggestions regarding the acquisition of STEM pedagogical content knowledge for pre-service teachers were that training should be provided and courses should be added. In line with these answers, it is possible to say that they do not receive training in STEM and do not see it as a course.

It is seen that the most common response to the methods and techniques that can be used in the implementation of STEM education in science courses is research investigation. It is possible to say that teaching research activities to students through problem-solving in research investigation and creating designs on solutions developed for problems in STEM education are preferred by pre-service teachers because they are similar. As a result, it is seen that methods and techniques in which the student is active and the teacher is a guide in the process are preferred. It is possible to say that pre-service teachers see STEM as an education in which students are at the center; however, without evaluating the relationship between STEM and methods and techniques, it is possible to say that they only comment on the methods and techniques they know.

When the opinions of the pre-service primary school teachers about making use of STEM education in science courses in their teaching life were examined, it was seen that they mostly answered "to have a better teaching" and "if I have information about STEM, I will make use of it". According to this result, it can be said that although they do not have knowledge about STEM education, they think that using it in lessons will give good results.

In the opinions of pre-service teachers about their knowledge of technology, it is seen that the answer that makes our lives easier is mostly given. Therefore, it can be said that pre-service teachers have positive views about technology. Regarding the necessity of using technology in science lessons, they mostly stated that it provides permanent learning. In terms of the relationship between technology and STEM education, pre-service teachers mostly stated that STEM is technology - it is related. These results suggest that they believe that STEM and technology are related. However, they may not know the methods and techniques that can be utilized while using technology in STEM education.

Regarding technology, most of the pre-service teachers stated that it was sufficient. According to this result, it is possible to say that pre-service teachers should be intertwined with technology as a necessity of the age we live in. In terms of benefiting from STEM education while using technology, it was seen that most of them thought, "I will benefit if I get a good education - if I know". On the other hand, the pre-service teachers who did not want to benefit from it stated that they did not know the subject and were unaware of all technological developments. While integrating technology into STEM education, it was seen that they mostly answered that presentations, slides, and videos could be used.

When the engineering knowledge of the pre-service teachers was examined, they mainly stated their views of electrical-electronics, construction, making deep investigations in their fields, making something, developing, creating, ensuring the formation of structures (house, construction, etc.), related to each other, concretization. Therefore, it was observed that pre-service teachers generally focused on engineering fields in building- construction.

With this result, it is possible to say that pre-service teachers do not have sufficient knowledge about engineering and engineering education, as they mostly lack knowledge about the methods and techniques that can be used in STEM education and engineering teaching. The pre-service teachers' lack of knowledge about STEM education and engineering caused them to feel inadequate in terms of integration. It is seen that their knowledge of engineering is insufficient and therefore they approach engineering with prejudice.

When pre-service teachers' opinions about the relationship between STEM education and mathematics are examined, it can be said that those who do not know are in the majority. According to this result, pre-service teachers are inadequate in associating mathematics and STEM education. The opinion that STEM education is mostly unfamiliar with the methods and techniques used in mathematics teaching was stated. On the other hand, it was determined that they mainly considered themselves sufficient in mathematics teaching due to the small class level. It can be said that their knowledge of integrating mathematics into STEM education is inadequate because they mainly stated that they do not know how to integrate mathematics into STEM education.

It was observed that pre-service teachers gave technology as an example of 21st-century skills. Regarding this answer, it can be said that the rapid development of technology in the 21st century and the fact that it has become a part of life are influential in shaping pre-service teachers' views. Regarding the methods and techniques used in teaching 21st-century skills in STEM education, pre-service teachers mostly answered, "I don't know". The insufficient knowledge of pre-service teachers about 21st-century skills can explain this situation. When associating 21st-century skills and STEM education, the majority of the answers were technology, and the emergence of STEM education as a necessity of the change in the 21st century, science and technology, explains this result.

When all the results are analyzed, it is possible to say that pre-service primary school teachers' pedagogical content knowledge about STEM education is partially sufficient. For this reason, it was determined that pre-service teachers mostly considered themselves inadequate in implementing STEM education.

5. RECOMMENDATION

General recommendations and recommendations for further research are listed based on the research results.

5.1 General Recommendations

1. Although pre-service teachers have insufficient knowledge of STEM education, they were observed to have a favorable view of STEM education. Therefore, related courses can be offered during the undergraduate period and added to the curriculum.

2. For pre-service primary school teachers to gain pedagogical knowledge of STEM education, conferences, and seminars can be organized to raise awareness of STEM education.

3. The pre-service teachers were observed insufficient in integrating STEM education into different disciplines. In this direction, pre-service teachers can offer practical training to provide them with integration knowledge.

4. As a result of this study, no significant relationship was found between the high schools the pre-service teachers graduated from and the STEM-PCKs of pre-service teachers. Accordingly, courses on STEM education can be added to the high school curriculum.

5.2 Recommendations For Further Research

1. This study was conducted with pre-service primary school teachers to examine the pedagogical content knowledge of pre-service primary school teachers towards STEM. In future studies, in-depth analysis can be made by working with pre-service teachers studying in different departments.

2. The sample size of this study was small due to the pandemic, and it can be conducted with larger samples.

3. Due to the course of the pandemic, this research is limited to questionnaires and interviews, and experimental studies can be conducted in other studies.

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