JOURNAL OF BALTIC SCIENCE EDUCATION
ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

STEM APPLICATIONS IN MATHEMATICS EDUCATION: THE EFFECT OF STEM APPLICATIONS ON DIFFERENT DEPENDENT VARIABLES

Bekir Yıldırım,
Sabri Sidekli

Abstract. *The purpose of the research is to analyze the effect of STEM applications on mathematics pre-service teachers' mathematical literacy self-efficacy, technological pedagogical knowledge and mathematical thinking skills and their views on STEM education. This research has been carried out by 29 mathematics pre-service teachers who are schoolers at the educational faculties of Mus Alparslan University. The research was completed in 10 weeks (3 hours per week) in spring semester of 2016-2017 academic year. Mixed research approach was used in the study. "Mathematical Literacy Self-Sufficiency Scale", "Mathematical Thinking Scale", "Technological Pedagogical Area Information Scale" and "STEM Interview Form for Mathematics Pre-service Teachers" were used as data collection instruments. The collected data were analyzed, and it was certain that the STEM applications positively affected the pre-service teachers' mathematics literacy self-efficacy and technological pedagogical content knowledge. However, STEM applications were not seemed to have a positive effect on mathematical thinking. Moreover, when the opinions of the pre-service teachers were examined, it was identified that the STEM applications changed positively the opinions of the pre-service teachers about the mathematical literacy, and that they lacked many subjects such as field knowledge and pedagogy knowledge about STEM education. Suggestions were made in the direction of the findings obtained.*
Key words: *science, technology, engineering, mathematics education, mathematics pre-service teacher.*

Bekir Yıldırım
Mus Alparslan University, Turkey
Sabri Sidekli
Mugla Sıtkı Kocman University, Turkey

Introduction

Rapid change in science and technology is changing the skills that countries expect from individuals of today (Yıldırım & Selvi, 2017). As a result of these changes, countries' expectations for their skills in education also change. In this change, those who understand mathematics and do mathematics have more options to shape the future. Along with the changes, the mathematics and mathematics education need to be redefined and reviewed in line with the determined needs (Ministry of National Education [MoEN], 2004). Those who understand STEM disciplines in our changing world and who are equipped with the skills and knowledge of the 21st century in relation to these disciplines play an important role in shaping the future of countries in economics, technology and world leadership (Yıldırım, 2016). When all this is taken into consideration, it is necessary to realize that mathematics must be literate for all individuals in order to understand mathematics and use it in everyday life, and that mathematics is important for economic development. Mathematical literacy focuses on measuring the capacity of students to formulate, use and interpret mathematics in different contexts (MoEN, 2016).

Thus, countries are constantly amending in mathematics programs (MoEN, 2004). However, another important reason for changing the mathematics program is the PISA / TIMSS exams which enable the mathematics proficiency to be determined. Mathematical competence helps individuals to recognize the role mathematics plays in the world and to help them make judgments and decisions that are solid grounds for individuals to be constructive, responsive, and reflective citizens (MoEN, 2017). From this point of view, it is important for the students to be mathematically literate individuals in order to be successful in the PISA / TIMSS exams. With this point, the first task falls to the teachers. It is important for the students that the teachers are primarily literate in mathematics. Therefore, firstly, teachers should be educated as mathematics literate. STEM education also has an important effect on the education of individuals for being literate in mathematics.

From this point of view, mathematics education has an important role in training well-equipped individuals with the skills and knowledge required by the 21st century. Mathematical literacy is very important to come to this important position. There is also a need for individuals with adequate skills in technology as well as the need for mathematically literate individuals in the 21st century business world. Today, the need for technology literate individuals who understand technology, use it correctly and closely follow technological developments has also increased. According to MoEN (2006), technology is not just electronic devices such as computers and their various applications. Technology is both a type of knowledge that uses concepts and skills derived from other disciplines (science, mathematics, culture, etc.), as well as the provision of this knowledge to human service in order to meet a specified need by using materials, energy and tools, or to solve a specific problem. Technology is expressed as a process in which tools, structures or systems are developed and changed to meet people's needs and demands. Cavanagh and Trotter (2008) present the opportunity to use science and mathematics knowledge to solve the problems with technology faced by the people in their everyday life. In this context, it is important to integrate technology into educational environments. Therefore, it is necessary to integrate technology into teacher training programs and to have technology skills so that teachers can use technology and teach their students accordingly (Hofer & Grandgennett, 2012). In this context, it is up to the pre-service teachers to be conscious about the Technological Pedagogical Domain Information (TPACK) for future reference). Bilici and Baran (2015) emphasized that science teachers must be equipped with the knowledge and skills necessary to integrate technology effectively into the teaching process, that is, they must have TPACK. It is important for mathematics teachers to have TPACK as well as the science teachers have and use them effectively in the teaching process. TPACK can be expressed as an effective and efficient use of technology in students' learning during the teaching of a subject (Mishra & Koehler, 2006). In this context, technology can be used effectively in educational activities and allows a deeper understanding of science, mathematics and engineering. It also includes a product releasing process that incorporates the engineering, scientific and mathematical theoretical sub-structure of the engineering design process. Moreover, technology allows students to use the information they learn in everyday life, as well as the information available in STEM fields (Lantz, 2009). In other words, the technology dimension, which is one of the components of STEM education, is important in the STEM education in effectively using it in educational environments.

When the literature is examined, it appears that there are many studies in which the effects of various research groups and STEM education on students' attitudes, motivation, academic achievement, scientific process skills and problem-solving abilities are examined. (Cotabish, Robinson, Dailey & Hughes, 2013; Yamak, Bulut & Dündar, 2014). Similary, there are also studies in which the opinions of teachers and pre-service teachers on STEM education were presented (Gülgün, Yılmaz & Çağlar, 2017; Lee, Park & Kim, 2013; Lee et. al., 2012; Thomas, 2014; Wang, 2012). However, when the literature is examined, no research has examined the effects of STEM education applications on mathematics literacy self-efficacy, mathematical thinking and TPAB. This is important because this is the first research to examine the effects of STEM applications on these variables. Moreover, it is seen that the work done on elementary school mathematics teachers was not sufficient, this research is proven to be an important contribution to the literature.

In this research, it has been aimed to determine the effects of STEM applications on mathematics pre-service teachers' mathematical literacy self-efficacy, technological pedagogical content knowledge and mathematical thinking skills and the opinions of mathematics pre-service teachers on STEM education. For this purpose, answers to the following research questions have been sought.

1. What is the effect of STEM applications on math literacy self-efficacy?
2. What is the effect of STEM applications on technological pedagogical content knowledge?
3. What is the effect of STEM applications on mathematical thinking skills?
4. What are the views of mathematics pre-service teachers for STEM education?

Methodology of Research

Model

In this research, mixed research approach has been used. This research is one of the mixed research approach and it is a quantitative weighted study. The main reason for using the mixed method in the research is that it involves both quantitative and qualitative studies of the mixed research approach. Creswell (2006), Jhonson &

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Onwuegbuzie (2004) stated that the purpose of mixed research approach is to present the study investigate the study in all its dimensions examining thoroughly.

This research was performed with STEM applications integrated with Science, Technology and Society courses. In order to determine the effects of these applications, a single group pre-test post-test model was applied. While STEM practices are independent variables, mathematics literacy self-efficacy, mathematical thinking skills, and technological pedagogical knowledge of pre-service teachers are dependent variables. The symbolic view of the research model is shown in Table 1 below.

Table 1. Symbolic view of the experimental model.

Group	Pre-test	Application	Post-test
D	MLSS MTS TPACK	SA	MLSS MTS TPACK

D: Study Group; SA: STEM applications integrated with Science, Technology and Society courses
MLSS: Mathematics literacy self-efficacy scale; MTS: Mathematical Thinking Scale
TPACK: Technological pedagogical content knowledge scale

Sample

The quantitative sample of the research is composed of 29 students who are studying at a Muş Alparslan University in elementary mathematics teaching in the spring of 2016-2017 academic year. The qualitative study group of the study consisted of 12 students studying in the 4th grade mathematics education department which took Science, Technology and Society courses. A purposeful sampling method was used in selecting the qualitative study group. Two criteria were chosen in the selection of the students in the qualitative study group. The criteria for these criteria are those who participate in all of the applications and do not miss the school. The second criterion is the students who want to improve themselves in STEM education and voluntarily participate in the interview.

For the simple, students who were studying in the field of mathematics education were selected. This is because, when the field text is examined, a study on mathematics education in this department of STEM applications has not been found. It is also seen that STEM education applications are carried out especially in science course. With this study group both the studies were carried out with mathematics teaching students and STEM applications were integrated in mathematics courses. For these reasons, studies were carried out with the pre-service teachers who are studying in the elementary school mathematics teaching department.

Study Environment and Process

STEM applications within the scope of Science, Technology and Society lessons were carried out in the STEM Laboratory for 10 weeks during spring semester of the 2016-2017 academic year. The STEM laboratory is made up of hexagonal tables designed for pre-service teachers' group work. In these laboratories, prospective teachers have materials for STEM applications. Among these materials are materials used in everyday life and STEM building sets.

Applications in the STEM laboratory have been developed in accordance with the STEM integration stages developed by Yıldırım (2016). In this context, STEM applications are started with Mathematics domain. Theoretical background is given firstly in the field of mathematics. Subsequently, a connection with science was established and the theoretical sub-structure of Science was given. In the direction of mathematics and science theoretical sub-structure, engineering applications were done, and a product was created. The applications performed in primary school mathematics teaching are given in Table 2.

Table 2. Steps of STEM application regarding the research.

Mathematics: Learning Field	Science: Subject Field	Engineering design processes	Technology		21st century skills
Teaching Whole Numbers	Simple Machines	Elevator Designs	Elevator	Instructional tech-nologies added in the application process (Computer etc.)	Cooperation Communication Creativity Critical thinking
	Temperature-Heat	Heat-insulated house	House		
Ratio and proportion	Simple Machines	Catapult Design	Catapult		
Conversion Geometry	Wind Energy	Windmill Design	Windmill		
Probability and Statistics	Kinetic energy to Potential energy	Roller Coaster Park Design (3 tracks)	Roller Coaster Tracks		
Field Measurement	Balance	Bridge Design	Bridge		
Geometrical shapes	Optics	Hexagonal Telescope design	Telescope		
Problems	Chemical Reactions	Rocket design	Rocket		

When the table is examined, firstly, the 5E learning model and the lesson plan suitable for project - based learning have been prepared in STEM education about the STEM applications. The STEM applications related to the lesson plans were prepared in accordance with the steps given in Table 2.

Data Collection Instruments

Quantitative Dimension

"Technological Pedagogical Area Information Scale" developed by Hacıömeroğlu, Şahin and Arcagök (2014) was used. This scale was developed in accordance with the 5-point Likert type. The researchers found the KMO value of the scale to be .88. The Barlett test of the scale was found to be significant. The reliability value of the scale was calculated as 0.94, while for the sub-scale included in the scale, the reliability value was calculated as .89, .87, .87, .86, .82, .87, .84, .77, .81. The scale consists of 9 sub-dimensions and 46 items in total. The reliability value of the scale within the scope of the research was calculated as .80.

The "Mathematical Thinking Scale" developed by Ersoy and Başer (2013) was used. This scale was developed in accordance with the 5-point Likert type. The researchers calculated the KMO value of the scale as .759 and the Barlett sphericity test was found to be significant. The reliability of the scale was calculated to be .78. The scale consists of 4 sub-dimensions and 25 items in total. In the scope of the research, the reliability value of the scale was calculated as .84.

The "Mathematics literacy self-efficacy scale" developed by Özgen and Bindak (2008) was used. This scale was developed in accordance with the 5-point Likert type. The researchers found the KMO value of the scale to be .92. The Barlett test of the scale was found to be significant. The reliability of the scale was calculated to be .92. The scale consists of one dimension and 25 items. The reliability value of the scale within the scope of the research was calculated as .90.

The reliability of the scales used to collect quantitative data were examined separately and the value of all was found to be higher than .70. This indicates that these scales can be used in research.

Qualitative Dimension

A fully structured interview form consisting of 10 questions was formed in order to determine the views of the 12 pre-service teachers (Mathematics Pre-service Teachers STEM Interview Form) who are researching in Mathematics Education. The fully structured interview form created was implemented after the application. In the course of the creation of the interview form, two experts were consulted, one being a lecturer in mathematics education and the other being a lecturer in the field of science education. Regulations were made on the fully structured interview form in line with the views received. After the regulations, a pilot research was carried out by applying this interview form to a student studying in mathematics education major. The form was finalized as a result of the pilot study. As a result of the fully structured interview form applied to the pre-service teachers, questions were also asked in the places where they thought that they were missing through a fully structured interview form in order to clarify the opinions of the pre-service teachers. In the scope of the research, interviews have been held

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

in order to be able to reveal the views of the pre-service teachers about the implementations. Negotiations have recorded with the help of a voice recorder after obtaining permission from pre-service teachers. The obtained voice recordings have been put on paper and transcripts have been created. Data have been analyzed with the help of created transcripts. When interviewing with pre-service teachers, it has been asked what kind of features on a teacher are needed for STEM education, thoughts about the disciplines in abbreviation of STEM, mathematics literacy. Moreover, pre-service teachers have been asked whether they are qualified for STEM implementations and their answers have been received.

Results of Research

Quantitative Results

This part of the research has included the findings from quantitative data. Findings are explained alternately in line with mathematical literacy self-efficacy, technological pedagogical knowledge and mathematical thinking skills. In this context, the results of Shapiro Wilk have been first given in order to understand whether the quantitative data were distributed homogeneously for the first time.

The data obtained in the Shapiro Wilks analysis to find the results of the first research question are given in Table 3.

Table 3. Shapiro Wilks test results on the scale of mathematical literacy self-efficacy, mathematical thinking and technological pedagogical content knowledge.

Scale	Test	Statistics	df	p
Mathematical Literacy Self-Efficacy Scale	Pre-test	.948	28	.197
	Post-test	.984	28	.937
Mathematical Thinking Scale	Pre-test	.979	28	.817
	Post-test	.964	28	.405
Technological Pedagogical Content Knowledge Scale	Pre-test	.973	28	.640
	Post-test	.954	28	.613

When Table 3 is examined, it is seen that Mathematical Literacy Self-Efficacy, Mathematical Thinking and Technological Pedagogical Content Knowledge scales have a normal distribution according to the results of Shapiro Wilks test. Therefore, parametric tests were used to analyze the scales. Descriptive statistical information about the scales is given in Table 3.

The information on descriptive statistics obtained from mathematical literacy self-efficacy, mathematical thinking skills, and technological pedagogical content knowledge scales used in the first research questionnaire are given in Table 4.

Table 4. Descriptive statistics on mathematical literacy self-efficacy, mathematical thinking, and technological pedagogical content knowledge scales.

Scale	Test	N	$\overline{X}$	SD	Minimum	Maximum
Mathematical Literacy Self-Efficacy Scale.	Pre-test	29	91.33	9.36	74	112
	Post-test	29	96.74	11.76	72	113
Mathematical Thinking Scale	Pre-test	29	93.58	7.78	78	108
	Post-test	29	94.55	9.22	75	115
Technological Pedagogical Content Knowledge Scale	Pre-test	29	162.48	21.86	115	199
	Post-test	29	175.55	16.56	159	209

When Table 4 is examined, the points for the scales are found as followed; mathematical literacy self-efficacy scale pre-test ($\overline{x}$= 91.33) and post-test ($\overline{x}$ = 96.74); The Mathematical Thinking Scale pre-test ($\overline{x}$ = 93.58) and the post-test ($\overline{x}$= 94.55) and the Technological Pedagogical Content Knowledge scale pre-test ($\overline{x}$ = 162.48) and post-test ($\overline{x}$=175.55).

The results obtained from the t-test analysis for the dependent groups, which were made in order to determine the effects of the STEM applications on the effects of the mathematics literacy self-efficacy of the pre-service teachers, are given in table 5.

Table 5. T-test results test results on the scale of Mathematical Literacy Self-Efficacy.

		Pre - test		Post test			
	N	$\overline{X}$	SD	$\overline{X}$	SD	t	p
Mathematical Literacy Self-Efficacy Scale.	29	91.33	9.36	96.74	11.76	2.670	.013*

When Table 5 is examined, there is a significant difference statistically between the mathematical literacy self-efficacy scale pre-test and post-test points arithmetic calculations of the pre-service teachers who research in mathematics teaching (28) = 2.670, p <.05]. The results obtained from the t-test analysis for the dependent groups in order to reveal the effects of the STEM applications on the mathematical thinking ability of the pre-service teachers are given in the Table 6.

Table 6. T-test results of the mathematical thinking scale.

		Pre-test		Post-test			
	N	$\overline{X}$	SD	$\overline{X}$	SD	t	p
Mathematical Thinking Scale	29	93.58	7.78	94.55	9.22	.406	.688

When Table 6 is examined, there is no statistically significant difference between pre-test post-test arithmetic average of Mathematical Thinking Scale results of pre-service teachers who research mathematics teaching [t (28) =.406, p> .05]. It is also examined whether there is a difference in terms of the sub-dimensions of the mathematical thinking scale. The t-test results for the sub-scales of the mathematical thinking scale are given in Table 7.

The data obtained as a result of the t-test analysis for the dependent groups in order to be able to reveal the effects of the STEM applications on the sub-dimensions of the mathematical thinking scale of the pre-service teachers are given in Table 7.

Table 7. Results of t-test for sub-dimensions of mathematical thinking scale.

			Pre-test		Post-test			
		N	$\overline{X}$	SD	$\overline{X}$	SD	t	p
Mathematical Thinking Scale	High-Level Thinking Tendency	29	23.65	3.08	25.31	2.53	2.188	.037*
	Reasoning	29	15.89	2.76	23.65	1.92	2.079	.047*
	Mathematical Thinking	29	33.75	4.18	33.03	3.42	.677	.504
	Problem Solving	29	26.37	3.09	26.58	3.08	.240	.812

.

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

When t-test results for mathematical thinking scale sub-dimensions are examined, it is seen that there is a significant difference between high-level thinking tendency pre-test and post-test arithmetic average [t(28)=2.188, p <.05], and reasoning pre-test and post-test arithmetic average [t(28)=2.079, p <.05]. However, there is no significant difference between Mathematical Thinking Skill pre-test and post-test arithmetic averages [t(28)=.677, p >.05] and Problem Solving pre-test and post-test arithmetic averages [t(28)=.240, p >.05] .

The data obtained from the t-test analysis for the dependent groups in order to reveal the effects of the STEM applications on the pedagogical content knowledge of the pre-service teachers are shown in Table 8.

Table 8. T-test results of the technological pedagogical content knowledge scale.

		Pre-test		Post-test			
Technological Pedagogical Content Knowledge Scale	N	$\overline{X}$	SD	$\overline{X}$	SD	t	p
	29	143.28	21.86	175.55	16.56	2.490	.019*

When Table 8 is examined, it is seen that there is a statistically significant difference between the pre-test and post-test arithmetic average [t(28)=2.490, p <.05] of the Technological Pedagogical Area Knowledge Scale of the pre-service teachers who are studying in the department of mathematics education. Whether or not there is a differentiation in terms of subdimensions of the Technological Pedagogical Content Knowledge Scale has also been examined. The t-test results for the sub-dimensions of the Technological Pedagogical Content Knowledge Scale are given in Table 9.

The data obtained from the t-test analysis for the dependent groups in order to be able to reveal the effects of the STEM applications on the sub-dimensions of the technological pedagogical content knowledge scale of the pre-service teachers are shown in Table 9.

Table 9. T-test results for the sub-dimensions of the technological pedagogical content knowledge scale.

		N	Pre-test		Post-test		t	p
			$\overline{X}$	SD	$\overline{X}$	SD		
Technological Pedagogical Content Knowledge Scale	Technology Knowledge	29	22.86	5.23	25.48	5.39	1.785	.085
	Content Knowledge: Mathematics	29	9.62	2.62	11.17	2.77	2.531	.017*
	Content Knowledge: Social sciences	29	7.37	2.32	9.13	2.35	2.628	.014*
	Content Knowledge: Science	29	7.38	2.33	8.79	2.40	3.532	.001*
	Content Knowledge: Reading/Writing	29	10.58	3.25	12.75	2.76	2.649	.013*
	Pedagogy Knowledge	29	24.24	5.69	28.00	5.02	2.685	.012*
	Pedagogical Content Knowledge	29	12.79	3.23	14.27	2.89	1.989	.057
	Technological Field Information	29	12.96	3.12	14.20	2.65	1.695	.101
	Technological Pedagogy Knowledge	29	13.44	3.42	15.17	2.31	2.375	.025*
	Technological Pedagogical Content Knowledge	29	27.03	6.16	30.34	4.05	2.753	.010*

When Table 9 is examined, it is seen that there is a statistically significant difference between the pre-test and post-tests' arithmetic means of subscales of the Field Knowledge of STEM applications' technological pedagogical content knowledge scale - Mathematics, Social Science, Science and Literacy. In addition, it is observed that STEM applications have a statistically significant difference between the pre-test and post-test of arithmetic means of Pedagogical Information, Technological Pedagogical Knowledge and Technological Pedagogical Content Knowledge subscales. However, there is no statistical difference between the pre-test and post-test results of the sub-dimensions of Technology Knowledge, Pedagogical Content Knowledge and Technological Field Knowledge.

Information on Qualitative Findings

Qualitative findings related to the qualitative data obtained in the second research question of the research were given in order to form an integrity in the research. In this context, firstly the opinions of pre-service teachers on mathematical literacy were included.

Answers to yhe Question "What is Mathematics Literacy?"

Pre-service teachers were asked "What is mathematical literacy?" Pre-service teachers have defined mathematical literacy as "following mathematical developments, reading the history and theories of mathematics, reading mathematics correctly and using it correctly in our lives, and understanding the philosophy of mathematics and practicing it in everyday life". However, some pre-service teachers have defined mathematical literacy in the following way.

O1: To express mathematical terms in a clear way, to master the field, to make connection with real life and follow mathematical developments.

O3: It is said that countries that understand what they read and solve them in the PISA / TIMSS examinations have a good mathematical literacy. From this point of view, teaching mathematics in a concrete way is to understand, to make connection with everyday life and to follow the developments is the mathematical literacy.

O9: Mathematics literacy is the constant improvement of the teacher to convey mathematics to the students in a concrete way.

O11: Mathematics literacy is to understand mathematics, develop a positive view of mathematics, and use mathematics in line with their needs.

After the opinions of the prospective teachers about the mathematical literacy were asked, the prospective teachers were asked whether they were mathematical literate or not. Pre-service teachers' answers are shown in Table 10.

Table 10. The answers given in the question "Do you think you are a mathematical literate individual?

Codes		f	%
I am a mathematical literate individual	Yes	8	66.66
	No	4	33.34

When Table 10 is examined, 66.66% (n = 8) of the pre-service teachers stated that they are mathematical literate individuals whereas 33.34% (n = 4) of the pre-service teachers stated that they are not mathematical literate. From this point of view, it is inferred that the majority of pre-service teachers are mathematical literate. Pre-service teachers were asked whether the STEM practice has made a change in their views on mathematical literacy. The answers given by the pre-service teachers are given in Table 11.

Table 11. Answers to the question "Have your views on Mathematical literacy changed after STEM applications?"

Codes		f	%
STEM applications have changed my views on Mathematical Literacy	True	6	50
	False	6	50

When Table 11 is examined, it is seen that STEM applications cause a change in the opinion of 50% of the pre-service teachers (n = 6), but in the remaining half, there is no change in their opinions. Pre-service teachers were asked what the letters in the STEM abbreviation mean. The answers of the pre-service teachers about words "Science", "Technology", "Engineering" and "Mathematics" are given in Tables 12, 13, 14 and 15.

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Table 12. Answers related to the question "Could you define what the letter "S for Science" means in the word STEM?"

Codes	Student Codes	f	%
It is the basis of STEM education	O1, O2, O3, O4, O6, O10, O11, O12	8	66.66
Effort for understanding and studying the nature	O1, O4, O5, O7, O9, O12	6	50
Science is in every area of life	O2, O8, O12	3	25
More broad and meaningful than science and contains of it.	O1	1	8.33

When Table 12 is examined, it is seen that pre-service teachers state that Science is the basis of STEM education, that it is an effort for understanding and studying the nature, that Science in in every area of life and Science is not just physical science but consists of it and is broader and more meaningful.

Table 13. Answers related to the question "Could you define what the letter "T for Technology" means in the word STEM?"

Codes	Student Codes	f	%
Technology is the process of creating new ideas, products and innovation.	O1, O3, O4, O5, O7, O8	6	50
Technology is formed by the combination of disciplines of science, mathematics and engineering.	O2, O3, O9, O11, O12	5	41.65
Technology is not just a computer or a phone, but also is a pencil.	O3, O9, O11	3	25
Technology stands for economy and prosperity.	O8, O10, O12	3	25
Technology is a tool used in high-quality lesson.	O1	1	8.33
Technology is a field that has emerged to meet people's needs.	O10	1	8.33

When Table 13 is examined it is seen that, half of the pre-service teachers state that technology is the process of creating new ideas, products and innovation, 41.65% of them state that technology is formed by the combination of disciplines of science, mathematics and engineering and that it is not just a computer or a phone, but also is a pencil. Furthermore, pre-service teachers state that technology stands for economy and prosperity, that it is a tool used in high quality lessons, and that Technology is a field that has emerged to meet people's needs.

Table 14. Answers related to the question "Could you define what the letter "M for Mathematics" means in the word STEM?"

Codes	Student codes	f	%
Mathematics is a must for STEM	O3, O4, O5, O7, O8, O9, O10, O12	8	66.66
Mathematics is mathematical modeling	O1, O4, O5, O8, O10	5	41.65
Mathematics is a discipline that links with other disciplines.	O6, O8, O9, O12	4	33.33
Mathematics is a discipline that is used everywhere in life	O7, O8, O9	3	24.99
Mathematics is a discipline that enables the development of many characteristics of the students	O10, O12	2	16.66
Mathematics is the field that enables one to be successful in the PISA / TIMSS exams.	O10, O11	2	16.66
Mathematics is a systematical field.	O2	1	8.33

When Table 14 is examined, it is seen that pre-service teachers state that mathematics is a must for STEM education, that it represents mathematical modeling, and that mathematics is a discipline that links with other disciplines. Pre-service teachers also state that mathematics is a discipline that is used everywhere in life, that it enhances students' skills in many aspects, that mathematics is the field that enables one to be successful in the PISA / TIMSS exams and that it is a systematical field.

Table 15. Answers related to the question "Could you define what the letter "E for Engineering" means in the word STEM?"

Codes	Student codes	f	%
Engineering is a combination of Science and Mathematics disciplines.	O1, O2, O3, O4, O5, O6, O9, O11, O12	9	74.97
Engineering is a process of designing and creating a product.	O1, O2, O3, O4, O5, O7, O9, O11, O12	9	74.97
Engineering is the solution to real-world problems.	O1, O4, O11, O12	4	33.33
Engineering is the application part of the STEM education.	O1, O6, O9	3	24.99
Engineering is an approach that responds to human needs and requirements.	O9	1	8.33

When Table 15 is examined, it is seen that the pre-service teachers state that engineering is a combination of disciplines of science and mathematics, that engineering is a process of designing and creating a product and a solution to real-world problems. In addition, pre-service teachers expressed that engineering is the application part of STEM education and that it is an approach that responds to human needs and requirements.

The question "What are the features teachers should have as a result of STEM applications?" was asked the pre-service teachers and the answers given by the pre-service teachers are shown in Table 16.

Table 16. The answers to the question "What are the features teachers should have as a result of STEM practice?"

Codes	Student codes	f	%
Should have STEM Content Knowledge	O1, O2, O3, O4, O6, O8, O9, O11, O12	9	75
Should have Pedagogical Knowledge	O1, O4, O5, O6, O7, O8, O9, O12	8	66.66
Should be able to establish interdisciplinary correlation	O1, O4, O6, O10	4	33.33
Should be enthusiastic	O1, O8, O10	3	24.99
Should have integration knowledge	O5, O12	2	16.66
Should associate with real life	O3, O5	2	16.66
Should be able to develop product	O4, O5	2	16.66
Must follow developments	O6, O7	2	16.66
Should be open to innovations	O10, O12	2	16.66
Should have general knowledge and ability.	O9	1	8.33
Should have 21st century life sciences knowledge	O5	1	8.33

When Table 16 is examined, it is emphasized that pre-service teachers should have STEM knowledge, pedagogical knowledge and establish interdisciplinary correlation at the top qualifications that pre-service teachers should have in order to know how to apply STEM education. These are followed by being an enthusiastic person, having integration knowledge, associating with real life, developing products, following developments, being open to innovations, having 21st century life sciences knowledge and having general knowledge and ability.

The difficulties faced during STEM applications in preparing the lesson plan were asked the pre-service teachers. The answers to the question about the difficulties experienced by pre-service teachers are shown in Table 17.

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Table 17. Answers to the question "What were the difficulties faced while preparing the lesson plan during the STEM applications?"

Codes	Student codes	f	%
Lack of STEM content knowledge	O2, O3, O4, O7, O8, O9, O10, O11, O12	9	75
Lack of establishing interdisciplinary correlations	O1, O2, O3, O4, O8, O12	6	49.98
Lack of associating with real life	O2, O3, O4, O8, O12	5	41.65
Lack of lesson developing knowledge	O5, O6, O8, O9, O12	5	41.65
Lack of pedagogical knowledge	O9, O12	2	16.66
Lack of application knowledge	O10	1	8.33
Lack of integration knowledge	O8	1	8.33
Lack of assessment and evaluation skill	O4	1	8.33

Examining Table 17, it is evident that the pre-service teachers have difficulty in expressing the difficulties they encountered while preparing the lesson plan, and that they are lacking in STEM content knowledge, interdisciplinary correlationship and association with real life. These are followed by the lack of knowledge on lesson planning preparation, pedagogy knowledge, integration knowledge, and assessment and evaluation skills.

They were asked whether they felt sufficient about STEM education. The answers given by the teacher for this question are given in Table 18.

Table 18. Answers to the question "Do you feel sufficient about STEM education?"

Codes		Student codes	f	%
	Sufficient	O1, O6, O7	3	24.99
About STEM education, I believe I am…	Partially Sufficient	O2, O8	2	16.66
	Insufficient	O3, O4, O5, O9, O10, O11, O12	7	58.35

When Table 18 is examined, it is found that 24.99% of the pre-service teachers are sufficient and 16.66% are partially sufficient with STEM education. However, 58.35% of pre-service teachers feel insufficient about STEM education.

Discussion

In this research, the effects of STEM applications on math literacy self-efficacy, technological pedagogical content knowledge and mathematical thinking skills have been examined. As a result of the study, it has been determined that the STEM applications changed the mathematics literacy self-efficacy of the prospective teachers positively. According to this result, it can be said that STEM applications have a positive effect on mathematical literacy. It can be said that researches related to mathematics education conducted during the implementation of STEM applications have positive effects on mathematical literacy. When examining the literature on STEM education, it has been emphasized that STEM education improves mathematics and science literacy in many studies (Medeiros, 2011; Weber, Fox, Levings & Bouwma-Gearhart, 2013). In Figliano (2007), STEM education has contributed to the development of science and mathematics literacy, and even to the development of STEM literacy. It is also understood that STEM education also improves the technological literacy (Wang, Moore, Roehring & Park, 2011). Moreover, this study is also important in terms of the fact that the STEM applications are the first applied studies on mathematical literacy.

In the scope of the research, the effects of STEM applications on mathematical thinking of pre-service teachers have been also examined. As a result of the study, it was concluded that STEM applications did not positively affect the Mathematical Thinking of students of mathematics teaching department. STEM applications seem to have a positive impact on the high-level thinking tendency and reasoning dimension. However, it shows that STEM applications have no positive effect on mathematical thinking and problem solving. Studies on STEM education have improved students' high-level thinking skills positively (Morrison, 2006; Yıldırım & Selvi, 2017). Yıldırım (2016) studied the effects of STEM applications on high-order thinking skills of students. As a result of the research, it was concluded that STEM applications positively affected students' high-level thinking skills. It is seen that the results obtained by the researcher are similar to those obtained in this study. Kim and Choi (2012) researched the effect of the science-based STEAM program on problem solving skills. As a result of the research, it is found that the science-based STEAM program had a positive effect on students' problem-solving skills. Krishnamurthi, Ballard and Noam (2014) studied the effects of post-school STEM programs. As a result of the researches, they found that STEM programs contributed positively to the development of problem solving skills. Wang (2012) stated that the purpose of the STEM integration courses was to improve problem-solving skills. However, when the literature is examined, it is seen that STEM applications also have positive effects on the attitude, interest, academic success, scientific process skills and motivation of the individuals (Chittum, Jones, Akalin & Schram, 2017; Olivarez, 2012; Park & Yoo, 2013; Yamak, Bulut & Dündar, 2014). These results show that STEM applications have a positive effect also on different variables.

In the scope of the research, the effect of STEM applications on pre-service teachers ' technological pedagogical content knowledge has been examined. As a result of the study, it is concluded that STEM applications had positive influence on Technological Pedagogical Content Knowledge of pre-service teachers. The effects of STEM applications on Technological Pedagogical Content Knowledge sub-dimensions are also examined. As a result of the findings, it was determined that the STEM applications had positive effects on the sub-dimensions of Mathematics, Social Science and Science-Literacy Knowledge and Pedagogical Knowledge sub-dimensions. These results show that STEM applications have a positive effect on the field of knowledge. In addition, this end result supports the results obtained during the interviews with pre-service teachers. Similar results were obtained in the studies in which the effects of STEM applications on teacher opinions were examined (Lee, Park & Kim, 2013; Lee et al., 2012; Thomas, 2014; Wang, 2012).

Pre-service teachers were asked about their views on mathematical literacy, and in the light of their views it is seen that, all of the pre-service teachers were able to define mathematical literacy. In addition, while the vast majority of pre-service teachers express that they are mathematics literate individuals, some pre-service teachers have stated that they are not mathematics literate. However, STEM education applications have shown that half of the pre-service teachers have positively changed their views on mathematical literacy. This result also supports the results of the first sub-problem. The results obtained from the opinions of the pre-service teachers seem to support the results obtained from the quantitative data. In this context, the results show that STEM applications have positive effect on pre-service teachers to have positive views on mathematics literacy. Weber, Fox, Levings and Bouwma-Gearhart (2013) also pointed out that a teacher must be a science and mathematics literate in order to solve a problem in everyday life. They also stated that it developed science and mathematics literacy.

Pre-service teachers expressed the need for teachers to have STEM knowledge, pedagogy knowledge, interdisciplinary correlations, integration knowledge, association with real life and to be enthusiastic in order for a teacher to apply STEM education. They also pointed out that teachers need to be productive, follow developments, be open to innovations, have 21st century life sciences knowledge, and have general knowledge and ability. When the literature is examined, it is emphasized that teachers should have a lot of knowledge about STEM education such as STEM knowledge, pedagogy knowledge, integration knowledge, 21st century life sciences (Abell, 2007; Ball, Thame & Phelps, 2008; Kula, Özgür & Elçi, 2013; Shulman, 1986; Yusof, Zakaria & Maat, 2012; Wang, Moore, Roehring & Park, 2011). It can be said that the teachers who do not have adequate equipment in the STEM content knowledge will have problems in their teaching. Besides this, besides having sufficient knowledge about STEM, a teacher should also have good pedagogy knowledge (Briscoe & Peters, 1997; Shulman, 1986). A teacher with good pedagogical knowledge will play an important role in teaching the subject effectively. Kennedy, Ahn and Choi (2008) emphasized that teachers should have knowledge of STEM-related content and pedagogy. Ostler (2012) states that teachers should have pedagogical knowledge to know and learn the knowledge of STEM disciplines so that they can apply STEM education in their lessons. Weber, Fox, Levings and Bouwma-Gearhart (2013) in their work with teachers emphasized the importance of integrating with STEM disciplines in order to practice STEM-related applications. These considerations show parallelism with the results obtained in this study.

It has been determined that candidate teachers do not have enough information about STEM content knowledge, interdisciplinary relationship, connection with daily life, pedagogy information, integration knowledge, practice and measurement and evaluation while preparing appropriate course plan for STEM education. However, it was also found that the majority of the pre-service teachers were insufficient in STEM education, and that a small

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

part of them felt themselves sufficient and partially sufficient with STEM education. In their work with teachers, Weber, Fox, Levings and Bouwma-Gearhart (2013) have mentioned about the difficulties faced by teachers. The first of these difficulties is that teachers cannot establish interdisciplinary correlations and cannot master the entire STEM disciplines. In this study, teachers expressed that the second difficulty is the lack of resources even if they are sufficient about STEM education. In their work with teachers, Wang, Moore, Roehring and Park (2011) stated that teachers are lacking digital technological resources and a good STEM program for their use. Similarly, Wang (2012) emphasizes that a good program for STEM education is a must but sadly it is lacking. It can be said that the results obtained from these studies are similar to the difficulties that pre-service teachers have expressed themselves.

Conclusions

Within the scope of the research, it has been determined that STEM applications have positively changed the mathematical literacy self-efficacy and mathematical thinking skills of the pre-service teachers who study in mathematics teaching. It has also been understood that STEM applications have a positive effect on the high-level thinking and reasoning skills of pre-service teachers. However, it is understood that the STEM applications have no positive effect on the mathematical thinking and problem-solving skills of the pre-service teachers.

Another result obtained within the scope of the research is that the STEM applications have a positive effect on the Technological Pedagogical Content Knowledge of the pre-service teachers. Moreover, it is understood that STEM applications have positive effects on mathematics, social sciences, science and literacy field knowledge and pedagogical knowledge. Moreover, it is understood that STEM applications have a positive effect on technological pedagogical knowledge. However, it has also been understood that STEM applications do not have a positive impact on Technology Knowledge, Pedagogical Content Knowledge and Technological Field Knowledge.

In the scope of the research it has been understood that STEM applications positively changed the opinions of pre-service teachers on mathematical literacy. In addition, in the direction of the opinions of pre-service teachers, in order for a teacher to apply STEM education it has been emphasized that STEM field knowledge, pedagogy knowledge, ability to associate interdisciplinary relationship, willingness, integration knowledge and connection with daily life must be found. This is also the result that pre-service teacher feels insufficient about STEM applications.

Limitations of the Study and Recommendations

This research was carried out with 29 pre-service teachers studying in elementary mathematics teacher education department for 3 hours a week for 6 weeks in 2016-2017 academic year spring semester. In this context, future researchers can work with pre-service teachers studying in different departments. In this study, dependent variables are "Mathematical Thinking Skills", "Mathematical Literacy Self-efficacy" and "Technological Pedagogical Content Knowledge"; while the independent variable is STEM applications. Therefore, future researchers may examine the effects of STEM education on different dependent variables. Moreover, in this study, the opinions of pre-service teachers on STEM education were examined. Future researchers may examine different groups' opinions on STEM education.

References

Abell, S. K. (2007). Research on science teacher knowledge. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 1105-1150). London: Lawrence Erlbaum Associates Publishers.

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education*, *59* (5), 389–407.

Baran, E., & Canbazoğlu Bilici, S. (2015). Teknolojik pedagojik alan bilgisi (TPAB) üzerine alanyazın incelemesi: Türkiye örneği [A Review of the Research on Technological Pedagogical Content Knowledge: The Case of Turkey]. *Hacettepe Üniversitesi Eğitim Fakültesi ergisi [Hacettepe University Journal of Education], 30* (1), 15-32.

Özgen, K., & Bindak, R. (2008). Matematik okuryazarliği öz-yeterlik ölçeğinin geliştirilmesi [The development of self-efficiacy scale for mathematıcs literacy]. *Kastamonu Eğitim Dergisi, 16* (2), 517-528.

Briscoe, C., & Peters, J. (1997). Teacher collaboration across and within schools: Supporting individual change in elementary science teaching. *Science Teacher Education, 81* (1), 51-64.

Bukova-Güzel, E., Cantürk-Günhan, B., Kula, S., Özgür, Z., & Elçí, A. N. (2013). Scale development for pre-service mathematics teachers' perceptions related to their pedagogical content knowledge. *South African Journal of Education*, *33* (2), 1-21.

Cavanagh, S., & A. Trotter. (2008). Where's the "T" in STEM?. Retrieved 15/09/2017, from http://www.edweek.org/ew/articles/2008/03/27 /30stemtech.h27 .html/.

Chittum, J. R., Jones, B. D., Akalin, S., & Schram, A. B. (2017). The effects of an afterschool STEM program on students' motivation and engagement. *International Journal of STEM Education, 4* (11), 2-16.

Crewell, J. W. (2006). Understanding mixed methods research, (Chapter 1). Retrieved 15/12/2017, from http://www.sagepub.com/upm-data/10981_Chapter_1.pdf/.

Creswell, J. W. (2003). *Research design: Qualitative, quantitative, and mixed methods approaches.* Thousand Oaks, CA: Sage.

Cotabish, A., Dailey, D. Robinson, A., & Hunghes, G. (2013). The Effects of a STEM intervention on elementary students' science knowledge and skills. *School Science and Mathematics*, *113* (5), 215-226.

Ersoy, E. ve Başer, N. (2013). The develeopment of mathematical thinking scale. *Kastamonu Eğitim Dergisi, 21* (4), 1471-1486.

Figliano, F. (2007). *Strategies for integrating STEM content: A pilot case study.* (Unpublished masters dissertation). Virginia Polytechnic Institute and State University, Virginia.

Hacıömeroğlu, G. Şahin, Ç ve Arcagök, S. (2014). Turkish adaptation of preservice teachers' technological pedagogical content knowledge assessment ınstrument. *Eğitimde Kuram ve Uygulama,10* (2), 297-315.

Gülgün, C , Yılmaz, A., & Çağlar, A . (2017). Fen bilimleri dersinde uygulanan stem etkinliklerinde bulunması gereken nitelikler hakkında öğretmen görüşleri [Teacher opinions about the qualities required in stem activities applied in the science course]. *Journal of Current Researches on Social Sciences, 7* (1), 459-478.

Hofer, M., & Grandgenett, N. (2012). TPACK development in teacher education: A longitudinal study of preservice teachers in a secondary M.A.ED. program. *Journal of Research on Technology in Education, 45* (1), 83-106.

Jhonson, R. B., & Onwuegbuzie, A.J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational Research*, *33* (7), 112-133.

Kennedy, M. M., Ahn, S., & Choi, J. (2008) The value added by teacher education. In M. Cochran-Smith, S. Feiman-Nemser, and J. McIntyre (Editors). *Handbook of Research on Teacher Education: Enduring Issues in Changing Contexts* (3rd edition, pg 1249-1273) Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Kim, G. S., & Choi, S. Y. (2012). The effect of creative problem solving ability and scientific attitude through the science based STEAM program in the elementary gifted students. *Elementary Science Education, 31* (2), 216-226.

Krishnamurthi, A., Ballard, M., & Noam, G. G. (2014). Examining the Impact of Afterschool STEM Programs. *Afterschool Alliance*. Retrieved 12/10/2017, from http://alabamaacn.org/wp-content/uploads/2014/11/Examining-the-Impact-of-Afterschool-Programs-STEM-Implementation.pdf/

Lee, J. W, Park, H. J., & Kim, J. B. (2013). Primary teachers' perception analysis on development and application of STEAM education program. *Elementary Science Education, 31* (1), 47-59.

Lee, H., Son, D., Kwon, H., Park, Kyungsuk, Han, I., Jung, H., Lee, S., Ok, H. J., Nam, J. C., Oh, Y. J., Phang, S. H., & Seo, B. H. (2012). Secondary teachers' perceptions and needs analysis on ıntegrative STEM education. *Journal of Korea Association for Research in Science Education, 32* (1), 30-45.

Medeiros, D. J. (2011). *The Influence of female social models in corporate STEM initiatives on girls' math and science attitudes.* (Unpublished doctoral dissertation). University of Pennsylvania, Pennsylvania.

Ministry of National Education [MoEN]. (2004). *The curriculum of elementary mathematics education course*. Ankara: Board of Education and Discipline.

Ministry of National Education [MoEN]. (2016). *The Curriculum of mathematics education course.* Ankara: Board of Education and Discipline.

Ministry of National Education [MoEN]. (2017). *The Curriculum of mathematics education course.* Ankara: Board of Education and Discipline.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: a framework for teacher knowledge. *Teachers College Record, 108* (6), 1017–1054.

Morrison, J. S. (2006). Attributes of STEM education: The student, the academy, the classroom. TIES STEM Education Monograph Series. Retrieved 15/08/2017, from https://www.partnersforpubliced.org/uploadedFiles/TeachingandLearning/Career_and_Technical_Education/Attributes%20of%20STEM%20Education%20with%20Cover%202%20.pdf/.

Olivarez, N. (2012). *The Impact of a STEM program on academic achievement of eighth grade students in a south texas middle school.* (Unpublished doctoral dissertation).Texas A & M University, Texas.

Ostler, E. (2012). 21st Century STEM education: A tactical model for long-range success. *International Journal of Applied Science and Technology, 2* (1), 28-33.

Park, S. J., & Yoo, P. K. (2013). The Effects of the learning motive, interst and science process skills using the "light" unit in science-based STEAM. *Elementary Science Eucation, 32* (3), 225-238.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15* (2), 4–14.

Thomas, T. A. (2014). *Elementary teachers' receptivity to integrated science, technology, engineering, and mathematics (STEM) education in the elementary grades*. (Unpublished doctoral dissertation). Retrieved 15/07/2017, from https://proquest.com/.

Wang, H. H. (2012). *A new era of science education: science teachers' perceptions and classroom practices of science, technology, engineering, and mathematics (STEM) ıntegration.* (Unpublished doctoral dissertation). The University of Minnesota, Minnesota.

Wang, H. H., Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM integration: Teacher perceptions and practice. *Journal of Pre-College Engineering Education Research (J-PEER), 1* (2), 2.

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Weber, E., Fox, S., Levings, S. B., ve Bouwma-Gearhart, J. (2013). Teachers' conceptualizations of integrated STEM. *Academic Exchange Quarterly, 17* (3), 1-9.

Yamak, H., Bulut, N., & Dündar, S. (2014). The impact of STEM activities on 5th grade students' scientific process skills and their attitudes towards science [5. sınıf öğrencilerinin bilimsel süreç becerileri ile fene karşı tutumlarına FeTeMM etkinliklerinin etkisi]. *Gazi Eğitim Fakültesi Dergisi*, *34* (2), 249-265.

Yıldırım, B. (2016). *An examınatıon of the effects of scıence technology engıneerıng mathematıcs (stem) applıcatıon and mastery learnıng ıntegrated ınto the 7th grade scıence course [7. Sınıf fen bilimleri dersine entegre edilmiş fen, teknoloji, mühendislik, matematik (STEM) uygulamaları ve tam öğrenmenin etkilerinin incelenmesi*]. Unpublished doctoral thesis. Ankara. Gazi Üniversitesi.

Yıldırım, B., & Selvi, M . (2017). An experimental research on effects of STEM applications and mastery learning. *Eğitimde Kuram ve Uygulama, 13* (2), 183-210.

Yusof, Y. M., Zakaria, E., & Maat, S. M. (2012). Teachers' general pedagogical content knowledge (PAB) and content knowledge of algebra. *The Social Sciences, 7* (5), 668-672.

Received: *December 31, 2017* Accepted: *January 30, 2018*

Bekir Yıldırım	PhD, Assistant Professor, Education Faculty, Department of Mathematics and Science Education, Mus Alparslan University, Mus, Turkey. E-mail: bekir58bekir@gmail.com
Sabri Sidekli	PhD, Associate Professor, Education Faculty, Department of Primary Education, Mugla Sıtkı Kocman University, Mugla, Turkey. E-mail: ssidekli@gmail.com