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The Effect of Science, Technology, Engineering and Mathematics (STEM) Project Based Learning (PBL) on Students' Achievement in Four Mathematics Topics

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ABSTRACT

The integration of project-based learning in Science, Technology, Engineering, and Mathematics activities has received much attention because of its potential in engaging students with real–world problem solving. This study was designed to examine the effectiveness of Science, Technology, Engineering, and Mathematics project-based learning lessons on students' achievement in algebra, geometry, probability and problem solving. The achievements of two groups of students who participated in the study were compared longitudinally in 2008, 2009, and 2010. The results showed that lessons integrating Science, Technology, Engineering, and Mathematics project-based learning improved students' scores in mathematics in general (d= 1.311), algebra (d=1.500), geometry (d=1.837), and probability (d=.487), but not in problem solving (d=.343). In addition, students in Science, Technology, Engineering, and Mathematics project-based learning schools showed higher scores in geometry, probability, and problem solving than those in non Science, Technology, Engineering, and Mathematics project-based learning schools. Implications for reforming instructional approaches and suggestions for further study were discussed.

Keywords: Project-based Learning; Science, Technology, Engineering and Mathematics (STEM).

INTRODUCTION

Science, Technology, Engineering and Mathematics (STEM) are critical fields to ensure a country's development. For this reason, increasing the STEM workforce has been regarded as an urgent assignment. In order to encourage more students to pursue STEM majors in colleges and to obtain careers in STEM fields, it is important to support them in learning about and exploring STEM disciplines (Han, 2015). To attain this goal, diverse pedagogical strategies such as project-based learning (PBL) have been attempted and the curriculum for mathematics and science subjects has been revised (Capraro & Nite, 2014).

Despite efforts, students have demonstrated less interest in STEM disciplines and received lower scores on standardized national tests (National Center for Education Statistics, 2003; Hennessey, 2007; Mann, 2009). In addition, Marino (2010) argued many students with

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learning and other disabilities have been struggling in inclusive STEM classrooms and few of these students have pursued their studies in advanced STEM courses. This situation is alarming and negatively affects student enrollment jn post-secondary institutions, which results in low numbers transitioning into in STEM fields.

To resolve the problems associated with STEM fields in schools, project-based learning (PBL) has been developed as a targeted strategy and pedagogical practice by integrating knowledge of science, technology, engineering and mathematics as cohesive components for solving real-world problems (Breiner, Harkness, Johnson, & Koehler, 2012). Capraro and Slough (2013) stated PBL is broader than problem-based learning consisting of several activities/tasks utilizing contextualized and authentic experiential problems to scaffold student's learning in STEM concepts. STEM PBL is a student-centered methodology using "an ill-defined task within a well-defined outcome" to spark interest and to tap prior knowledge in building new concepts and understandings (Capraro & Slough, 2013, p. 2). The combination of appropriate pedagogy, technology and STEM content during a PBL activity can support student construction of knowledge (Marino, Black, Hayes & Beecher, 2010). Previous research findings have shown some positive inherent outcomes when implementing PBL STEM approaches in expanding students' knowledge of science and mathematics and deepening their understanding of interdisciplinary relationships among principles, concepts, and skills across engineering and technology domains (Barron et al., 1998; Han, Capraro, & Capraro, 2014; Lou, Liu, Shih, Chuang, & Tseng, 2011; Marino et al., 2010).

STEM education has become part of the school curriculum especially in the United States; thus, many PBL activities based on engineering and technology applications have been designed and implemented by teachers to engage students in learning (Breiner et al., 2012). For instance, the engineering components in STEM PBL lessons provide students with real-world contexts, promote interest, and improve student problem solving and communication skills. While students explore the projects in classrooms using STEM PBL, they are engaged in solving problems within the project individually and in groups. This allows students to arouse their curiosity and critical thinking skills while engaging in scientific inquiry through doing and learning. However, these potential benefits from utilizing STEM PBL cannot guarantee that students will learn the necessary skills included in the National Council of Teachers of Mathematics [NCTM, 2000] principles or state's standards (e.g. Texas Essential Knowledge and Skills [TEKS]). Studies are necessary to identify factors influencing the effects of implementing STEM PBL activities especially on students' academic achievement longitudinally.

Previous research studies have shown a number of researchers have explored student academic achievement and attitude towards STEM at the same time. However, there seems to be few empirical studies examining the effectiveness of STEM PBL in relation to students' academic achievement alone. Multiple studies suggested STEM PBL had strongly influenced student cognitive development during problem solving activities (e.g., Barron et al., 1998; Lou et al., 2011; Marino et al., 2010). In fact, Barron et al. (1998) contented meaningful learning happened when students actively and collaboratively solved real world problems wherein eventually affecting their academic performance. Similarly, Lou et al. (2011) found that the select students in their study not only gained profound knowledge in science and mathematics, but also can apply engineering and science knowledge during exploration activities. Along these same lines, Marino et al. (2010) argued that students with reading difficulties had demonstrated significant differential performance on STEM achievement after participating in a technology-enhanced astronomy curriculum, but their academic achievement was affected by several factors. This evidenced the consistent assimilarion of factors such as integrated technology-enhanced STEM curricular materials, which contributed to students with disabilities' performance in STEM.

Studies have also focused on the impact of STEM PBL on students' attitude and behavior toward STEM fields that indirectly affected their academic performance (Awang & Ramly, 2008; Blumenfeld, Fishman, Krajcik, Marx & Soloway, 2000; Wah & Chu, 2009). STEM PBLs contain diverse hand-on activities along with communication and collaboration with peers. The group-focused activities help students develop more positive attitudes and reduce anxiety toward science and mathematics (Blumenfeld et al., 2000). However, students' academic success through STEM PBL classes can only be evaluated in the presence of teachers' fidelity to the program (Stearns, Morgan, Capraro, & Capraro, 2012) environment, and students' ability. That is why further diverse research on students' academic improvement through STEM PBL is necessary.

The purpose of this study was to examine how STEM PBL lessons affect student achievement in terms of four mathematical topic areas (i.e. algebra, geometry, probability and problem solving) and to compare the student achievement of two groups (i.e. students who participated in the STEM PBL lessons versus students in schools where teachers have not utilized STEM PBL in lessons) longitudinally for three years (2008, 2009, and 2010). This longitudinal study is an in depth analysis revealing the individual level of change based on participant involvement in a three year STEM PBL program. It is also practically significant to draw a causal relationship between the STEM PBL program and student achievement in four areas of mathematics contents.

STEM PBL has been focused as a reformed instructional approach to improve students' interests and academic achievement in STEM fields. Previous studies regarding the impact of STEM PBL on students' affect and cognition have revealed that a lesson integrating STEM PBL encouraged students' positive attitude toward STEM fields and improved students' academic achievement in mathematics. However, it has not been investigated how STEM PBL positively influenced student academic achievement in mathematics, or what specific sub topic areas of mathematics were influenced by STEM PBL. Therefore, the present study is focused on the following research questions:

1. Are there differences in students' academic achievement in each sub topic area of mathematics (e.g., algebra, geometry, probability, and problem solving) between Year 1 and Year 2 and between Year 2 and Year 3?

2. Are there differences in students' academic achievement in each sub topic area of mathematics (e.g., algebra, geometry, probability, and problem solving) between STEM PBL and non-STEM PBL schools for three years (Year 1, 2, & 3)?

METHODOLOGY

a) Participants

The participants were diverse students enrolled in six small, urban, low socio-economic high schools. Three of the six schools provided teachers with an opportunity to participate in a sustained (30 days, 7 hours per day) professional development provided by one STEM center. As a result of the professional development, the teachers were required to implement a STEM PBL series of activities in their classes. Students were continually involved in STEM PBL activities implemented by their teachers in science and mathematics classes from 2008 to 2010. On the other hand, the other three schools were in the same region but had no opportunities for teacher training in the STEM PBL instructional approach. In this study, these six schools were called either STEM PBL schools or non-STEM PBL schools depending on whether teachers in the school were offered professional development in STEM PBL.

Specifically for the current study, we selected only students who had lower scores than the median to examine the effect of STEM PBL on student achievement because STEM PBL is an appropriate instructional approach for students who were low academic achievers (Han et al., 2014). Demographics of the participating students in this study are reported in Table 1.

Table 1. *Demographics of the Participating Students in the Initial Year*

	STEM PBL schools (N=661)	Non STEM PBL schools (N=526)
Gender/Sex		
Female	332 (50.2%)	268 (51%)
Male	329 (49.8%)	258 (49%)
Ethnicity		
Hispanic	336 (50.8%)	272 (51.7%)
African American	204 (30.9%)	227 (43.2%)
Others	121 (18.3%)	27 (5.1%)
Economically Disadvantaged		
Yes	625 (94.5%)	472 (89.7%)
No	36 (5.4%)	54 (10.3%)
At-Risk		
Yes	486 (73.5%)	405 (77%)
No	175 (26.5%)	121 (23%)

Note. Others include White, American Indian, and Asian. According to Texas Education Agency (2011), "at-risk" refers to students who had limited English proficiency, and/or were in the care of a state agency.

b) STEM PBL Pedagogical Approach

Teachers in STEM PBL schools were involved in a professional development provided by a research university in the U.S. from 2007 through 2010. While the professional development was being delivered, the teachers and university researchers collaborated in developing STEM PBL lesson plans. An example of the STEM PBL lesson plan is shown in the Appendix section. Once the lesson plans were designed, the teachers utilized the lessons integrating STEM PBL in their mathematics or science classrooms. In general, a STEM PBL lesson was usually implemented for 3 to 5 days and sometimes up to 2 weeks. On the first day, an interdisciplinary project including real-world problems was introduced to students. The teachers were advised that the project should include ill-defined tasks. Also, mathematics or science curriculum standards connected to the projects were provided. In the introduction phase, it was critical to have students understand learning objectives (i.e., well-defined outcomes) and ill-defined tasks. While exploring the project, students could collaborate with peers to perform the tasks. If students were having difficulties accomplishing the tasks, the teacher advised them and helped these students as a facilitator and supporter. When students sometimes had difficulties in solving a problem, teachers provided an explanation lecture teaching basic content knowledge. At the end of the project, students were generally required to present their experiences, outcomes, and artifacts from the project. The Appendix section displays the lesson plan that focusing on a project of designing and building an irrigation system. In specific, this irrigation system project is used as real-life problem to scaffold students' science knowledge construction when learning about the dynamics of water, water conservation, kinetic energy, and fluid dynamics.

c) Data Sources

The state accountability instrument, Texas Assessment of Knowledge and Skills (TAKS) provided empirical data (2008 to 2010). The reason this test was used is because its subscales measured the same topics taught by the teachers using STEM PBL and was a sufficient estimate of how STEM PBL activities influenced students' achievement in the mathematical areas: algebra, geometry, probability, and problem solving. Students took this mandated test once a year. The test included 52-60 items and 10 mathematics objectives. The numbers of items tested in Year 1, 2, and 3 measuring mathematics achievements for each objective are reported in Table 2.

Table 2. *Objectives and Number of Items for Each Objective*

Objective	Year 1	Year 2	Year 3
1. Functional Relationships	5	5	5
2. Properties and Attributes of Functions	5	5	5
3. Linear Functions	5	5	5
4. Linear Equations and Inequalities	5	5	5
5. Quadratic and Other Nonlinear Functions	4	5	5
6. Geometric Relationships and Spatial Reasoning	4	5	7
7. Two- and Three-Dimensional Representations	4	5	7
8. Measurement and Similarity	6	7	7
9. Percents/Proportions/Probability/Statistics	5	5	5
10. Mathematical Processes and Tools	9	9	9

The ten objectives were categorized into four topic areas such as Algebra, Geometry, Probability, and Problem Solving. That is, objective 1 through 5 were focused on diverse functions and their properties. Therefore we classified the five objectives as a topic area named “Algebra.” Objectives 6, 7, and 8 covered geometric relationships and spatial reasoning, dimensional representations, and measurement. Therefore, we classified these three objectives as “Geometry”. Lastly, a single objective 9 and 10 represented “Probability” and “Problem Solving” respectively. To calculate students’ scores for these topic areas, we summed the scores of the objectives provided by the Texas Education Agency [TEA] and used the composite scores as dependent variables.

d) Data Analysis

As the first phase, descriptive statistics (e.g., mean and standard deviation) of the dependent variable were calculated. In addition, the 95% confidence intervals were computed to estimate the population means to lie between the intervals’ upper and lower limits, which were captured 95% of the time using SPSS 18.0.

To answer the first research question, one-way analysis of variance (ANOVA) was used to compare the means of four mathematical topic areas across three years. In this analysis, the independent variables used were years of STEM PBL instruction. Two kinds of Post Hoc tests, Tukey and Scheffe, were used to examine statistically significant differences. Before using ANOVA, the required assumptions were checked. The dependent variable was continuous and the independent variable (i.e., years of STEM PBL) was ordinal. Therefore, an ANOVA analysis was applicable for the first research question.

In answering the second research question, *t*-tests were used. A *t*-test was executed to determine whether there were any statistically significant differences between STEM PBL and non-STEM PBL schools in terms of the means of students’ scores in the four mathematical topic areas. Similar to the ANOVA test, three assumptions were checked. First, the dependent variables were students’ scores in mathematics and four sub-areas of mathematics, and they were all continuous variables. Second, there was an independent variable (i.e., PBL—indicating whether teachers in a school were involved in STEM PBL professional development) employed in the current study. This independent variable consisted of two categorical, independent groups. Last, the dependent variable was approximately normally distributed for each group of the independent variable. Therefore, the data for this study did not fail the assumptions, and a *t*-test was applicable. To illustrate the trajectories of students' scores in the four topic areas across three years, graphs of broken lines were drawn.

FINDINGS

Table 3 presents the descriptive statistics including means, standard deviations, and confidence intervals (lower and upper limits) for three years followed by the results for the first and second research questions.

a) Comparing Across Years

Results from ANOVA analyses indicated that there were statistically significant differences for student achievement in each mathematics sub-area across years. The ANOVA analyses were conducted separately for students in STEM PBL and non-STEM PBL schools (see Table 4). The results from ANOVA analyses were similar between STEM PBL and non-STEM PBL schools except in the area of problem solving. For the topic areas of algebra and geometry, the differences of students' scores between Year 1 and 2 and between Year 2 and 3 were statistically significant. For the area of probability, the difference between Year 1 and 2 was not statistically significant whereas the difference between Year 2 and 3 was statistically significant. For the area of problem solving, STEM PBL and non-STEM PBL schools demonstrated different results. Students in STEM PBL schools showed improved scores in problem solving across the three years whereas students in non-STEM PBL schools had a significant improvement from Year 1 to 2 but not from Year 2 to 3.

b) Comparing STEM PBL Schools with Non-STEM PBL Schools

T-tests were conducted to examine whether there were statistically significant differences between students in STEM PBL and those in non-STEM PBL schools in terms of the scores in mathematical topic areas during the three years (see Table 5). The results from the *t*-tests demonstrated students in STEM PBL and non-STEM PBL schools did not have statistically significant differences on scores for each mathematical topic area in Year 1 and 2. However, in Year 3, students in STEM PBL schools showed higher scores than those in non-STEM PBL schools in the topic areas of geometry, probability, and problem solving.

Table 3. *Differences of Students' Scores in Four Mathematics Topic Areas Across Years*

	Area	Year 1				Year 2				Year 3					
		Mean	*SD*	*CI Lower*	*CI Upper*	*Mean*	*SD*	*CI Lower*	*CI Upper*	*Mean*	*SD*	*CI Lower*	*CI Upper*	*d pre-pst*	*d T-C*
STEM PBL Schools	Mathematics	23.203	6.847	22.68	23.73	26.963	9.073	25.96	27.96	34.843	10.501	33.48	36.21	1.311	.288
	Algebra	10.744	3.649	10.466	11.023	12.325	4.015	11.877	12.773	16.469	3.979	15.945	16.993	1.500	.067
	Geometry	6.207	2.317	6.030	6.384	8.550	2.835	8.234	8.866	11.862	3.685	11.376	12.347	1.837	.228
	Probability	2.319	1.194	2.23	2.41	2.331	1.211	2.20	2.47	2.902	1.201	2.74	3.06	.487	.098
	Problem Solving	3.932	1.791	3.80	4.07	4.537	1.820	4.33	4.74	4.545	1.877	4.30	4.79	.334	.343
Non-STEM PBL Schools	Mathematics	23.61	6.337	23.07	24.15	27.472	9.206	26.39	28.55	32.565	10.801	31.21	33.92		
	Algebra	10.947	3.433	10.653	11.241	12.895	4.301	12.387	13.404	15.950	4.386	15.391	16.509		
	Geometry	6.413	2.248	6.220	6.605	8.339	2.888	7.9977	8.681	10.946	3.834	10.457	11.434		
	Probability	2.41	1.119	2.31	2.50	2.289	1.289	2.14	2.44	2.636	1.246	2.48	2.79		
	Problem Solving	3.84	1.753	3.69	3.99	4.444	1.816	4.23	4.66	3.987	1.804	3.76	4.22		

Note. SD=Standard Deviation. Pre-pst is the Cohen's d effect size for the STEM PBL group year 3 gains over year 1. T-C is the net effect-comparing year 3 for the STEM and non STEM PBL groups.

Table 4. *Differences of Students' Scores in Four Mathematics Topic Areas Across Years*

Schools	Area	F value	*p* value	Tukey Year 1-Year 2		Tukey Year 2-Year 3	
				MD	Std. Error (*p* value)	MD	Std. Error (*p* value)
STEM PBL	Mathematics	97.619	<0.001	-3.861	0.617 (*p*<0.001)	-0.593	0.729 (*p*<0.001)
	Algebra	135.620	<0.001	-1.949	0.290 (*p*<0.001)	-3.054	0.345 (*p*<0.001)
	Geometry	210.766	<0.001	-1.927	0.212 (*p*<0.001)	-2.606	0.252 (*p*<0.001)
	Probability	5.561	<0.001	0.120	0.089 (*p*=0.367)	-0.347	0.106 (*p*=0.003)
	Problem-Solving	10.461	<0.001	-0.602	0.132 (*p*<0.001)	0.457	0.157 (*p*=0.011)
Non STEM PBL	Mathematics	170.361	<0.001	-3.760	0.563 (*p*<0.001)	-7.881	0.714 (*p*<0.001)
	Algebra	189.018	<0.001	-1.580	0.262 (*p*<0.001)	-4.144	0.334 (*p*<0.001)
	Geometry	364.584	<0.001	-2.343	0.190 (*p*<0.001)	-3.312	0.242 (*p*<0.001)
	Probability	21.177	<0.001	-0.012	0.083 (*p*=0.988)	-0.571	0.105 (*p*<0.001)
	Problem-Solving	16.602	<0.001	-0.605	0.125 (*p*<0.001)	-0.008	0.159 (*p*=0.999)

Note. MD=Mean difference

Table 5. *Comparing Between STEM PBL and Non-STEM PBL Schools*

Area	Year 1 *t*	*df*	*P*	Year 2 *t*	*df*	*P*	Year 3 *t*	*df*	*p*
Mathematics	-1.062	1158.346	0.293	-0682	600	0.495	2.331	474	0.020
Algebra	-0.975	1185	0.330	-1.663	586	0.097	1.331	461	0.184
Geometry	-1.536	1185	0.125	0.891	586	0.373	2.618	461	0.009
Probability	-1.319	1185	0.187	0.411	586	0.681	2.334	461	0.020
Problem Solving	0.865	1185	0.387	0.619	586	0.536	3.257	461	0.001

To compare the trajectories of students' scores in STEM PBL and non-STEM PBL schools, graphs were drawn (see Figure 1). The trajectories connecting the mean scores of the three years indicate that students in STEM PBL schools outperformed those in non-STEM PBL schools for algebra after the second year. For geometry, students in STEM PBL schools showed higher scores than those in non-STEM PBL schools after the first year. For probability, students in non-STEM PBL schools had lower scores in the second year than in the first year. However, in the last year students in both types of schools demonstrated higher scores than in the first and second years. For problem solving, the mean scores of students in STEM PBL and non-STEM PBL schools were increasing from the first to the second year. After the second year, the scores of students in non-STEM PBL schools dropped, whereas students in STEM PBL schools showed even mean scores. For the four mathematical topic areas, students in STEM PBL schools commonly demonstrated higher mean scores in the last year even though there were not statistically significant differences in the initial year.

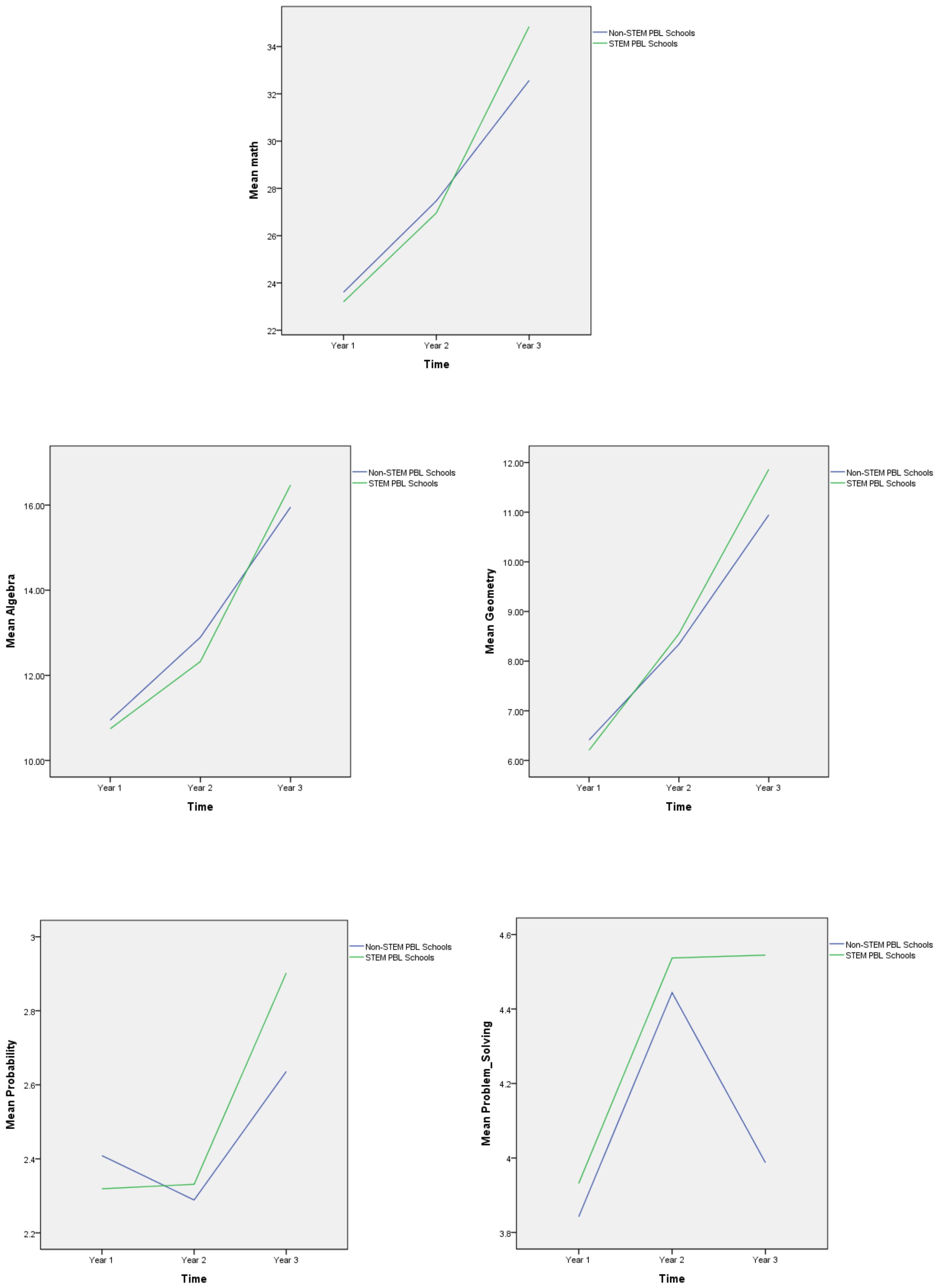

Figure 1. *Trajectories of Students' Mean Scores Across Three Years.*

DISCUSSION, CONCLUSION and IMPLICATIONS

The instructional use of STEM PBL has been examined as an appropriate instructional approach to improve students' mathematics scores, especially for low achievers (Han et al., 2014). In the present study, the impact of STEM PBL on student academic achievement in mathematics was investigated using a fine-grained strategy with respect to algebra, geometry, probability, and problem solving included in the curriculum of K-12 school mathematics. The findings for this study revealed that students in STEM PBL schools showed higher scores on geometry, probability, and problem solving than those in non-STEM PBL schools during the third year.

The current study expands the results regarding the impact of STEM PBL (i.e., Barron et al., 1998; Capraro et al., 2015; Han et al., 2014; Lou et al., 2011), on student achievement in mathematics. Students' scores in algebra, geometry, and probability showed similar trends using graphs of broken lines for students in STEM PBL and non-STEM PBL schools. However, problem solving showed no positive effects. This indicates that STEM PBL activities are likely to affect student knowledge connected to mathematical topics differently. Because STEM PBL has been regarded as a reformed instructional approach to improve students' problem solving skills (Capraro, Capraro, & Morgan, 2013), the results indicating there was no positive impact of STEM PBL on students' problem solving were not what was expected. As a reason for this unexpected result, the authors assumed that the term, "problem solving" or "problem" as measured by the test might be different from the construct defined by researchers. Problem solving was defined as finding "a way where no way is known, off-hand…out of a difficulty…around an obstacle" (Polya, 1945, p. 1) and capability to "engage in cognitive processing to understand and resolve problem situations where a method of solution is not immediately obvious. It includes the willingness to engage with such situations in order to achieve one's potential as a constructive and reflective citizen" (Programme for International Student Assessment, 2012, p. 30). According to these definitions, a problem must be non-routine to encourage students' problem solving skills. Unfortunately, most problems included on the test were word problems, but they did not all meet the bar for non-routine problems.

Students who demonstrate deep catalyzing understanding of integrated STEM develop profound understanding of the underlying content. From the results, student gained more than one might expect for just one year of year growth. When comparing to the control group, they gained on average about a quarter of a standard deviation for the best subjects and about a fifth of a standard deviation overall. The overall implications of the results is that sustained engagement with STEM PBL has a greater impact on student learning than did business as usual (no STEM PBL) group.

The findings of the study imply that lessons integrating STEM PBL should include diverse contents and contexts so students experience STEM PBL as an integrated whole. In the present study, students in STEM PBL and non-STEM PBL schools did not differ statistically on algebra performance. STEM PBL includes real world components, which are more likely to be integrated with geometry, probability, or problem solving because contextual situations based on a real world context might be more easily integrated.

Despite of the critical findings from the current study, there were two limitations that should be considered. Students' gender and the number of STEM PBLs students experienced could have had an effect on performance. Gender could have influenced the level of participation or functioned as a mediator for engagement. In particular, the STEM PBLs taught in science could have significantly contributed to their mathematics achievement. Therefore, the authors would strongly suggest further studies investigating the impact of STEM PBL on students' academic achievement in the subtopics of mathematics when considering student’s individual, teaching and learning environments, and curriculum and standards factors. Another limitation that might be pointed out was that the results from this study could not be generalized to any students in other areas or countries. Depending on various regions and countries, instructional approaches for the mathematics topic areas might be different and they could affect students’ scores in mathematics. Therefore, further studies need to examine the results from the current study with other students in other regions or countries.

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APPENDIX-1

15. THE WATER FLOWS THROUGH IT: DESIGN AND BUILD AN IRRIGATION SYSTEM

AUTHOR: JENNIFER WHITFIELD

SCHEDULE AT A GLANCE

Day 1	Day 2	Day 3	Day 4	Day 5
Engagement – Present scenario.	Discuss features and benefits of irrigation systems. Analyze professional sprinkler designs.	Discussion on water conservation and irrigation's role in conservation.	Research key topics.	Investigate the functionality of an actual irrigation system.

Day 6	Days 7-8	Days 9-10	Day 11
Create a blueprint of the house and plastic containers.	Draw the design of the irrigation system on	Build irrigation system.	Give presentations.

WELL-DEFINED OUTCOME

Students must design and build a scaled-down version of an irrigation (lawn sprinkler) system that equally distributes water to different containers meant to represent grass on a yard, so the water depth in each container is 1.25 inches.

TEACHER INTRODUCTION

This PBL is designed for an on-level or above-level high school student. It uses a real world event to give students the opportunity to apply their knowledge of two-dimensional and three-dimensional measurements, operations on decimals, spatial reasoning, estimation, and properties of basic angles (45°, 90°, and 180°). Prior to attempting this project students should know how to operate on decimals, calculate the area of basic two-dimensional geometric shapes (circles, rectangles, triangles, etc.), calculate the volume of basic three-dimensional objects (cylinders, rectangular prisms, etc.), use tape measures to precisely measure lengths, and convert fractions to decimals. This PBL can be used as a major project for students to demonstrate understanding and ability to problem solve and think critically.

In this project, the teacher will give each group of students a shallow plastic tub that contains a small house constructed from Lego© and other plastic containers that are fixed to the box. The Lego© house should be constructed so students can easily measure its dimensions. The plastic containers represent the sections of a grass lawn that need to be watered, and the plastic containers will also hold the water that is dispensed from the irrigation system that students build. The plastic containers must be carefully chosen because students need to measure the dimensions and calculate the volume of the containers. Figure 1 shows a possible configuration of the house and the plastic containers.

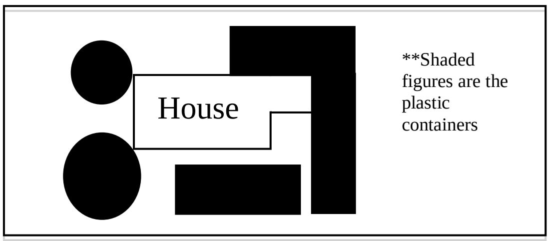


Figure 1. Sample configuration of Lego house and plastic containers.

One of the features of an irrigation system is that it spreads water uniformly across a given plot of land. In an attempt to duplicate this feature of irrigation systems in this PBL, students will build an irrigation system, with actual PVC pipe, that distributes water as uniformly as possible to each of the different containers. Students may only use hydrostatic pressure and the earth's gravitational pull as the force to move the water through the PVC pipe; students cannot make any adjustments to the plastic containers in the given box. Students must use only materials on the "Materials List" to build the irrigation system, and they will record the cost of building the irrigation system. The cost of the system will help them generate an invoice used to bill the customer.

Students must design the irrigation system so the water depth in each container is 1.25 inches. Students will have a main water source that will hold all the water used for one cycle of the irrigation system.

When students run the irrigation system through the cycle, they will fill the water main with a pre-calculated amount of water (i.e., enough water to fill each container with 1.25 inches of water). Then they will turn the valve so that the water runs through the system and consequently fills each water container. Students must record how long it takes the irrigation system to run through one cycle and try to minimize the amount of time it takes to uniformly disperse the water.

Once students have finished their irrigation systems (i.e. designed, built, tested, and refined the system), they will present their irrigation designs to an irrigation contractor and justify their designs. With the irrigation contractor present, students will run their irrigation systems through one cycle. Once the cycle is complete, students will measure the water level (height) for each container and report to the contractor how accurately the irrigation systems dispersed the water.

OBJECTIVES

This PBL will allow students to develop the following knowledge and skills in each of the identified areas below.

Mathematics – The student is expected to:

Apply mathematics to problems arising in everyday life, society, and the workplace.
Use a problem-solving model that incorporates eighbour given information, formulating a plan or strategy, determining a solution, justifying the solution, and evaluating the problem-solving process and the reasonableness of the solution.
Communicate mathematical ideas, reasoning, and their implications using multiple representations, including symbols, diagrams, graphs, and language as appropriate.
Display, explain, and justify mathematical ideas and arguments using precise mathematical language in written or oral communication.
Apply the formulas for the volume of three-dimensional figures.
Explain flow rates and compare flow rates among their peers.

Science – The student is expect to:

Identify source, use, quality, management, and conservation of water.
Recognize and demonstrate that objects and substances in motion have kinetic energy.
Learn the dynamics of water.
Demonstrate basic principles of fluid dynamics, including hydrostatic pressure, density, salinity, and buoyancy.

English – The student is expected to:

Use appropriate strategies for rehearsing and presenting speeches.
Use appropriate interpersonal communication strategies in professional and social contexts.
State new vocabulary terms and use them in both written and verbal forms.
Determine the meaning of grade-level technical academic English words in multiple content areas.

STEM CONNECTIONS

This PBL will reinforce and strengthen the following concepts and skills already learned by the student.

Science

Water flow – Explain how flow rate can be measured in gallons per minute and liters per minute.
Hydrostatic Pressure.
Water conservation.
Inner workings of valves and other pipe fittings.

Technology

Learn how technology has advanced irrigation installation and learn about the innovative irrigation products available on the market to help conserve water.

Engineering

Apply design concepts to problems in physical and mechanical systems.
Use consistent units for all measurements and computations.
Engage in design and prototype development.
Use teamwork to solve problems.
Complete work according to established criteria.
Develop a plan for implementation of an individual product.

Mathematics

Add, subtract, multiply and divide decimals.
Analyze ratio, proportions, and measurement scales.
Calculate volume of solids.
Calculate area of common shapes (e.g., squares, rectangles, circles, and triangles).
Measure objects with precision.
Use special reasoning to devise a sprinkler plan.

STUDENT INTRODUCTION

In this PBL you will use graph paper to design a model irrigation system for a scaled down replica of a model home. The design will serve as the blueprint of the house and will need to be as detailed as possible, especially with measurements. Once you have the blueprint of the home, you will use PVC pipe and pipefittings to construct the model irrigation system you designed. You will have a main water source that will hold the water used for the irrigation system. When you are ready to run your irrigation system, you will turn the valve to release the water from the main water source and watch your irrigation system water the "lawn" of the model home. Your goal is to have a water level of 1.25 inches in each of the water containers surrounding your model home.

MATERIALS USED

For the Model Home

Large, shallow plastic tub
Structure to represent the house (a house built from Legos works nicely)
Water Containers of various sizes and shapes
Hot glue gun to secure the house and water containers in the plastic bin

For the Irrigation Design

Graph Paper
Colored Pencils and/or Markers
Scotch Tape
Ruler
Compass

To Build the Irrigation System

Pipe cutters
Pipe Glue (May be used by teacher only)
PVC Pipe Fittings (ells, cross, corner ells, couplers, caps, tees)
Hand Drill with various drill bits (May be used by teacher only)
Buckets of Water for testing system
Safety Goggles
½” PVC pipe
1”, 2”, and 3” PVC pipe
Reducers: 3” to 1½”, 2” to 1”, 1½” to ½”, and others as needed
Sharpie Markers
Towels for Clean-up
1” and ½” Ball Valves

For Assessments

Strips of colored paper
Copies of Formative Assessment #1
Copies of Final Rubric

DAY 1 (20 MINUTES)

Read the following scenario to the students.

It is May and school is almost out! You start thinking about how great it is going to be to stay up late every night and sleep-in every morning. You just can’t wait until the first day of summer when your life does not revolve around a schedule. You can go to bed when you want; you can eat what you want and when you want; you can play when you want; and you can get up when you want. Boy! That is the life! Wait….get up whenever you want…Oh no…that is not going to happen! Suddenly, you remember that last summer every Tuesday, Thursday, and Saturday you had to wake up at 4am to water the yard. Yes, your parents made you spend 2 hours, three days a week, early in the morning, moving hoses and water sprinklers around the lawn. Your parents are sticklers for water conservation and saving money. They have found that the best hours of the day to run a sprinkler system is from 4am-6am. So, they required you to water the lawn during these identified hours. You begin to remember how miserable you were waking up at 4am. You think about how wonderful it would be to have an automatic sprinkler system installed at your house. After all, last summer you saw the eighbour’s sprinkler turn on and off automatically while everyone in the house slept peacefully. Wouldn’t it be wonderful if a sprinkler system automatically turned on at 4am, went through each watering cycle, and then turned off automatically? You don’t know how your parents will react to the proposition of installing a sprinkler system, but you decide to go ahead and try to convince them of the benefits of having an automatic sprinkler system. The next night before bed you discuss this with your parents. You tell them how miserable you were last summer, state the benefits of having an automatic sprinkler, and share with them how many of the neighbors have an automatic sprinkler system. Much to your surprise your parents say they are open to the idea of getting an automatic sprinkler system installed. You can hardly believe it! They actually listened to you! The discussion continues for a few more minutes and then finally, they agree to have the system installed! How fantastic! Oh, but wait, they tell you this is contingent on a few things and you will find out about specifics of the plan in the morning. Specifics in the morning! Oh no….they have always been sticklers about details! You begin to wonder if getting up at 4am may be a better option. Nonetheless, you doze off to sleep. When you awake the next morning you notice an envelope with your name on the front. You grab the envelope, open it and begin to read.

At this point the teacher gives each student an envelope that contains the letter to the child (see Appendix for sample letter). Let the students either take the letter home to read or read the letter in class.

DAY 2 (50 MINUTES)

Start by showing the class the following images:
http://www.missouribotanicalgarden.org/Portals/0/Gardening/Gardening%20Help/images/Pests/Pest2460.jpg
http://www.outsidepride.com/blog/wp-content/uploads/2013/03/lawnUCVerde.jpg
Ask students to identify similarities and differences among the pictures. Students should notice one lawn is covered in green grass and the other has spots of brown and green. Conduct a discussion on how a sprinkler system can affect the appearance of a lawn and how the design of the system is a large factor in maintaining a lawn that looks nice. The discussion should bring out important concepts like:

The placement of the sprinkler pipe in the yard
The placement of the sprinkler heads in the yard
The number of sprinkler heads used in the system
How much water is released from each sprinkler head

You could have the students discuss where they think the pipe and heads would be placed in the pictures previously shown. You could show different pictures of lawns and see where the pipe is laid and where the sprinkler heads are placed. You could also show pictures of a sprinkler system that is watering a lawn and ask students if they can figure out where the pipe is laid. The whole discussion must focus on the importance of the design of the sprinkler system. If more motivation is needed during the discussion, show them this video: https://www.youtube.com/watch?v=uBKCDHnxJZw#t=28 (3:08).

Next put the students in groups and give each group of students a professional sprinkler design. Some sample sprinkler designs are given in the Appendix section, but there are also examples on the Internet. Have the students discuss, as a group, why the sprinkler pipe and sprinkler heads are placed as they are on the plan. Once each group has discussed the irrigation plan, distribute Formative Assessment #1 and have the students turn it in before they leave the classroom. A handout for Formative Assessment #1 is given in the Evaluation section of this PBL.

DAY 3 (50 MINUTES)

Conduct a discussion on the conservation of water and the role lawn irrigation systems play in the conservation of water. The discussion should surface concepts like the control of water flow (i.e. you don't want too much pressure or too little pressure), the strategic positioning of the sprinkler heads, and the time of day at which the automatic system can run. Follow this up by showing students the following two videos to help motive the idea of lawn irrigation and the details of designing an irrigation system.
https://www.youtube.com/watch?v=2UVoDRXx66Q (1:56)
http://www.youtube.com/watch?v=mhZrzIomNSo#t=257 (start at beginning but stop at 5:10)

After watching the videos have students break into groups. In their groups have the students list three roles that sprinkler systems play in the conservation of water. Give each group of students a different colored strip of paper and have the students neatly write the results of their discussion on the strip. They should write one idea per strip of paper. When the discussion period is over, have the students post their strips on a wall in the back of the classroom. Once all strips are posted, have a class discussion to share the ideas written on the strips of paper and sort the strips of papers so those that have the same theme are grouped together.

DAY 4 (50 MINUTES)

Allow students to research key topics online. There are at least two key concepts students should understand.

The basic concept of hydrostatic pressure and the role that it plays in this PBL. Students need to know how hydrostatic pressure will help push the water through their irrigation system. Students should do a web search of simple videos that explain fluids and hydrostatic pressure. Here is a website in the event students are having a difficult time finding simple explanations of pressure due to fluids. http://www.thenakedscientists.com/HTML/content/kitchenscience/exp/water-pressure/

The features and purposes of each of the different pipefittings. Students need to research irrigation design. What parts are they going to use and how will each of these parts affect the flow of water within their irrigation systems? It will be helpful for them to go to a home improvement store (i.e., Lowe's, Home Depot) and look at the fittings. Alternatively, you could have some of the fittings and small pieces of PVC pipe available in the classroom for students to play with and see how they fit together. A list of necessary fittings is given in the materials list that is located in the Appendix section of this PBL.

DAY 5 (50 MINUTES)

During this time students will explore the functionality of a real sprinkler system. To do this you could invite a sprinkler contractor to class as a guest speaker and allow some time for students to ask questions. Ideally, this would be the same sprinkler contractor that will listen to the presentations of the students at the end of the PBL. If possible, the class could take a field trip to a job site where the contractor is installing an irrigation system. This would allow the students to see how the system is installed and ask the contractor questions. If a field trip is not possible, try to get some video footage of an actual sprinkler system being installed.

DAY 6 (50 MINUTES)

Once students have had the opportunity to research irrigation design and are familiar with the physical parts that make up the system, it is time for students to begin designing their irrigation systems. In this process students need to create a blueprint of the model houses they selected. The blueprints should be precise scale drawings of their model houses. Have students draw their blueprint on grid paper. Tip: Grid paper that has one-inch squares subdivided into a 10x10 grid work nicely. The blueprint should include the following:

A drawing of the house and of each water container. Students need to measure the dimensions of the house and of each water container, paying close attention to the location of the water containers relative to the house.

Labels of the dimensions of the house and of the water container.

The location of the main water source.

A legend that identifies icons used on the blueprint as well as scale factors (i.e. 1 square = 1 inch).

DAY 7-8 (50 MINUTES EACH DAY)

After the students have the model houses drawn on the blueprints, it is time for the students to draw the designs of the irrigation systems. During this stage, students need to consider the following items:

Students should consider the irrigation fittings that are available. The supplies students will use can be found on the supplies page (see Appendix). Notice that most of the fittings allow only for 90 degree or 180 degree turns in the system. Students must consider these angles during the design stage.

Students must be sure they plan for the pipe to stay on the exterior of the house. It is unreasonable, for example, to have pipe go over the house. In a real situation, sprinkler contractors do not bore pipe under the house. Sprinkler contractors bore under driveways and other small concrete objects, but not under an entire home. The pipe needs to remain outside the perimeter of the house and on the ground.

Students need to think about how much water needs to flow to each water container. Some of the bigger water containers will hold more water (at a 1.25 inch depth) than others and will consequently need more water flow. Water flow can be managed by the size of PVC pipe used and the number of turns in the system. If the students design a linear system (i.e. no tees) then the water flow will be different at the start of the linear design (closest to the water source) than at the end.

During the design stage, students need to plan where each water orifice will be placed and how many orifices will supply each water container. Discussion should also take place about the size (in diameter) of each orifice and the distance between each orifice, especially if there will be more than one orifice feeding one water container.

Students need to think about where they are going to put the pipe relative to the water container. Are they going to design the pipe to go through the center of the water container or are they going to place it more toward the edge?

Once students have an idea of their irrigation designs and all the intricacies of the designs, they need to draw the irrigation designs on the blueprints. Students should use some icon to show where all the orifices will be located on the irrigation system and also label the linear measurements of the system. In the sample blueprint different colors are used to represent a different aspect of the design. For example, black lines could represent the borders of the house, green lines the borders of the water containers, and blue lines the location of the pipes that will be carrying the water. The blueprint also contains a unique name for each water container and displays the volume of water each container will hold if the water level is 1.25 inches.

Once students have the designs of the system completed, they need to calculate the following and add to their blueprints.

The total amount of pipe they will need (in linear feet).

The total number of fittings they will need to construct the system.

The total cost of the system (based upon the prices in the supply list that is provided to them). Students will use the Irrigation PBL Customer Invoice sheet to help them calculate the total cost of their system. See Evaluation section of this PBL for Invoice handout.

The total amount of water (in cups) they will need to start with to ensure each container has 1.25 vertical inches of water in each container. This will involve a conversion from cubic inches to cups (students can figure this conversion factor on their own).

When students are finished with all aspects of the blueprint they should take their blueprint and the Checklist For Blueprint (see Appendix section) to at least 2 other groups for evaluation. Each group should have the blueprint peer reviewed – via the checklist – by at least 2 other groups.

DAY 9-10 (50 MINUTES EACH DAY)

Students will build the systems they designed in the blueprints. For this portion of the PBL it is important students have access to all the materials listed at the beginning of this PBL. Students will measure and cut the PVC pipe as indicated on the blueprints. Students should go through several iterations of measuring pipe, cutting pipe, and then making sure that they can lay the pipe over the containers and the Lego© house to ensure their construction is practical. Some adjustments may need to be made during this phase so their configuration of pipes matches the configuration of the Lego© house and containers. The students should wait to glue the final products together in the event changes are necessary to make the products operational. Once the final products are glued together, students can put the holes in the PVC pipes as planned on the blueprint.

DAY 11

After the students have designed their irrigation systems it is time to put them to the test. Each group – one at a time - will take the plastic bin that contains their Lego home and lay their irrigation system over the containers that will hold the water. Then the group will measure out the amount of water that was previously calculated to run one cycle of the system and put the water in the main water source. Once all water is in the main water source, the group will turn the value and let the system run through its cycle. When the system has finished running the cycle, the teacher will measure the water depth in each water container and record it for each group. Ideally, the irrigation contractor should be at this presentation to make a final rating on the design and demonstration of operation of the system.

EXTENSION

There are a number of different extensions you can provide for students.

For most students , they should use ½" pipe for their whole project. ButHowever, for students who are more advanced, you can allow them to mix the sizes of pipe for their project. This will require students to think about how water will flow in the different sized pipes and what happens to the flow of water when the pipe size changes (i.e. what happens if they change from 1" pipe to ½" pipe, how the change affects the water flow).

For most students, the teacher should have the water main constructed for them so they can focus on the sprinkler design. But, for students who are more advanced, you could have the students construct their own main water source.

Advanced students could figure the scale factor of their models and then figure the amount of materials needed for the large-scale designs. Additionally, they could construct the full "bid" for the sprinkler system and use the computer software a contractor uses to design their systems. IRRICAD is an example (http://www.irricad.com/).

Students could research the effects of friction on water flow through the pipes. After the research they could discuss how the concept of friction was involved in their designs.

Students can research how pressure affects the rate of flow within the system.

EVALUATION

Final Product Rubric

CATEGORY	4	3	2	1
Resembles the Design	90%-100% of the final product follows the design of the blueprint.	80%-89% of the final product follows the design of the blueprint.	70%-79% of the final product follows the design of the blueprint.	69% or less of the final product follows the design of the blueprint.
Materials	For the entire project, appropriate materials were selected.	For most of the project, appropriate materials were selected.	For some of the project, appropriate materials were selected.	For most of the project, inappropriate materials were used.

Care During Construction	Great care was taken in the construction process so that the structure is neat and follows plans accurately.	Construction was careful and accurate for the most part, but 1-2 details could have been refined to improve the product.	Construction accurately followed the plans, but 3-4 details could have been refined to improve product.	Construction appears careless or haphazard. Many details need refinement.
Accuracy of Measurements	The total amount of pipe used is the same amount calculated on the blueprint.	The total amount of pipe used is not the same as the amount calculated on the blueprint; it is off by 10%.	The total amount of pipe used is not the same as the amount calculated on the blueprint; it is off by 20%.	The total amount of pipe used is not the same as the amount calculated on the blueprint; it is off by more than 20%.

Functionality of the Final Product Rubric

CATEGORY	4	3	2	1
System Accesses all Water Containers	The system distributes water to all of the water containers.	The system distributes water to all BUT one of the water containers.	The system distributes water to all BUT two of the water containers.	The system did not distribute water to three or more of the water containers.
Water Level of Each Water Container	The system distributed 1.25" of water to all of the water containers.	The system distributed 1.25" of water to all BUT one of the water containers.	The system distributed 1.25" of water to all BUT two of the water containers.	The system did not distribute 1.25" of water to three or more of the water containers.
Amount of Water at the Water Main	The system had the exact amount of water in the water main to run the system.		The system had too little or too much water in the water main to run the system.	
Amount of Time to Run One Cycle of System	The amount of time it took for the system to run through one cycle was very reasonable.	The amount of time it took for the system to run through one cycle was reasonable. One adjustment could have made the system run more efficiently.	The amount of time it took for the system to run through one cycle was somewhat reasonable. Two adjustments could have made the system run more efficiently.	The amount of time it took the system to run through one cycle was not reasonable. Major improvements are required for the system to run efficiently.

Design of the System Rubric

CATEGORY	4	3	2	1
The Blueprint	Lines are clear and not smudged. There are almost no erasures or stray marks on the paper. Color is used carefully to enhance the drawing. Overall, the quality of the drawing is excellent.	There are a few erasures, smudged lines or stray marks on the paper, but they do not greatly detract from the drawing. Color is used carefully to enhance the drawing. Overall, the drawing is good.	There are a few erasures, smudged lines or stray marks on the paper, which detract from the drawing OR color is not used carefully. Overall, the quality of the drawing is fair.	There are several erasures, smudged lines or stray marks on the paper, which detract from the drawing. Overall, the quality of the drawing is poor.
Checklist for Blueprint	3 other groups completed the Checklist for Blueprint.	2 other groups completed the Checklist for Blueprint.	1 other group completed the Checklist for Blueprint.	No other groups completed the Checklist for Blueprint.

Modification/Testing	Clear evidence of troubleshooting, testing, and refinements based on data or scientific principles.	Clear evidence of troubleshooting, testing and refinements.	Some evidence of troubleshooting, testing and refinements.	Little evidence of troubleshooting, testing or refinement.

Formative Assessment #1

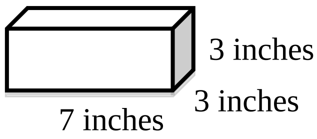
After you have listened to another group's presentation list three reasons why the sprinkler pipes and heads were placed as they were on the irrigation plan. 1. 2. 3.

Multiple Choice Problems

1) Sally had a sprinkler pipe that was 3.5 feet long. She wants to cut this piece of pipe into four equal pieces. Where should she make the first cut on the pipe?

    A) The first cut should be made at 7/8 of a foot.
    B) The first cut should be made at 7/16 of a foot.
    C) The first cut should be made at exactly 1 foot.
    D) The first cut should be made at 1/4 of a foot.

2) Find the volume of the three-dimensional container below.



    A) 21 cubic inches
    B) 63 cubic inches
    C) 13 inches
    D) 9 cubic inches

3) Which of the following are ways in which automatic sprinkler systems help with water conservation?

    A) Water in 2-3 short cycles rather than a single long period of time.
    B) There are numerous accessories (rain sensor, smart controller, etc.) that can be added onto sprinkler systems to help prevent the system from running when unnecessary.
    C) Program the system to run in the early hours of the morning.
    D) All of the above.

4) A rectangular block of length 8 cm and width 4 cm has a volume of 96 cm^3. What is the height of the block?
    A) 32 cm
    B) 3 cm
    C) 8 cm
    D) 54 cm

5) For every 33 feet (10.06 meters) you go under water, the pressure ____________ by 14.5 pounds per square inch (1 bar).
    A) Decreases
    B) Increases

Correct Answers: 1-A 2-B 3-D 4-B 5-A

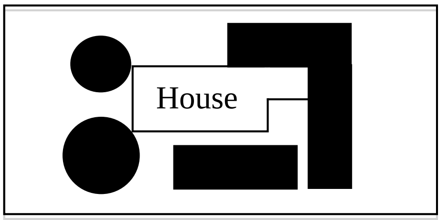
APPENDIX-2

Letter to Child

To our dear and sweet child;

We are thrilled that you have approached us with the idea of installing an automatic sprinkler system. This could be a great thing for all of us involved. For us to finalize this deal, however, we want you to use this as a learning opportunity. We want you to design and build a model of an irrigation system for a scale-model of a house. Here is how it will work:

We will give you a box that contains a Lego©-constructed house and other containers that are fixed to the box. These containers represent the sections of the lawn that need to be watered and will hold the water that is dispensed from the irrigation system. Here is a possible configuration of the house and containers you may see.



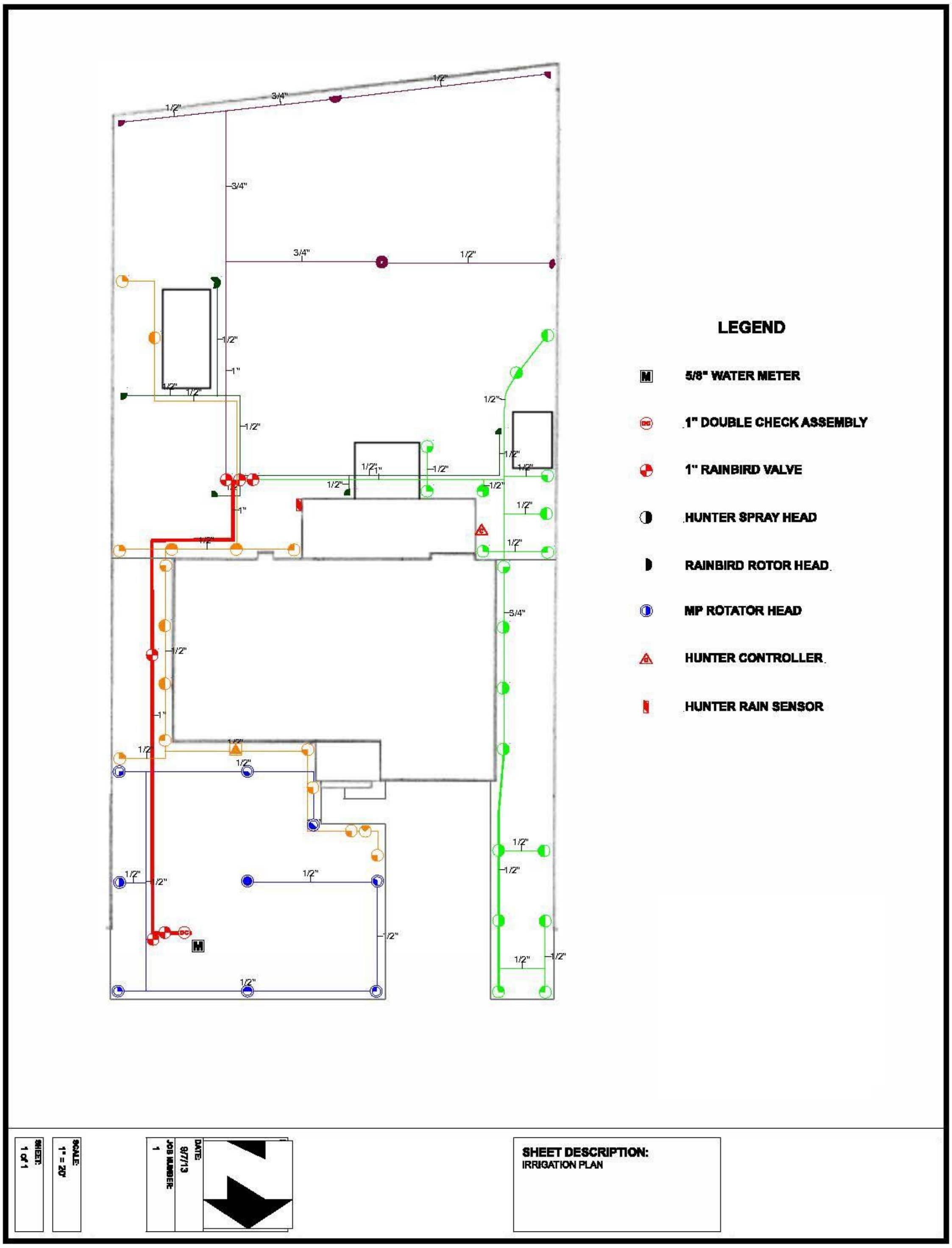
You told us that one benefit of an irrigation system is that it can spread water uniformly across a given plot of land. Thus, you must design an irrigation system that disperses water as uniformly as possible to each of the different containers. You may only use hydrostatic pressure and the earth's gravitational pull as the force to move the water and cannot make any adjustments to the containers in the given rectangular box. We will give you a list of materials you can use for the project and their corresponding prices. You may only use materials listed on this supply list. You must minimize the cost and adhere to the prices given on the supply list. You must design the system so the water depth in each container is 1.25 inches. You will have a main water source that will hold all the water you will use for one cycle of the irrigation system. When you run the irrigation system through the cycle, you will fill your water main with a pre-calculated amount of water. Then you will turn the valve so that the water runs through your system and consequently fills each water container. You must record how long it takes your irrigation system to run through one cycle and try to minimize the amount of time it takes to uniformly disperse the water.

Once you have finished your irrigation system (i.e. designed, built, tested, and refined your system), you will present your irrigation design to an irrigation contractor and justify your design (i.e., why did you design it the way you did). With the irrigation contractor present, you will run your irrigation system through one cycle. Once the cycle is complete, you will measure the water level (height) for each container and report to the contractor how accurately your irrigation system dispersed the water.

If the irrigation contractor is convinced that your irrigation system is well designed, then we will pay the irrigation contractor to install the sprinkler system. If the irrigation contractor is not convinced your irrigation system is well designed, then you will have to help the contractor install the system so you can better master the details regarding irrigation design and construction.

With Love,
Mom and Dad

Professional Sprinkler Design #1



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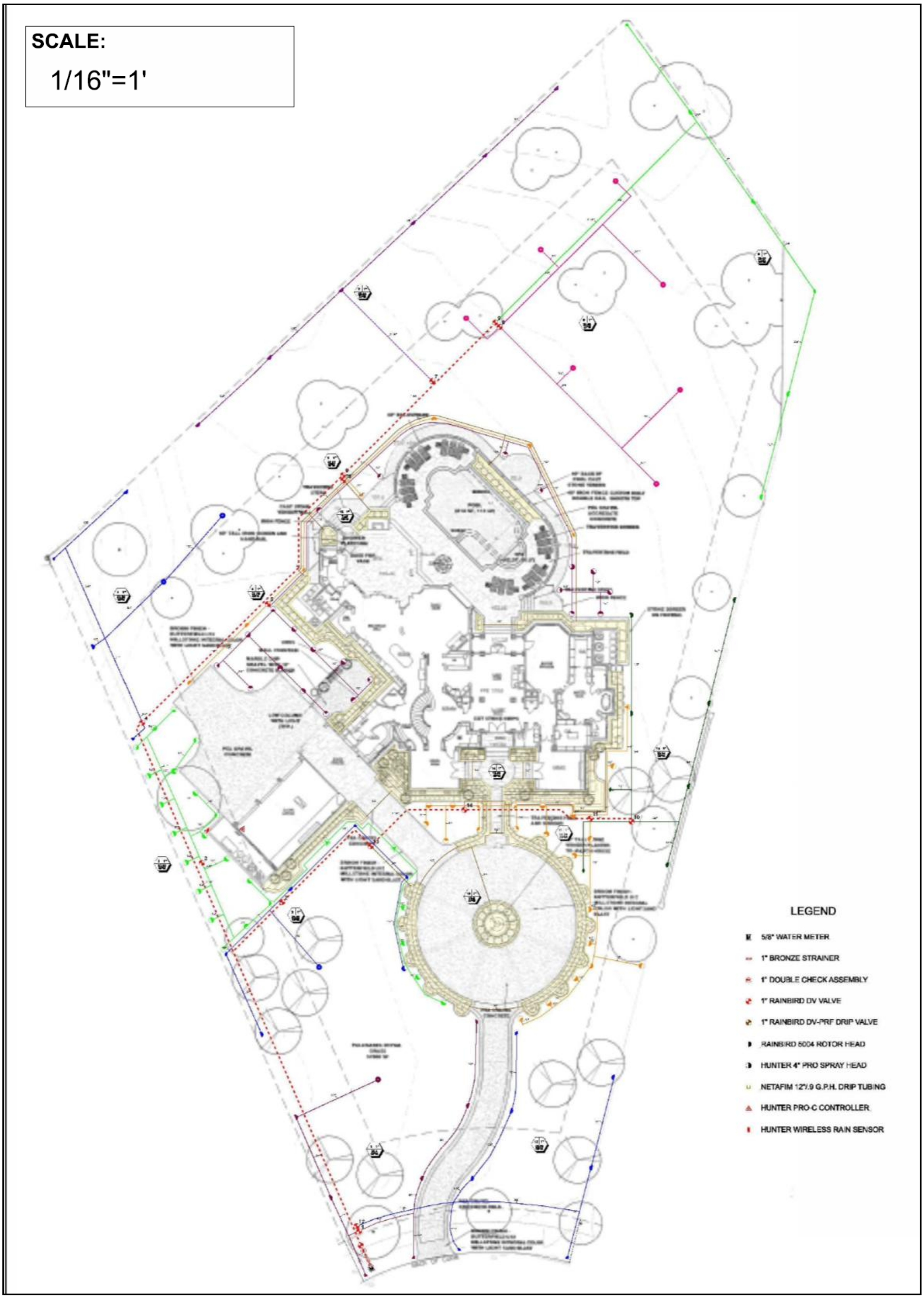
Professional Sprinkler Design #2



Materials List

ITEM	UNIT COST
½” 90 degree Slip Elbow	$0.19
½” 45 degree Slip Elbow	$0.58
½” 90 degree Side Outlet Elbow	$1.18
½” Coupling	$0.29
½” 90-degree Tee	$0.35
½” Cap	$0.35
½” 90-degree Cross Tee	$0.98
½” PVC Pipe (1 linear foot)	$0.20
½” PVC In-line Ball Valve	$2.52
¾” 90 degree Slip Elbow	$0.35
¾” 90-degree Cross Tee	$1.79
¾” 45 degree Slip Elbow	$0.74
¾” Coupling	$0.35
¾” 90-degree Tee	$0.42
¾” Cap	$0.42
¾” PVC Pipe (1 linear foot)	$0.26
¾” PVC In-line Ball Valve	$3.05
¾” x ½” Bushing	$0.39
½” x ½” x ¾” 90-degree Tee	$0.71
1 ½” x ½” Bushing	$0.88
3” x 1 ½” Adapter Coupling	$3.72
2” x ¾” Bushing	$0.98
1 ½” x 3” Adapter Coupling	$3.72
3” x 2 ft. PVC-DWV Pipe	$6.28
Primer and Glue charge	$1.50

Sample Customer Invoice

Date	Order No.	Sales Rep.	FOB	Ship Via	Terms	Tax ID

Quantity	Item Description	Unit Price	Total

Subtotal:	
Tax:	
Miscellaneous:	
Balance Due:	

Checklist for Blueprint

Once you believe your blueprint is complete, take your drawing and this checklist to at least 2 other groups and have them check for the following items:

BP=blueprint	Yes	No
1. The BP contains the drawing of the house and is labeled as such on BP.		
2. The drawing of the house on the BP is accurate (measured correctly).		
3. The drawing of the house on the BP is precise.		
4. The BP contains drawings of all the water containers.		
5. The drawing of the water containers on the BP is accurate.		
6. The drawing of the water containers on the BP is precise.		
7. The dimensions of all house measurements are labeled on the BP.		
8. The dimensions of all water container measurements are labeled on the BP.		
9. The volume of water that each water container will hold (depth = 1.25”) is labeled.		
10. The location of the pipe is drawn on the BP.		
11. The length of each section of pipe is labeled on the BP.		
12. The location of the orifices are drawn and labeled on the BP.		
13. The total amount of pipe (in linear feet) is displayed on the BP.		
14. The total number of fittings they will need to construct the system is displayed on BP.		
15. The total amount of water (in cups) necessary to run the system is displayed on the BP.		

REFERENCES

For help creating rubrics try http://rubistar.4teachers.org/index.php
A simpler version of this PBL is found at http://tryengineering.org/lesson-plans/irrigation-ideas
Special thanks to the owner of Raintec Irrigation Systems for helping with this PBL. http://www.raintecirrigationsystems.com/
Videos and other resources to help with concepts within this PBL:
https://www.youtube.com/watch?v=2UVoDRXx66Q
http://www.youtube.com/watch?v=mhZrzIomNSo#t=257
http://www.thenakedscientists.com/HTML/content/kitchenscience/exp/water-pressure/

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Integrating GIS into Science Classes to Handle STEM Education

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ABSTRACT

STEM stands for science, technology, engineering and mathematics and is an approach to education that aims to integrate these four separate disciplines. In theory, the idea of integration is clear, but in practice in a school setting it proves to be problematic due to the current structure of the educational curricula. In the current structure of educational curricula, usually only mathematics and science courses from STEM disciplines are included in school programmes and these courses are conducted in an isolated manner separate from other disciplines. This problem may be overcome by using interrelated applications such as the Geographic Information Systems (GIS) to integrate mathematics and science courses within STEM disciplines. As an interdisciplinary technology, GIS serves as a pedagogical tool for use in STEM education. Using a qualitative research paradigm, the current study evaluated a sample of junior (third-year) science teacher candidates (N=34) in a STEM educational setting using GIS. The data was collected from the written science texts of teacher candidates (e.g. the role of GIS in STEM teaching and science teaching; the implementation of STEM education in science classes) before and after the teaching intervention. At the end of the study, it was discovered that a four-week long teaching intervention had a positive effect on the science teacher candidates' views of implementing STEM as well as improving their views on and awareness of GIS.

Keywords: Geographic Information Systems (GIS); Integrated Education; Science Teacher Candidates; STEM Education.

INTRODUCTION

In conjunction with the concepts of technological innovation (Çorlu, Capraro & Capraro, 2014; Porter, Roessner, Oliver & Johnson, 2006), economic development (Archer, DeWitt & Dillon, 2014; Nugent et al., 2015; Williams, 2011) and a qualified work-force (Christensen, Knezek & Tyler-Wood, 2015; Meng, Idris & Eu, 2014), the STEM approach to education has been the focus of international organisations, governments, politicians, industrial enterprises and civil society organisations as well as educators because of what it promises to deliver (Adamuti-Trache & Sweet, 2014; English, 2015). From such a varied group of stakeholders, the question "What is STEM education?" can elicit multiple perspectives (Breiner, Harkness, Johnson & Koehler, 2012). This question can only be answered by an approach that targets the integration of science, technology, engineering and mathematics disciplines and considers it from an educational perspective (Chiu, Price & Ovrahim, 2015; Dugger, 2010; Meng et al., 2014). The work of STEM professionals is

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consistent regarding their understanding of education in this context (NAE & NRC, 2009; Wang, 2012) and they see it as better serving learners by connecting them with matters of everyday life (Breiner et al., 2012; Chiu et al., 2015; Harrel, 2010). This is because the problems encountered in real life cannot be restricted to one specific discipline (Beane, 1991), and necessitates information and skills belonging to different disciplines being used together (Wang, 2012). STEM education requires an integrated education designed in such a way as to enhance students' comprehension of professional STEM activities in real life and to eliminate the boundaries between disciplines (Asghar, Ellington, Rice, Johnson and Prime, 2012; Roberts, 2012).

This integration seems to be clear in theory, but its practical use in the school setting proves to be problematic (Pitt, 2009). Even though there may be many reasons for this implementation-oriented problem (Lederman & Lederman, 2013), the current structure of educational curricula can be said to be one of the main reasons (Bybee, 2010; NAE & NRC, 2009; NRC, 2012; Williams, 2011), because in the current structure of educational curricula, usually only mathematics and science courses from STEM disciplines are included in school programmes (Dugger, 2010; NAE, 2010) and these courses are conducted in an isolated manner separate from other disciplines (Roberts & Cantu, 2012). Under the current structure of educational curricula, integrating the other STEM disciplines into science and mathematics courses is seen to be a comprehensive way to implement STEM education (Dugger, 2010; Roberts, 2012; Sampurno, Sari & Wijaya, 2015). However, the teachers of either science or mathematics who are expected to restructure their classes to implement STEM, will probably only be specialists in their own field (Lederman & Lederman, 2013), and will likely focus on learning objectives specific to their own subject areas (English, 2015; Williams, 2011). Therefore, the realised STEM education will be quite different from the desired STEM education (Breiner et al., 2012).

The teacher is one of the most vital elements in STEM education as in any education reform movement (Han, Yalvac, Capraro, & Capraro, 2015). Teachers' competency related to the STEM approach needs to be developed for its successful implementation (Williams, 2011). Teachers are educated to teach a subject, such as science or mathematics in an isolated manner (Lederman & Lederman, 2013), so require a change in pedagogical orientation for the integrated STEM approach to education to be successful (Han et al., 2015). It is important for teachers to be exposed to STEM experiences through either in-service or pre-service training that allows them to discover contexts necessary for the integration of subjects (English, 2015; Han et al., 2015; Williams, 2011).

One of the applications that teachers should be introduced to is the Geographic Information System (GIS) (Duran, Höft, Lawson, Medjahed & Orady, 2014), which is defined as an interdisciplinary technology (Henry & Semple, 2012), that serves as a pedagogical tool for STEM education (Srisawasdi, 2012), because it renders applications that students use to collect real data, analyses the data and helps students to develop technology-assisted solutions for real-life problems related to the STEM disciplines (Baker & White, 2003; Meyer, Butterick, Olkin & Zack, 1999; Nugent, Barker, Grandgenett & Adamchuk, 2009). The models created by STEM professionals can be built using GIS (Audet & Abegg, 1996; Kerski, 2008), and in addition, issues such as climate change, energy efficiency and the establishment of safe eco-systems where GIS is frequently used (Kerski, 2011), accurately reflect the context required for activities related to STEM education (Bybee, 2010). In short, GIS renders all applications carried out by STEM professionals accessible and applicable for students (Baker, 2012). Such a teaching process enables students to gain a deeper understanding of STEM disciplines (Baker & White, 2003; Kerski, 2008), and positively affects their attitudes towards these disciplines (Aladag, 2014; Whitaker, 2011). When considered from all these perspectives, GIS seems to have the potential to pave the way for science classes where science and STEM disciplines are carried out at the same time (Patterson, Reeve & Page, 2003).

This study, conducted in the light of these theoretical explanations, focused on how the implementation of a sample STEM education using GIS was assessed by the participating science teacher candidates, and sought answers to the following specific sub-problems:

1. What are the science teacher candidates' opinions on the use of GIS in science education before and after the instruction?
2. What are the science teacher candidates' opinions on the use of GIS in STEM education before and after the instruction?
3. What are the science teacher candidates' opinions on the implementation of the STEM education approach in science classes before and after the instruction?

METHODOLOGY

This study was conducted in accordance with qualitative research methods in a manner appropriate to the nature of research problems and focused on how the implementation of a sample STEM education using GIS was assessed by science teacher candidates.

a) Study Group

A total of 34 science teacher candidates enrolled on the "Laboratory Application in Science Education II" course, and constituted the study group. Included among the outcomes of this course were "the use of technology in laboratory works for science education" and the "design and implementation of scientific research processes related to topics in the primary school science curriculum", which along with the planned teaching process, were effective in the realisation of this course. A purposeful sampling strategy was used on the study group as is usual in qualitative research (Punch, 2005) and the selection criteria for identifying the participants should primarily be determined by this strategy (Merriam, 2013). Two criteria - "participating in all activities during instruction" and "ensuring a flow of rich information in written texts" - were determined within the context of the study.

Of 83 enrolled teacher candidates, a total of 45 were absent from the four-week long in-school practices for at least a week or failed to participate in field work, so were not included in the study group, and a large number of teacher candidates were absent from the field work. Four teacher candidates were excluded from the study group on the grounds that they did not respond to the open-ended questions directed at them. Therefore, out of the 83 enrolled teacher candidates, a sample of 34 (22 females and 12 males), who met the identified criteria, formed the study group.

Teacher candidates in the study group took the opportunity to learn the theoretical explanations for STEM education within the context of the "Laboratory Applications in Science Education I" course they had previously received. They took part in the practices of the teaching model (Design-Based Learning) for the integration of other STEM disciplines into science classes, within the context of this course. Therefore, the teacher candidates included in the study group can be said to have had a general understanding of STEM education prior to instruction.

b) Procedures

As part of the implementation process of the study that lasted for four weeks (16 class hours), candidates were requested to develop an analysis model in the GIS environment for the properties of freshwater resources located in different residential areas. During the first week of the instructional process (four class hours), they were given instruction in how to use GIS (data collection, database creation, spatial analysis, data visualisation, creation of output and various software used in the realisation of these processes). Then, working in groups of three to four people, they determined the mathematical location of the freshwater source located in the residential area they were responsible for (with the help of GPS) and collected water samples. Following this field-work, each group analysed their water samples in accordance with the pre-determined parameters (water hardness and pH) and shared the results with other groups on the "laboratory works" course. The process of developing models in the GIS environment was initiated by the candidates after obtaining the data. The candidates created their respective spatial databases, performed data entry, analysis processes and created visual models (density maps) in relation to the results using ArcGIS 10.0 software (under the guidance of an expert). The process concluded with class presentations of reports, prepared by candidates regarding the processes they performed. The instructional process is summarised in Table 1.

Table 1. *Instructional Process.*

Phases of Instructional Process	Performed Activity	Related Content and Practices
1st week	Basic Education for GIS	- Recognition and use of GIS technologies in general
Field work	Collection of water samples	- Recognition and use of GPS technologies - Determination of mathematical location using GPS
2nd week	Laboratory work - Water hardness analysis - pH analysis	- Water hardness and pH concepts - Recognition of technologies used to determine water hardness and pH from the past to the present - Mathematical thinking - Unit conversion among different hardness units
3rd week	Creation of models on GIS	- Selection and use of GIS technologies - Mathematical modelling
4th week	Presentation of study reports and class discussion	- Communication and evaluation

Bybee (2010) notes there can be no single accepted model of STEM education, and Williams (2011) says there are several application models dealing with the approach from different perspectives in the related literature. Despite these views, there are some general criteria that implementations of integrated STEM education should possess (Glancy & Moore, 2013), including enabling teachers to establish connections between STEM disciplines (Bowers, 2015). Teaching content and some practices, such as water hardness, pH concept, GIS technologies, unit conversion and mathematical modelling included in the teaching activity performed, displayed a structure consistent with this criterion by allowing connections to be established between STEM disciplines.

Another criterion is the capacity of teaching activity to provide the participants with the opportunity to experience the process of scientific research using real-life activities (Bowers, 2015; Stohlmann, Moore & Roehrig, 2012). Teacher candidates, working within the framework of a problem consistent with real-life, collected water samples from sources whose mathematical locations they determined with the help of GPS. They analysed the data in "laboratory works" and made sense of the results by analysis using GIS software within the context of the teaching activity performed. The process, carried out by students, was said to allow the realisation of various scientific and engineering practices (NRC, 2012) against another criterion expressed by Bowers (2015). Teacher candidates carried out activities using ArcGIS software such as developing and using models, using mathematics and computational thinking in mathematical models, developing processes, planning and carrying out investigations, analysing and interpreting data and obtaining, evaluating, and communicating information activities in the scientific research process carried out during the instructional process.

Another suggestion for STEM education was the provision of opportunities for students to choose and use appropriate technological tools in the process of finding solutions and forming answers to problems in a real-life context (Bowers, 2015; Stohlmann et al., 2012). A variety of GIS technologies related to data collection and the creation of mathematical models, and various technological tools for use in the analysis of water hardness and pH (from simple test measurement kits to digital measurement tools) were offered to teacher candidates to use when planning and delivering their teaching within the scope of the study.

The instruction, performed in accordance with all these explanations, can be said to constitute a suitable model for integrated education aimed at different STEM disciplines.

c) Data Collection and Analysis

The study data was collected using written texts in which teacher candidates expressed their opinions regarding the use of GIS in the context of science and STEM education and the implementation of the STEM education approach in science classes. The candidates were asked to express their opinions in written format on designated topics before and after the application.

During data analysis, the written texts of teacher candidates were read line by line in order to determine any significant dimensions of the raw data (Glesne 2013). Using an inductive approach, code lists of data were generated for analysis (Yıldırım & Şimşek, 2008). The codes obtained were revised to reveal connections between them and so they could be categorised and classified. The codes and categories generated by each of the researchers were presented for evaluation by other researchers after the process was carried out separately by two researchers. The codes were finalised and consensus reached after discussion and after the attributed meanings were compared to the categories and codes. Finally, the findings of the study were revealed by organising the data collected within this system. Sample responses included in the presentation of study findings were coded with the letter M for male teacher candidates and the letter F for female teacher candidates. According to this display, the abbreviation in the form of "F_5", seen in the presentation, referred to the female teacher candidate with number 5.

FINDINGS

a) Findings related to the opinions of teacher candidates on the use of GIS in science education

The findings obtained from the analysis of the texts written by teacher candidates prior to the instruction were presented in Table 2. Frequency values, expressed in the table, showed the number of evaluations conducted by teacher candidates. Teacher candidates' inclusion of multiple ideas to be assessed in different codes or categories in written texts led to the total number of frequencies indicated in the table to be different from the number of teacher candidates.

As can be seen in Table 2, the opinions of teacher candidates on the use of GIS in science education were evaluated under three categories prior to the application. Candidates were seen to assess the GIS use as a factor contributing to science education in many aspects (motivation, attracting attention, context …) when examining sample texts presented for the category called "Supports learning". The 2nd category, determined as "Not used", included the opinions declaring that GIS cannot be used within the context of science education. All of the candidates expressing opinions in this direction stated that there was no relationship between science education and GIS. Candidates' opinions on the use of GIS in science education which would support various scientific skills found their place in the 3rd category determined as "the development of scientific process skills". When examining the sample texts for this category, it was seen that while F_6 established a direct relationship between the use of GIS in science education and scientific process skills, M_1 pointed out the data collection process. In this regard, the relevant responses of the candidates were assessed under the category called "the development of scientific process skills".

Table 2. *Opinions of teacher candidates on the use of GIS in science education prior to the instruction*

Codes	Categories	f(N)	Sample response
Restricted use for the content Draws attention Increase motivation	Supports learning	11	*M_3: There are some topics related to the environment in science curriculum. They can be learnt easily if GIS is used while teaching them.* *M_5: ...the use of such computer programs in the class will draw students' attention to that particular course.* *M_{11}: Even the use of simplest technologies in class increases student motivation. GIS technologies also facilitate the class by increasing student motivation.*
Not related	Not used	7	*F_1: I cannot establish any connection between GIS and science education. In fact, science education is related to many things but I do not know GIS very well.* *M_9: ...I do not know how this technology can be used in science classes. I think there is not much connection between them.*
Data collection Modeling	Development of scientific process skills	4	*F_6: ...the development of different skills is also targeted in science education. It can be used to teach skills of scientific process such as collecting, interpreting and modeling the data.* *M_1: ...GIS can be used while teaching the locations of different plants.*

The findings reflecting the opinions of teacher candidates on the same topic after the instruction were given in Table 3.

It was seen when examining Table 3 that the opinions of teacher candidates on the use of GIS in science education after the instruction were evaluated under 4 categories. The first of them was the category of "Supports learning" which was also called in the same way prior to the instruction. But, at this stage, the candidates were seen to associate GIS with the items highlighted in modern learning-teaching theories such as student-centered teaching and real-life connection in their evaluations. The relationship teacher candidates established between higher-order thinking skills included among the final objectives of science education and the use of GIS was given a place in the context of the 2nd category entitled as "higher-order skills development". F_{19} was seen to make an emphasis on the development of problem solving skills when examining the sample response for the category. For this reason, the evaluation made by F_{19} was included in this category. Another category, included both before and after the application, was seen to be "the development of scientific process skills". While the number of evaluations in this category was four prior to the instruction, this number was seen to increase to eight after the instruction. The opinions on the use of GIS in science education, which can be evaluated in the axis of technology literacy such as positive attitude towards technology and skills development, were included in the last category entitled as “contribution to technological literacy”.

Table 3. *Opinions of teacher candidates on the use of GIS in science education after the instruction*

Codes	Categories	f(N)	Sample response
Real-life context Student-centered Increases motivation Suitability for the content Meaningful learning	Supports learning	16	*F_{20}: ...in other words, GIS-assisted science education enables students to establish a relationship with real-life.* *F_{22}: ...it makes the class more meaningful for students and this may lead to meaningful learning.* *M_6: Units in science are related to life, GIS is something used in real life and therefore GIS can be used to teach most of science subjects.*
Problem solving Creativity	Higher-order skills development	3	*F_{19}: We carried out real practices related to science in the application we performed. We solved a real problem. Performing these kinds of practices will definitely develop students’ problem solving skills.*
Data collection Data analysis Modeling	Development of scientific process skills	8	*F_6: ...it can be used in teaching scientific process skills such as data collection and analysis.*
Attitude towards technology Technological skills development	Contribution to technological literacy	6	*F_4: ...students already use the technology well; it will become more meaningful when they see that the technology serves their purpose in this way. Their attitudes towards technology will become positive.* *F_{15}: ...using these programs will increase their skills, the more technology is used in classes, the more developed the students will become.*

It was observed when evaluating all these findings obtained before and after the instruction together that teacher candidates discovered deep connections between GIS and science education depending on the instruction performed and considered GIS applications as a necessity for the final objectives of science education (problem solving, creativity, etc.) as different from before the instruction.

b) Findings related to the opinions of teacher candidates on the use of GIS in STEM education

The majority of candidates (n=21) provided no response when they were asked to state their opinions on the use of GIS in STEM education prior to the instruction. It was stated in all of the few responses given in this regard that GIS would only reflect the technological dimension of STEM education. Samples on the responses given were as follows:

> M_3: *All disciplines should be included in STEM education. GIS technologies constitute its technological dimension.*
> F_1: *The technology that should be included in applications for STEM education is supplied in this way.*

The findings reflecting the opinions of teacher candidates on the same topic after the instruction were shown in Table 4.

Table 4. *Opinions of teacher candidates on the use of GIS in STEM education after the instruction*

Codes	Categories	f(N)	Sample response
Inserting Technology	Inserting Technology	9	*M_{10}: ...all the fields should be included for STEM implementations in classrooms. Science is already simple because subjects are chosen from there. The field of technology will also be included in implementations by using GIS.*
Real-life context Integration of all the disciplines	Pedagogical tool	16	*F_3: ...science, technology, engineering and mathematics were all included in the implementation we conducted. GIS brings all disciplines together for STEM education.* *M_1: We always talked about the necessity of real-life context for STEM education in laboratory classes. We thought that it would only be possible with engineering designs there. But, we can exactly tell that this is the real-life context after seeing GIS application.*
Interest in technology Interest in science Interest in engineering	Interest in STEM disciplines	14	*M_4: ...these applications will increase students' interests in STEM fields such as technology and science.* *M_8: ...we worked like a computer engineer while creating database in the program. Doing such a work with computer will attract the attention of students and increase their interest in engineering and technology.*

As can be seen in Table 4, the opinions of teacher candidates on the use of GIS in STEM education after the instruction were evaluated under 3 categories. The first of these categories included the opinions of candidates that GIS would reflect the “T” (technology) dimension in STEM education as stated by candidates prior to the instruction. For this reason, the response given by M_{10} would constitute as a sample for this category entitled as “inserting technology”. It was seen when examining this response that the candidate put emphasis on the inclusion of different STEM disciplines into a class before referring to the connection between these disciplines and considered GIS as a means of inserting technology a bit into science class. The opinions in which candidates considered GIS as an educational tool that meets with the requirements for the implementation of STEM education were included within context of 2nd category entitled as "pedagogical tool". Two of the responses, evaluated under this category, were given by F_3 and M_1. It was observed when examining these responses that while F_3 considered GIS as a tool for the integration of STEM disciplines, M_1 regarded it as an application that transports the real-life context required for this integration into classrooms. The opinions of teacher candidates on the use of GIS in STEM education would increase students' interests in STEM fields were included within the context of the last category entitled as "interest in STEM disciplines".

It was seen when examining the findings obtained prior to and after the instruction that the candidates, who regarded GIS to be associated only with technology from STEM fields prior to the instruction, considered it as a ground reflecting the real-life context needed for STEM education and a tool providing the integration of STEM disciplines naturally after the instruction. In addition, the candidates stated after the instruction that such a relationship would increase students' interests in STEM disciplines.

c) Findings related to the opinions of teacher candidates on the implementation of STEM education approach in science classes

The opinions prior to the instruction were firstly included in this section in which the opinions of teacher candidates on the implementation of STEM education approach in science classes were assessed. Table 5 prepared in this regard was shown below.

Table 5. *Opinions of teacher candidates on the implementation of STEM education in science classes prior to the instruction*

Codes	Categories	f(N)	Sample response
DBL	Applicable	19	*F_{21}: We saw in our previous laboratory classes that design tasks enabled STEM education. In other words, science classes, conducted by means of engineering designs, provided STEM education.* *M_8: Design-based science education can be performed in order to conduct STEM education.*
Inapplicable	Inapplicable	12	*M_1: I think that the programs need to be changed for STEM education. We are required to learn science in science class through this program, but other fields should also be taught in STEM education.*

As can be seen in Table 5, the evaluations of candidates on the implementation of STEM education approach in science classes concentrated on two categories as being "applicable" and "inapplicable" prior to the instruction. All the candidates, who expressed opinions as "applicable", were found to put the emphasis on Design-Based Learning (DBL) which they were familiar with within the context of classes they received prior to teaching activities. Opinions related to the non-realization of STEM education in science classes were included within the context of another category entitled "inapplicable". In his response which could constitute as an example in this category, M_1 stated that the current science curriculum should be implemented in science classes and this program was not designed within the context of STEM education and therefore, STEM education could not be implemented in science classes under current conditions.

The evaluations of teacher candidates on the implementation of STEM education approach in science classes after the instruction were presented in Table 6.

Table 6. *Opinions of teacher candidates on the implementation of STEM education in science classes after the instruction*

Codes	Categories	f(N)	Sample response
DBL GIS Different applications	Applicable	41	*F_5: We were only aware of DBL for transforming science classes into STEM classes. We discovered in this application that GIS was also beneficial for this purpose.* *M_7: We did not know that such a lesson could be conducted by GIS prior to this application. In my opinion, there are certainly other applications allowing the implementation of STEM in science classes.*

As can be seen in Table 6, all of the assessments, made by the candidates after the instruction, were in the direction of the applicability of STEM education in science classes. It was seen when evaluating these findings together with the findings prior to the instruction that the opinions which some candidates possessed on inapplicability of STEM education in science classes showed changes after the instruction and the candidates held some beliefs that an education in this direction could also be structured in different forms.

CONCLUSION and DISCUSSION

The results of this study on how the implementation of STEM education structured using GIS changed the opinions of teacher candidates, were discussed within the framework of sub-problems. First of all, the opinions of teacher candidates on the use of GIS in science education were scrutinised. It was seen that the candidates perceived GIS as a factor facilitating learning in science education prior to the instruction, and were able to defend their opinions by generating appropriate arguments after the instruction. In addition, the candidates were observed to establish deep connections between science education and GIS and considered GIS applications a necessity for the ultimate objectives of science education (problem solving, creativity, etc.,). Technology literacy stood out as an area where there had been a change in the opinions of teacher candidates regarding the use of GIS in science education. Making no evaluation on this aspect before instruction, after instruction the candidates stated that using GIS in science education would contribute to students enhancing their attitudes towards technology and improving technologic skills.

When addressing these assessments from the perspective of science education curricula (MEB, 2013), teacher candidates considered the use of GIS in science education beneficial for student improvement in all areas (knowledge, perception, skills, science-technology-society-environment) of the curricula.

The assessments of teacher candidates on the contribution the use of GIS in science education would make included inferences made on the basis of their teaching experience, which is supported in the relevant literature. For example, in the study carried out using innovative technologies (GPS, GIS, probes, sensors etc.) in authentic research contexts, Ebenezer, Kaya and Ebenezer (2011) noted that students' scientific inquiry abilities and perception contributed to their fluency with innovative technologies. As a consequence, it can be argued that the instructions have contributed to raising awareness of the potential of using GIS in science education in science teacher candidates'.

In line with the findings associated with another sub-problem of the study in the relationship between GIS and STEM education, the candidates' perspectives of initially only considering GIS as a "T" component of STEM substantially changed after the instruction, and they were seen to consider it as a basis for reproducing a real-life context required for STEM education as well as a tool for ensuring the integration of STEM disciplines (Audet & Paris, 1997; Kerski, 2003; Srisawasdi, 2012). They were also found to consider GIS an important factor in increasing interest in STEM disciplines (Nugent, Barker, Grandgenett & Adamchuk, 2010). Furthermore, the candidates' limited perception on the integrated nature of STEM education prior to the instruction was seen to undergo a positive change after instruction. In conclusion, the instruction performed, greatly developed science teacher candidates' understanding of STEM education (Baker, 2012).

Finally, the opinions of candidates with regard to the sub-problem of the implementation of STEM education in science classes, which they indicated was non-realisable or only realisable with DBL prior to the instruction, also underwent a change after the instruction, and all candidates expressed opinions on the practicability and necessity for integrated education in science classes. In addition, the candidates also evaluated the availability of different ways to integrate other than DBL in which they had prior experience and GIS which they used in this instruction. It can be said that the instruction performed increased candidates' beliefs on the practicability of STEM education in science classes. This progression in the beliefs of science teacher candidates on the implementation of STEM education in their respective classes is important for the promotion and dissemination of STEM education in Turkey.

It is obvious that Turkey, which is expected to make a breakthrough in technological innovation for sustainable development, will require a qualified work-force who have received training in STEM fields (TUSIAD, 2014). Addressing integrated teaching related to STEM fields at all levels of the Turkish education system is seen as a necessity in order to achieve this goal (TUBITAK, 2004).

In Turkey, in contrast to technology and engineering, science and mathematics have established learning standards and a long history in the K-12 curriculum. Consequently, the most convenient way to implement STEM education in K-12 schools around the country is to integrate other disciplines into science and mathematics courses. However, science and mathematics teachers in Turkey are only specialised in the teaching of their respective disciplines in teacher training programmes. They cannot find the opportunity to develop their proficiencies in integrated education that requires different pedagogical perspectives, strategies, and tools from the discipline based education they have received. Because teachers are constructing their own knowledge of teaching in instructional settings (Shulman, 1986), science and mathematics teacher candidates should be given the opportunity to take part in STEM education implementation, as in this study, in order to develop their proficiency in integrated STEM education.

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The Effectiveness of an In-Service Training of Early Childhood Teachers on STEM Integration through Project-Based Inquiry Learning (PIL)

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ABSTRACT

This article aims to establish the effect of a provision of an in-service professional development course for early childhood teachers on integrating STEM into early childhood education through **P**roject-Based **I**nquiry **L**earning (PIL). With the participation of 22 early childhood teachers in the three-day STEM Integration through PIL workshop using the context of 10 differing hands-on projects, this study employed an explanatory mixed-methods research design in which the quantitative data and analysis provide the main focus of the results while the qualitative data and analysis are used to elaborate on, refine, or explain the quantitative findings. In this study, the main foci were the effects of an in-service STEM Integration through PIL training workshop on early childhood teachers' self-perceived pedagogical knowledge, skills and attitudes, as well as their self-ratings on the in-service training. These quantitative findings are then elaborated on by means of participants' written comments. The findings indicated that the participants self-rated their STEM-related knowledge, skills and attitudes statistically significantly higher ($p < .001$) in the posttest as compared to the pretest. The qualitative data from the early childhood teachers with regard to their perceptions on the in-service training on STEM could be categorised into three main themes, namely interesting experiences, acquiring new knowledge, and sharing of ideas. This article culminates in a discussion on the outcome of this study in light of the related literature review on effective in-service training.

Keywords: Early Childhood; STEM; Project-Based Inquiry Learning; Science Education; Inquiry Learning.

INTRODUCTION

Malaysia places great importance on education as a means of becoming a developed nation by 2020. Accordingly, science education plays a big role as the catalyst in meeting the challenges and demands of our present and future economy. This has prompted the Malaysian government to institute the 60:40 Science/Technical: Arts (60:40) Policy in 1967 and started implementing it in 1970, because the National Council for Scientific Research and Development estimates that Malaysia needs 493,830 scientists and engineers by 2020 (Azian, 2015). However, the 60% ratio of students participating in Science/Technical has just yet to

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be met. Statistics indicate that, as of 2014, only about 45% of students graduated from the higher secondary schools were from the Science stream, including technical and vocational programmes. Additionally, the percentage of secondary school students who chose not to pursue the Science stream despite meeting the requirement based on their Form 3 National Standardised Examination (PMR) had increased to approximately 15% (Azian, 2015).

The dismal uptake of science-based subjects is not idiosyncratic to Malaysia as it is rather pervasive across the globe. Taking United States of America (USA), for example, the National Science Board [NSB] (2010) reports that the numbers of USA high school graduates choosing to pursue a STEM-related field has declined steadily. In overcoming such decline, the NSB (2010) recommends that, in order to support the identification and development of talented young men and women who have the potential to become the next generation of STEM innovators, research-based STEM preparation should be provided for general education (elementary) teachers in the area of pre-service training and professional development. Besides, early exposure to STEM opportunities and the opportunity for students to engage in inquiry-based learning, peer collaboration, and open-ended real-world problem solving should also be provided to all students. Hence the current interest in promoting STEM (Science, Technology, Engineering, and Mathematics) – an acronym which has spread within the education community since its inception by the National Science Foundation (NSF) in the 1990s (Bybee, 2013).

Research indicates that the development of science talent begins in the early years and as such, the science proneness among children could be nurtured and cultivated through “evocative instruction, stimulating idea-enactive, inquiry-oriented behaviour consistently in the classroom” (Brandwein, 1995, p.41). Lending further support, Keeley (2009) stresses the importance of science in the early grades to maximize the cumulative learning processes involved in developing science talent and argues that if children are not given an early exposure to science instruction, their science achievement and conceptual understanding would subsequently be adversely affected. Moreover, Pratt (2007) claims that the curiosity and enthusiasm for science among children may continually diminish if not fostered in the early grades. Such diminution and attenuation of interest in science will lead to students either pursuing another interest apart from science, or losing the desire to take an advanced course in science.

Accordingly, in the interest of developing Malaysia’s future STEM innovators, there is a need to revisit the early childhood program with the aims of uncovering opportunities to explicitly integrate STEM into the existing curricular, and providing in-service training to a group of early childhood teachers in terms of knowledge, skills and attitudes. This culminated in a proposed study on “STEM for Early Childhood Education in Malaysia” which was forwarded to the Early Childhood Division of the Malaysian Prime Minister’s Department and was bestowed with a generous grant to conduct the proposed study. Given that the proposed study aimed to explore the feasibility of integrating STEM into the existing Early Childhood Curriculum, the research team, comprising all the authors, developed and trialled ten modules which integrate STEM Education. Since the trialling would be done by the early childhood teachers, a group of early childhood teachers who are willing to trial the STEM Education modules was identified and be given an in-service professional training on the integration of STEM Education in their respective early childhood classrooms.

Research on in-service professional development indicates the need for highly intensive training of 160 hours before any positive changes in teachers’ attitudes towards any reform could be observed (Supovitz & Turner, 2000) and for the changes to have long-term effects in that they persisted several years after teachers concluded their training experience (Supovitz, Mayer, & Kahle, 2000). By contrast, some reviews on professional development indicate that narrowly focussed in-service professional development of moderate duration (e.g., one day in total) can have a considerable and lasting impact on teaching & learning within, for example, narrowly specified aspects of elementary/secondary science such as the use of inquiry methods (Cordingley et al., 2015).

Additionally, it has been recommended that professional development programs aimed at the development of teachers' pedagogical content knowledge (PCK) should be organized in step with teachers' professional practice, providing opportunities to enact certain instructional strategies, and to reflect on their experiences individually and collectively (Evans, 1986; Klein, 2001; Van Driel & Berry, 2012). Accordingly, these beneficial recommendations were taken into account in the planning and implementation of this research.

This article aims to determine the effect of an in-service professional development course on STEM Integration through Project-Based Inquiry Learning for early childhood teachers, establishing its effect on the pedagogical knowledge, skills and attitudes, measured by means of a questionnaire that elicits teachers' self-rating and personal written responses. More specifically, this study aims to seek illumination to the following research questions:

(1) *What are the effects of an in-service STEM Integration through Project-Based Inquiry Learning (PIL) on early childhood teachers' self-perceived pedagogical knowledge, skills and attitudes?*
(2) *What are the participants' views with regard to the in-service training on STEM Integration through Project-Based Inquiry Learning?*

Stem Integration Through Project-Based Inquiry Learning (PIL)

One of the most important goals of education across all levels is to support and strengthen the disposition to go on learning throughout life, promoting life-long learning from early childhood (Katz, 2010). Therefore, a crucial question would be what experiences are most likely to foster the disposition to go on learning, particularly at early childhood?

Research indicates that when children engage in projects in which they conduct investigations and/or involve in creation or invention around their personal questions, their intellectual capacities are very likely to be provoked and utilized (Katz, 2010; Katz & Chard 2000; Helm & Katz, 2001) as supported by a plethora of reports of project work in the early years in each issue of Early Childhood Research & Practice (http://ecrp.illinois.edu). Furthermore, while academic instruction puts children in a passive and receptive role, engagement in projects puts children in an active and interactive role where they take responsibility and initiative in inquiring by means of generating questions which they would like to seek answers to; exploring by means of collecting relevant data or information culminating in a suitable design or procedures; investigating based on the procedures or inventing based on the design; and showcasing or reporting their work (Katz & Chard, 2000). Such positive role which provokes self-regulation, according to Blair (2002), optimizes early brain development when children are involved in synchronous interaction (i.e., interacting with one another rather than being mere passive recipients of isolated bits of information). Additionally, longitudinal studies (Golbeck, 2001; Marcon, 2002) indicate that preschool curriculum and methods which emphasize children's interactive roles and provide opportunities for them to exercise initiative yield better school participation and achievement in the long term. The study by Koc and Boyuk (2012) indicates that the use of hands-on science learning promotes better attitutes towards science amongst students.

Having delved into the literature on engaging in projects or project-based learning as a way forward in fostering the disposition to go on learning throughout life, what then is inquiry learning? Ansberry and Morgan (2005) define inquiry as "an approach to learning that involves exploring the world and that leads to asking questions, testing ideas, and making discoveries in the search for understanding" (p. 17). Cincera (2014) summarises inquiry as being "interpreted as a holistic, student-centred approach to science education ... [in which] pupils follow a procedure similar to that of real scientists, i.e. they formulate their research questions and hypotheses, plan their research, collect, analyse, interpret data, and finally present what they have found" (p. 119). Meanwhile, The National Research Council (NRC) (1996) defines inquiry as "a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyse, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations" (p. 23).

In the context of early childhood education in Malaysia, while there is no explicit documentation of STEM in the Early Childhood Curriculum, elements of STEM can be inferred from the conceptual model of its curriculum as shown in Figure 1 which is lifted from PERMATA (2013, p. 34). "PERMATA", in the Malay language, means gemstone or diamond. The Malaysian Government believes that "every child is precious" just like a gemstone/diamond which needs to be cut, shaped, and polished to reveal its brilliant final beauty. Hence, the development of "*Kurikulum PERMATA Negara*" in 2007 which is the National Curriculum for Early Childhood Education for the 0-4 year olds, and was trialled and implemented nation-wide in 2008.

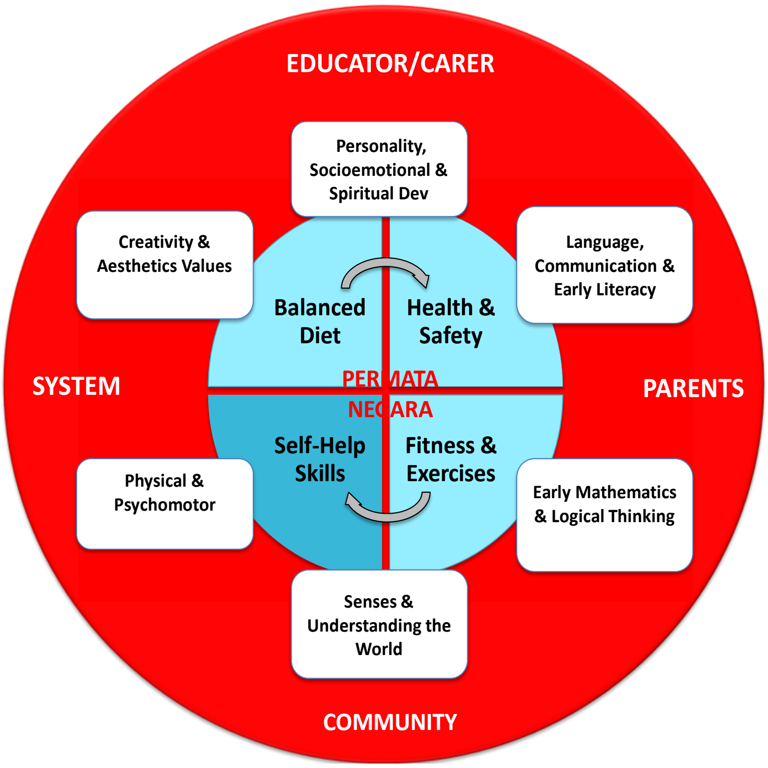

Figure 1. *Conceptual Model for the National Early Childhood Curriculum*

The conceptual model of the Malaysian Early Childhood Curriculum as depicted in Figure 1 shows the amalgamation of the four aspects in the Childcare component with that of the six Learning Areas for the Child Development achievable through the concerted efforts among the "Educator/Carer", "Parents", and the "Community" within a strong supportive "System" from the authorities. The four aspects of Childcare component are *Balanced Diet*, *Health & Safety*, *Self-Help Skills*, and *Fitness & Exercises*, while the six learning areas of children development consisted of: (1) *Personality, Socio-Emotional & Spiritual Development*; (2) *Language, Communication and Early Literacy*; (3) *Early Mathematics and Logical Thinking*; (4) *Senses and Understanding the World*; (5) *Physical & Psychomotor*; and (6) *Creativity and Aesthetics Values*.

Among the six learning areas on children development, two of which allude to STEM, namely the (a) Early Mathematics and Logical Thinking, and (b) Senses and Understanding the World. The former matches the “Mathematics” part of STEM, while the latter, the “Science” part. However, there is a confusion as to what STEM constitutes as indicated by Bybee (2013) who laments that “there seemed to be a lack of clarity about the meaning of STEM” (p. ix), due to the fact that the “meaning or significance of STEM is not clear and distinct” (p. x). Bybee (2013) raises the question of whether STEM refers to “a school discipline such as science or mathematics? … [or, does it refer to] four separate disciplines: science, technology, engineering, and mathematics? Or [does it refer to an integration of] two, three, or all four STEM disciplines?” (p.1). In the context of early childhood education in this article, we take the position of STEM as being an integration of four STEM disciplines which will be further elaborated during the discussion on STEM integration through Project-Based Inquiry Learning (PIL).

One of the characteristics of children is their inquisitive nature, constantly asking questions about the world around them. This leads to the strong advocacy of inquiry-based science education which is in step with the contemporary views on construction of knowledge through active participation. While the early childhood curriculum in Malaysia does introduce “play pedagogy” (PERMATA, 2013, p.34) which entails exploration, experimentation and experiencing (3E), it is nevertheless devoid of the explicitly stated opportunity for children to inquire (I), and to collaborate, create and communicate (3C) which have been strongly advocated for by early childhood educators (Katz, 2010; Katz & Chard 2000; Helm & Katz, 2001). Hence, the theorisation of the Project-Based Inquiry Learning (PIL) which promotes the “I + 3E + 3C” by means of four interdependent phases, namely Inquiry, Exploration, Experimentation/Creation, and Reflection. Figure 2 illustrates the enhancement or up-scaling of Play-Based Learning (i.e., the PERMATA pedagogy) to that of Project-Based Inquiry Learning which is the STEM pedagogy that we proposed.

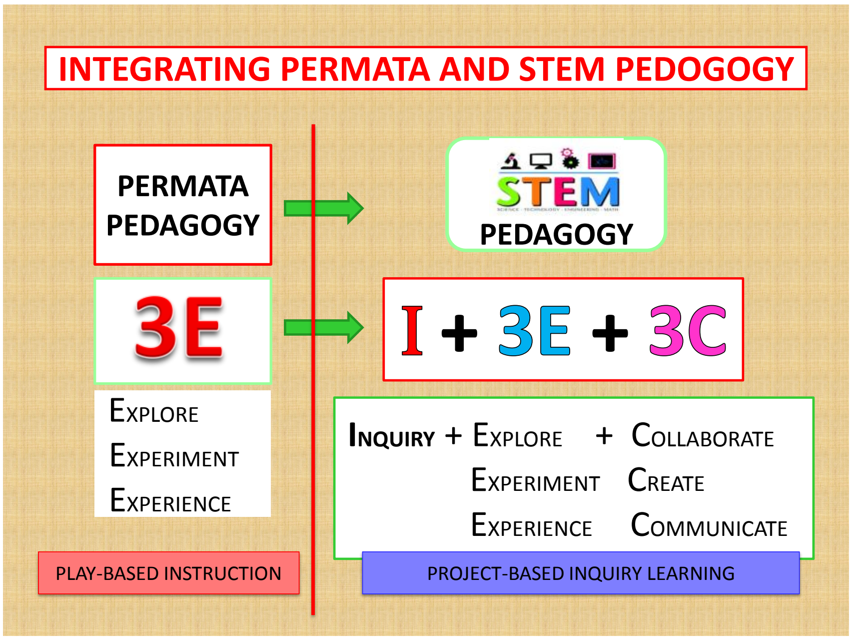

Figure 2. *STEM-Based Teaching and Learning Method*

Project-Based Inquiry Learning consists of four interdependent phases, namely Inquiry, Exploration, Invention/Experimental, and Reflection as depicted in Figure 3. Each of the four phases is briefly discussed in subsequent paragraphs using the context of "My Ship" which is one of the 10 projects designed to be used in familiarising early childhood teachers to the principles and practice of Project-Based Inquiry Learning.

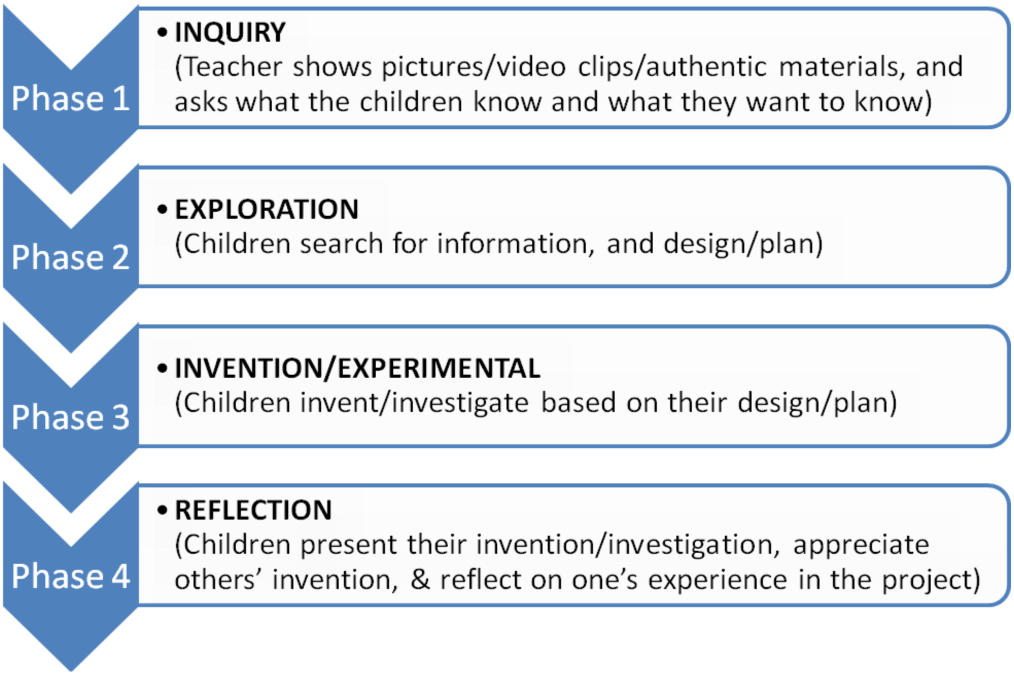

Figure 3. Project-Based Inquiry Learning Model

In the ***Inquiry Phase***, teacher begins the lesson by showing the children the phenomenon to be investigated in the form of a video clip, picture, and/or even authentic materials. In the context of "My Ship", the teacher shows clips of sailing ships. Two important prompts from the teacher based on the video clips, first being "what I know about ships", and second being "what I want to know about ships". Although many questions will be raised concerning the ships, it is expected that one question will match the learning objective(s), and in this case, "How do we build a ship?" Nevertheless, if the expected question was not posed or raised by the children, teacher can always direct children's attention towards ship construction, thus prompting children to ask the expected question.

In the ***Exploration Phase***, children search for information which will help them in their planning. In the context of "My Ship", children may explore a variety of things around them which float and the things which sink. Additionally, they may also think and attempt to make things which sink to float. They then determine the suitable materials to build a ship and plan a suitable design for their ships.

In the ***Invention/Experimental Phase***, children carry out the project or investigation or building a design according to the pre-planned design in the Exploration Phase. At this juncture, authentic real-life hands-on manipulative activities are used in the invention, and enhanced through the use of technology. The inventions, in this case, the ships, are put to the test in water. Children may even extend their inventions that include the challenge of making the ships move using a rubber band powered propeller. Besides, children are encouraged to work collaboratively, showing enthusiasm in undertaking the project at hand. In the **Reflection Phase**, children showcase and talk about their invention deriving from the project to their teachers, parents, or friends, which they have carried out. Additionally, children are encultured into displaying an appreciation towards the works of their peers. Meanwhile, teacher displays children's invention to students, other teachers, educators and parents, encouraging them to reflect on how they produced the invention and what could be done to improve it. Essentially, reflection in this phase operates at metacognitive level in which children think about their own learning experiences (Bransford, Brown, & Cocking, 2000; Flavel, 1985).

In essence, the inquiry-based learning centres on "Inquiry" regarding a ship, culminating in a question on "how to build a ship?" which in turn, leads to the "Exploration" of the phenomenon on floating and sinking, and of information pertaining to ships of different shapes and sizes which concludes with a design of a ship. Such design will be accomplished and materialised through project-based "Invention", and this is then followed by showcasing and reflection of the completed projects/inventions/investigations, and appreciation of the projects by peers; hence the conceptualisation of Project-Based Inquiry Learning. The STEM integration in this Project-Based Inquiry Learning encompasses the ***science*** concepts on buoyancy and energy, the ***technology*** which is reflected in building ships, the ***mathematics*** which is manifested in size and symmetry in ships, and ***engineering*** which involves designing of a ship.

METHODOLOGY

a) Research Design

This study employed an explanatory mixed-methods research design (Creswell, 2005; 2009), in which quantitative data were first collected and it was then followed by the collection of qualitative data in order to help support, explain, or elaborate on the quantitative results. The rationale for this explanatory mixed-methods research design is that "the quantitative data and analysis provide the main focus of the results; the qualitative data and analysis are used to elaborate on, refine, or explain the quantitative findings" (Mertler & Charles, 2008, p. 291). In this study, the main foci were the effects of an in-service STEM Integration through Project-Based Inquiry Learning (PIL) on early childhood teachers' self-perceived pedagogical knowledge, skills and attitudes, as well as their self-ratings on the in-service training. These quantitative findings are then elaborated on by means of participants' written comments.

Specifically, in view of the exploratory nature of this research to determine the impact of the in-service professional development course on STEM Integration through PIL, the "one-group pretest-posttest design" (Gay & Airasian, 2009, p.389) was deemed appropriate. This design involved a single group that was pretested, exposed to a treatment, and posttested. Additionally, qualitative responses in terms of written responses were gathered so as to illuminate what participants say they have learnt. Figure 4 depicts the explanatory mixed-methods research design used in this study.

QUANTITATIVE One group pretest-posttest design	→ Follow-up	**qualitative** Written responses

Legend: **Uppercase letters** = major emphasis
Lowercase letters = minor emphasis
Arrow = sequence

Figure 4. *Depiction of Explanatory Mixed-Methods Research Design.*

b) Sampling

Judgmental sampling was used in this study in which the segments of the population represented a variety of early childhood centres in urban and rural parts of Malaysia. In view of the cost constraint, only 22 early childhood teachers from 19 various childcare centres across urban and rural areas of Malaysia were selected to participate in this in-service training on integrating STEM through Problem-Based Inquiry Learning.

c) Intervention

The participants followed through a three-day (16-18 March 2015) fully residential in-service training workshop on the integration of STEM through Project-based Inquiry Learning (PIL) held at the Centre for the Gifted and Talented, National University of Malaysia (UKM). In the training workshop, participants were familiarised to the concept of STEM and PIL through PIL itself, in which participants took the dual role of a teacher and that of a child for each project, walking through the 4 phases of PIL under the facilitation of the researchers. Table 1 lists the 10 projects that were presented to the participants during the training workshop. Given that it was only a three-day in-service training workshop and that the time allocated was only sufficient to carry out three full cycle of PIL, each group chose one out of the 10 projects in each round (without any overlapping of projects among the groups) to walk through the full cycle of PIL in a collaborative manner, putting themselves in a dual role of a teacher and that of a child. For example, when they assumed the role of a teacher, they asked themselves "what do we want to know about ....", and when they switched role to that of a child, they explicated their questions with one of the team members listing down the questions posed by other members. At the end of each round (i.e., each full cycle of PIL), the groups presented the teaching and learning which took place in each of the four phases – Inquiry, Exploration, Invention, & Reflection. They then showcased their projects with other groups celebrated together with them.

Table 1. *The list of Projects Presented at the Training Workshop*

Project No	Title
Project 1:	Rubber-Band Powered Car
Project 2:	3R – Reduce, Reuse & Recycle
Project 3:	Terrarium
Project 4:	Buttons
Project 5:	Tie and Dye
Project 6:	Composting
Project 7:	Umbrella
Project 8:	Chicken Eggs
Project 9:	My Ship
Project 10:	Paper

d) Instrumentation

The questionnaire contains three parts. Part 1, consisting of 12 five-point Likert-scale items, measures participants' self-rating on their knowledge, skills and attitudes with regard to the Integration of STEM through Problem-Based Inquiry Learning, while Part 2, comprising six five-point Likert-scale items, solicits participants' self-rating on the in-service training workshop. Meanwhile, Part 3, consisting of an open-ended question, garnering participants' self-written views on the things or activities in the in-service training which they found to be interesting or rewarding.

This questionnaire has sufficient content validity in that every single item in Part 1 subsumes within the coverage of the STEM Integration through PIL, and that every single item in Part 2 measures the conduct of the in-service training (Sireci, 1998). Using the dataset of 22 participants, the Cronbach's alpha for Part 1 of the questionnaire was measured at 0.898 while the Cronbach's alpha for Part 2 was measured at 0.739, suggesting that the questionnaire has high internal reliability for Part 1 and adequate internal validity for Part 2

(Nunnally, 1978). In screening the data for normal distribution, the values of skewness and kurtosis for the mean of each of the 12 items were computed. It was found that the means for skewness ranged from 0.03 to 0.65, and these values fall within the acceptable range of not more than +1.00 or not less than –1.00 (Morgan, Griego, & Gloeckner, 2001), suggesting that none of the distributions was markedly skewed and consequently, none warranted the use nonparametric statistics. Meanwhile, the values of kurtosis fall within the acceptable range of not more than +1.00 or not less than –1.00 (Morgan, Griego, & Gloeckner, 2001) except for items 1, 5, and 9 which measured at -1.10, -1.03, and -1.04. Accordingly, the findings from these three items should be interpreted with caution.

While the pretest and posttest were basically the same questionnaire, there was an additional question in Part 3 of the questionnaire which solicits free responses from the participants in the posttest. The question was valid when it asks participants to write down their responses on the things/activities which they found interesting in the in-service training.

e) Data Gathering and Analysis Procedures

At the end of the in-service training, the questionnaire was administered to the participants as (a) pre- and posttest for Part 1 so as to obtain feedback on their perceived level of pedagogical knowledge, skills and attitudes before training and after training on the integration of STEM through PIL; (b) posttest only for Part 2 so as to obtain feedback on their perceptions regarding the conduct of the in-service training; (c) open-ended question to solicit participants' self-written views on the things/activities which they found interesting in the in-service training. The pretest-posttest differences were analysed using a paired-samples t-test, while the qualitative data were analysed recursively to uncover emerging themes (Patton, 2002).

FINDINGS

Research Question 1: What are the effects of an in-service STEM Integration through Project-Based Inquiry Learning on early childhood teachers' self-perceived pedagogical knowledge, skills and attitudes?

Table 2 shows the "before training" (pretest) and "after training" (posttest) means of self-perceived level of a group of 22 participants' on each of the 12 items in Part 1 that pertains to the knowledge, skills and attitudes in the integration of STEM through PIL, and the results of the analysis using a dependent samples t-test.

Based on Table 2, it was heartening to note that the participants had indicated that their ***content knowledge*** had statistically significantly increased ($p < .001$), specifically on the knowledge and understanding on STEM (Items 1 and 2), knowledge on project-based inquiry learning or PIL (Item 4) and the four phases in PIL (Item 5). Equally, the participants had also indicated that their ***practical knowledge*** had statistically significantly increased ($p < .001$), notably on how STEM could be integrated into the National PERMATA Curriculum (Item 3) and the enactment of inquiry, exploratory, invention and reflection phases of PIL (Items 6 through 9). In terms of self-perceived ***skills***, the participants have also indicated that they are able to teach STEM to PERMATA children (Item 11) with confidence (Item 12). In terms of affective domain, the participants indicated that their ***interest*** towards STEM has significantly increased (Item 10) upon the completion of the in-service training.

Table 2. *Results Obtained from t-Test for Paired Samples*

No	Item	Pre-Workshop Mean	Post-Workshop Mean	t	p
1*	Knowledge of STEM	1.91	4.18	13.893	<.001
2*	Understanding of STEM concept	1.73	4.18	15.588	<.001
3**	Knowing how to integrate STEM into National PERMATA Curriculum	1.82	4.00	12.872	<.001
4*	Knowing Project-Based Inquiry Learning in STEM	1.82	4.27	22.590	<.001
5*	Knowing all the 4 Phases in Project-Based Inquiry Learning in STEM	1.77	4.32	13.917	<.001
6**	Understand how to implement Phase 1 in STEM Project	1.68	4.32	12.969	<.001
7**	Understand how to implement Phase 2 in STEM Project	1.68	4.14	15.588	<.001
8**	Understand how to implement Phase 3 in STEM Project	1.68	4.27	14.229	<.001
9**	Understand how to implement Phase 4 in STEM Project	1.73	4.14	13.230	<.001
10+	Interest towards STEM	2.59	4.50	8.076	<.001
11#	Ability to teach STEM to PERMATA children	2.18	4.32	9.661	<.001
12#	Ability to teach STEM with confidence to PERMATA children	2.14	4.14	8.431	<.001

* Content Knowledge
** Practical Knowledge
\# Skills
\+ Attitudes

Research Question 2: What are the participants' views with regard to the in-service training on STEM Integration through Project-Based Inquiry Learning?

Table 3. *Participants' Self-rating on the Conduct of the Training Workshop*

		Min	Max	Mean	Std. Deviation
1.	Suitability of Workshop Objectives	4	5	4.55	.510
2.	Workshop contents and activities	4	5	4.64	.492
3.	Workshop Implementation	4	5	4.64	.492
4.	Facilitators' Expertise	4	5	4.95	.213
5.	Achieving Workshop Objectives	4	5	4.55	.510
6.	Workshop Duration	2	5	4.14	.834

Table 3 summarises the responses of the participants' self-rating on their views regarding the conduct of the workshop. Generally, participants were very satisfied with the conduct of the in-service training workshop which encompasses the suitability of its objectives (Q1), its contents & activities (Q2), its implementation (Q3), facilitators' expertise (Q4), the achievement of its objectives (Q5), and its duration (Q6). While items 1-5 with the means approximately equal to 5 when rounded up indicated that the participants were "very satisfied" with the conduct of the workshop, the mean of item 2 seems to approximate 4 (satisfied) when rounded up. Although the questionnaire does not require participants to justify their self-ratings, there were a few participants who rated dismally on Q6 and specifically scribbled some comments which, taken together, suggests that the duration of workshop should be longer so that they will have more grounded understanding and more knowledge to be learned.

The self-rating results are further triangulated by participants' written responses when asked to provide additional comments or responses on the things/activities which they found interesting in the in-service training workshop. Three resounding themes emerged from the qualitative data analysis of participants' responses, namely the ***Interesting Experiences***, ***Acquiring New Knowledge***, and ***Sharing of Ideas***.

Theme 1: Interesting Experiences

The participants indicated the in-service training workshop has given them interesting experiences especially in (a) learning about STEM through hands-on and minds-on manner and not through boring didactic method; (b) doing interesting projects; and (c) seeing the products of their projects. These interesting experiences were evidentially supported by the following excerpts from the participants' written comments:-

Many interesting activities in this workshop and the most interesting is the way in which we implemented Phases 1 through 4. I am so excited looking at the products of our projects.

(P-01)

The process through which we completed our projects was very hands-on. This is truly a very interesting new experience.

(P-08)

All the activities in each phase [of the PIL] are very interesting and I got new experience and better understanding of STEM.

(P-21)

It is an interesting experience and also new knowledge to me in seeing so many different projects and learning about these new projects

(P-20)

Theme 2: Acquiring New Knowledge

The second theme that emerged from the analysis of participants' written comments through a recursive process was the acquisition of new knowledge, particularly with regard to STEM pedagogy. They reckoned that the acquisition of such new knowledge is beneficial and applicable in their respective early childhood classrooms or educational contexts. We attributed such classroom applicability to the way in which the training was conducted. Instead of a didactic, lecture, and teacher-centred mode, the training was conducted in a constructivist and simulative manner where a PIL was espoused in a simulative way in which the participants acted as students as well as teachers while the facilitator was just guide on the side instead of sage on the stage. The following quotes from participants' comments, when cohere together, seem to support such contention.

I learned new ways or methods to expose my children to STEM

(P-02)

I learned much new knowledge about STEM Projects.

(P-09)

I received new knowledge in STEM field especially in invention activities

(P-11)

I now understood about the concept of the integration of STEM in teaching or integration of STEM into children's activities which I could use it for my early childhood children.

(P-12)

The invention activities are something new that l learned from this workshop.

(P-13)

Theme 3: Sharing of Ideas

The third theme that emerged was the sharing of ideas. Participants indicated that this workshop was interesting in that there were many opportunities where they could share their ideas among themselves which is akin to cross-fertilising of ideas among the early childhood teachers from different childcare centres.

I was able to share so many ideas [with other participants] which I am so thankful for.

(P-02)

I was able to share my experiences [with other participants] while undertaking the STEM process with other early childhood teachers from PAPN, KEPAS, JPNIN & YPKT [i.e., different childcare centres in Malaysia]

(P-07)

The group work was interesting and we could share and expand our ideas.

(P-11)

CONCLUSION and DISCUSSION

The findings of this study indicated that participants of the in-service training workshop perceived that their knowledge, skills and attitudes have been elevated as the outcome of the three-day in-service professional development course on STEM integration through Project-Based Inquiry Learning, evident in the differences of pretest and posttest scores across the 12 items in Part A which were all statistically significant. Additionally, based on the analysis of Part B of the questionnaire, the participants self-perceived that they were "very satisfied" with the conduct of the workshop which encompasses the suitability of its objectives, its contents and activities, its implementation, facilitators' expertise, and the achievement of its objectives, but were only "satisfied" with its duration with suggestions from the participants that the duration of the training should be extended. The significant gains observed in Parts 1 and 2 were further supported by the participants' self-written responses which, when qualitatively analyzed, gave rise to three major themes, namely "interesting experiences", "acquiring new knowledge" and "sharing of ideas".

This workshop was facilitated by the second author, assisted by all the other co-authors over the three-day duration. Even though the schedule was tight and that the participants had to complete each project by simulating through the complete cycle of four-phase Project-Based Inquiry Learning (PIL), there was no sign of boredom among the participants. This could be attributed to the employment of simulative and participants-centred hands-on, minds-on, hearts-on, and reality-on activities in the training where the underlying pedagogical principles of integration of STEM through PIL were revisited at each of the three plenary sessions with the opportunity to showcase their "inventions" and to celebrate together their achievement and the achievements of their colleagues.

While many reforms in science education have been initiated throughout the past two decades and these reforms advocated the use of inquiry-based instruction (American Association for the Advancement of Science [AAAS], 1993; National Science Teachers

Association, 1998), Capps, Crawford, and Constas (2012) reported that little has changed regarding how science is taught in majority of the US classrooms and subsequently, recommend that the key to the desired changes in the way teachers teach science is to provide innovative professional development for both pre-service and in-service teachers. Extrapolating this scenario to the integration of STEM through PIL of which the four-phase PIL approach was conceptualised and supported by 10 projects that exemplify how STEM could be integrated into the early childhood curriculum and be taught using the PIL approach, a nucleus of 22 early childhood teachers from various government-funded child care centres in urban and rural areas in Malaysia were familiarised through a three-day "innovative" in-service training workshop to the concept and pedagogy of STEM, with a particular focus on PIL. Innovative in the sense that, for each project, groups of participants carried out their respective chosen projects assuming a dual role of a child and that of a teacher, switching the roles as and when they deemed fit. For example, they asked themselves what they wanted to find out about a particular phenomenon by wearing the hat of a teacher, and subsequently changed their hats to that of a child, posing questions on what they wanted to find out.

The review of literature on the effectiveness of professional development shows that the quantity of professional development on inquiry-based teaching in which teachers participate is strongly linked with both inquiry-based teaching practice and investigative classroom culture (Supovitz & Turner, 2000) and that highly intensive (160 hours), inquiry-based professional development changed teachers' attitudes towards reform, their preparation to use reform-based practices, and their use of inquiry-based teaching practices, and that these changes have long-term effects in that they persisted several years after teachers concluded their experience (Supovitz, Mayer, & Kahle, 2000). In this study, while the early childhood teachers self-perceived that their pedagogical knowledge, skills, and attitudes had been elevated, the quantity of intensive training time spent in the three-day workshop was only 30 hours. Despite having less than 160 hours of training, such training was effective because it narrowly focussed on a pedagogical aspect, namely the integration of STEM through PIL, thus providing further support to the reviews on in-service training by Cordingley et al. (2015).

Although these early childhood teachers have been integrating STEM through PIL in their respective classrooms (Ayob et al., 2015) upon the completion of the in-service training, one question remains uncertain: Will the integration of STEM persist for a longer period, and if so, for how long? This necessitates a thoughtful plan for longer term monitoring and that teachers should be given a STEM Integration through PIL "booster dose" periodically to ensure continuous impact on their classroom practice.

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Low Socioeconomic Status Students' STEM Career Interest in Relation to Gender, Grade Level, and STEM Attitude*

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ABSTRACT

This study investigated low socioeconomic status middle school students' STEM career interest (in areas of physical science, life science, technology, engineering, and mathematics) in relation to demographic variables of gender and grade level and also attitudes towards STEM areas (science, math, engineering, and 21st century skills). The sample of the study consisted of 263 sixth, seventh, and eighth grade students attending one of five middle schools located in the rural areas of a city in the northeast region of Turkey. Analysis results showed that students had positive feelings in having a STEM career and these perceptions did not differ in terms of gender and grade level. Moreover, students' STEM career interest was high for both males and females. Among three grade levels, there was no significant difference in terms of STEM career interest, except for life science. Besides, canonical correlation analysis showed that students' career interest in STEM was positively related to students' attitudes towards STEM fields. Turkish low socioeconomic status middle school students have limited information about STEM career options and they should be given sufficient guidance about STEM occupations during middle school years. Additionally, we suggest investigating the ways of enhancing students' STEM career interest in further studies.

Keywords: Middle School; Socioeconomic Status; STEM Attitude; STEM Career Interest; STEM Education.

INTRODUCTION

Nowadays, the common motivation for nations is that improving educational system to make new generation much innovative and creative (Lederman, 2008). The main reason for this motivation is changing needs of the world. For instance, Organization for Economic Co-operation and Development, OECD, suggested that the technological revolution has shown its effects in many aspects of life, including economies of countries; hence, expectations for 21st century economies have changed (Outlook, 2013). Moreover, the same report refers to key information process skills, problem solving in technology-rich environments, and productivity as the 21st century skills which should be gained by individuals to keep up with these changes. Therefore, the global economy encourages individuals to be prepared for science, technology, engineering, and mathematics (STEM) professions. In other words, the role of STEM

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education in future's economy is recognized by nations, so it has become priority to improve students' STEM learning (McMahon & Showers, 2011). Although, the definition of STEM learning is a gap in the relevant literature, Lamb, Akmal, and Petrie (2015) describe it as "the acquisition of knowledge and skills through experience and study integrated though multiple lens allowing for the appreciation of the encompassing complexity and cross-cutting ideas across the STEM disciplines as a whole" (p. 411). In view of these researchers, STEM learning is considered by curriculum researchers in two ways; (1) interdependent and (2) integrating multiple disciplines into practices. In other words, STEM education comprises the knowledge, skills, and beliefs which also make STEM subject areas interconnected (Çorlu, Capraro, & Capraro, 2014).

United States consultants stated that STEM skills are necessary for everyone. Namely, they are not only for people who want to engage in STEM occupation, but also for people who are in non-STEM occupations (National Governors Association, 2011). U.S. consultants also underline the importance of STEM for workforce. Moreover, they suggest that even non-STEM fields, having STEM competencies will put in individuals front. Recently, STEM is also one of the hot topics of Ministry of Turkish National Education (MoNE). MoNE emphasizes importance of STEM for 2023 aims and intends to enhance students' inquiry, research, and evaluation skills which are critical to handle real life problems. While solving problems, students are targeted to learn science, technology, mathematics, and engineering fields (Cantürk, 2016). Therefore, the governments want to give priority to create scientifically literate populations. For example, PISA and TIMSS are international programs which assess middle school students' scientific and mathematical literacy. According to the results, China, Singapore, Korea, and Finland are high achieving countries. Regarding Turkey, the results are underwhelming. Turkish students' scores are below the average of OECD countries (MoNE, 2013). On the other hand, PISA 2012 results suggest that there is an increase in students' science and math literacy for many countries. Despite this positive change in students' science and math literacy, many capable students do not prefer STEM related careers in many countries such as United States (National Science Foundation, 2010). Turkey is also one of the countries that should encourage students to prefer STEM related careers. For instance, Korkut-Owen, Kelecioğlu, and Owen (2014) investigated Turkish students' career selection trends for the last 11 years based on the data from Evaluation, Selection and Placement Center. According to the results, careers about engineering have been selected by about 13% of students and this percentage did not change from 2002 to 2012. Moreover, the percentage of students who attended a college to study positive and natural sciences decreased from 13% to 8%. On the other hand, trends on studying social science are on the increase. In 2002, 22% of students entered to a college to study social sciences, while in 2012, 36% of the students entered to a college to study social sciences. Therefore, Korkut-Owen et al. suggested that the decline on positive and natural sciences and the stability on engineering should be considered to develop some solutions by policy makers.

One of the underrepresented groups in STEM related fields is socioeconomically disadvantaged individuals (Shaw & Barbuti, 2010). For example, Leslie, McClure, and Oaxaca (1998) suggest that parents' education and income level are significant predictors of students' college selection, especially for technical fields. The Royal Society (2008) suggests that the majority of people who study science, specifically physical science, at universities are those who come from high socioeconomic status groups. Actually, students' socioeconomic backgrounds' effects have been seen in early ages. For instance, international studies like TIMSS suggest that home background is a significant predictor of both science and math achievement (Gustafsson, Hansen, & Rosén, 2011). STEM education for low socioeconomic groups is important since it would expand individuals' not only economic opportunities, but also social opportunities (MacPhee, Farro, & Canetto, 2013). Recently, some studies investigated the effects of some STEM oriented interventions on students' STEM career interest and found positive effects (e.g., Peterman, Kermish-Allen, Knezek, Christensen, & Tyler-Wood, 2016; Xie & Reider, 2014). Moreover, pre-high school experiences are important for students' career choice in the future (Sadler, Sonnert, Hazari, & Tai, 2012). Therefore, the present study has two major aims: to investigate low socioeconomic students' career interest in relation to (1) gender and grade level and (2) STEM attitude.

STEM Career Interest in Relation to STEM Attitude

The level of students' interest in STEM careers is important to predict their future career choice. Studies showed that students' choosing a STEM career and maintaining their major in college depended on their interest in STEM careers (Astin & Astin, 1993; Maltese & Tai, 2011). For example, in a study with college students, Bonous-Harnmarth (2000) found that students' persistence was more strongly associated with their intention to major in STEM fields than their average high school achievement scores. Similarly, Astin and Astin (1993) examined the college students' retention rates in STEM majors in US and found a substantial loss of students from these majors. They also determined the science based career aspiration (measured at the first year in college) as one of the factors affecting students' possibility of completing majors in STEM fields. Sadler et al. (2012) found students' career interest at the beginning of the high school to be as the best factor to predict their career interest at the end of the high school. They emphasized the importance of the pre-high school experiences in young students' career intention. Thus, with the purpose of enhancing the number of people in STEM career fields, it is rational to focus on middle school students' career interest and examine the factors related to their interest. In Maltese and Tai's (2011) longitudinal study, eight grade students who were interested in science career and found science useful for their future were more likely to get a degree in STEM fields. Additionally, Maltese and Tai stated that students' early career interest played an important role in students' persistence in STEM major, however; middle school students' awareness about STEM career options were very limited. One of the aims of the present study is to figure out the low socioeconomic status middle school students' future career choice profiles. Hence, this study will help to expand our understanding in low socioeconomic status students' STEM career interest and awareness about these career options.

In this study, we utilize the Social Cognitive Career Theory (SCCT; Lent, Brown, & Hackett, 2000). The SCCT proposes that students' STEM career interest is influenced from students' attitudes toward STEM fields (Lent, et al., 2000). Unfried, Faber, Stanhope, and Wiebe (2015) considered STEM attitude as the composite of self-efficacy and outcome expectancy beliefs. According to SCCT, individuals' career and academic interest, education and vocational plans, and their success in their career plans are influenced from the interplay among personal, environmental, and behavioral factors (Lent et al., 2008). Namely, SCCT illustrates career choice and career interest of individuals with their self-efficacy beliefs ("beliefs about one's ability to successfully perform particular behaviors or courses of action") and outcome expectancy ("beliefs about the consequences of given actions") (Lent et al., 2008, p. 55). Recent research has also provided empirical evidence about the relationships between students' STEM career interest and STEM attitude measures. For instance, in a study, Milner, Horan, and Tracey (2013) investigated the relation between college students' STEM career interest and STEM career self-efficacy. The correlational analysis showed that there was a positive and high correlation between the two variables (*r*= .70). In another study, Riegle-Crumb, Moore, and Ramos-Wada (2011) investigated eighth grade students' science and math career aspirations in relation to attitude measures of enjoying science/math and science/math self-concept. It was found that both enjoying science and science self-concept were significantly and positively associated with science career aspirations. Similarly, enjoying math and math self-concept significantly and positively predicted math career aspirations. Furthermore, Tyler-Wood, Knezek, and Christensen (2010) examined the relationship between middle school students' STEM career interest and their learner dispositions of computer enjoyment, computer importance, motivation/persistence, study habits, empathy, creative tendencies, and attitude toward school. Except empathy, STEM career interest was significantly related to other all measures of learner disposition and the correlations ranged from .30 to .53. Based on these studies' findings, we expect that there will be a positive relationship between students' STEM career interest and STEM attitude.

Gender and Grade Level Differences in Students' STEM Career Interests

According to the SCCT, personal inputs like background variables are also important for individual's career choice (Lent et al., 2000). Relevant research suggests that female students tend to prefer university programs on some careers which are socially perceived to be appropriate for women (e.g., Griffith, 2010; Severins, & ten Dam, 2012). National Science Foundation of U.S. (2013) reported that female students choose careers such as nursing or psychologist, and show lower tendency to choose careers such as math or computer sciences. Similarly in Turkey, female students’ careers choices are influenced from gender roles (Korkut-Owen, Kepir, Özdemir, Ulaş, & Yılmaz, 2012). For example, Korkut-Owen et al. (2014) investigated Turkish students' university enrollment trends regarding to gender. Analysis showed that, in STEM fields, there were more males than females. Especially engineering was seen as a male dominant career. However, when the trend between 2002 and 2012 was considered, the gap between males and females on STEM fields was on decrease. The decrease of this gap between females and males may be an outcome of positive female discrimination policy of National Education of Turkey (Çalık, Ültay, Kolomuç, & Aytar, 2015). Sadler et al. (2012) discussed that although gender differences in STEM career interest was frequently studied by researchers, there was a mystery about which years were the most important on emerging these gender differences. With this purpose, they conducted a study to examine the gender gap in students' STEM career interest during the high school. The authors found that at the beginning of high school, there was a large gender difference between females' and males' STEM career interest. Additionally, they found that the number of male students with STEM career intentions were higher than the number of female students at both the beginning and the end of high school. Thus, they suggested that pre-high school activities are important for STEM career interest, especially to focus on increasing female students' interest. Hence, it is important to investigate students' STEM career interest regarding to gender in lower ages. Furthermore, although Unfried, Faber, and Wiebe (2014) found parallel declines in career interests for male and female students across grade levels (elementary, middle and high school) in the fields of physics, biology and zoology, veterinary work, mathematics, earth science, computer science, and energy, they found different trends in the fields of environmental work, medicine, medical science, chemistry, and engineering. Female students stated lower level of interest in STEM careers than males in most of these fields, especially in the field of engineering. They pointed out the need for more efforts in these fields to educators. In the light of the relevant literature, following research questions were asked in the present study:

1. What is the level of low socioeconomic status students' perceptions of a career in STEM areas and does this level differ in regard to students' gender and grade level?
2. What is the low socioeconomic status students' STEM career interest profile?
3. What are the low socioeconomic status students' career plans?
4. Is there a gender and grade level difference in low socioeconomic status students' STEM career interest?

5. Is there a relationship between low socioeconomic status students' STEM career interest and STEM attitude?

METHODOLOGY

The research design of the present study was cross-sectional survey method. Participants and data collection tools are explained below.

a) Sample

The participants of this study include 263 students from 5 middle schools located in the rural areas of a city in the northeast region of Turkey. 50% of them were females, and 46% of them were males, while 4% of the participants did not report their sexes. Most of the participants (70%) were from 7th grade while 13% of the participants were from 6th grade and 17% of them were from 8th grade. Students were from low socio economic families. Namely, all of the mothers of students were housewife. Additionally, approximately 35% of the fathers worked as a farmer or in animal husbandry and 10% of the fathers were unemployed. Except a few of them, remaining fathers were labor in several works such as construction worker and janitor. Regarding to educational level of parents, most of mothers (93%) and fathers (86%) were graduated from middle school or lower. 32% of students have 6 or more siblings, and only 9% of them have less than 3 siblings. Most of the students (70%) do not have a computer at their home.

b) Instruments

The STEM Semantic Survey for Career Interest: This survey was developed by Tyler-Wood, Knezek, and Christensen (2010) to examine middle school students’ perceptions about a STEM career (see Appendix-1). Five adjective pairs based on a 7-point response scale were used and Cronbach alpha was .93. In the present study, these adjective pairs were translated in Turkish by the researchers and examined by a language expert (See Appendix-1). Students were asked to rate their response on the 7 point scale between the related adjective pairs to state the degree of their interest in STEM careers. Although the first and second adjectives were placed from negative to positive, remaining adjectives were from positive to negative. To make the interpretations simpler, last three items were reverse coded. Cronbach alpha was found to be .75, indicating sufficient internal consistency of the scores.

Student Attitudes toward STEM (S-STEM) scale: S-STEM scale was developed by Unfried et al., (2015) based on items in Friday Institute for Educational Innovation Survey (2012) and adapted for Turkish middle school students by Yıldırım and Selvi (2015). This scale is used to measure students’ attitudes toward STEM disciplines based on four factors: science (9 items, 1 of them is reverse), math (8 items, 3 of them are reverse), engineering and technology (9 items), and 21st century skills (11 items). Response scale is based on a likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Yıldırım and Selvi provided evidence for the construct validity of S-STEM with Turkish sample by confirmatory factor analysis (χ^2/df= 4.72, RMSEA= .06, SRMR=.05, CFI= .96, NFI= .95) Cronbach alphas of the subscales were ranged from .86 and .89. In the present study, CFA results (χ^2/df= 1.97, RMSEA= .06, SRMR= .07, CFI= .96, NNFI= .95) indicated good model fit to the data, as well. Sample items for each subscale and Cronbach alphas obtained from this study were presented in Table 1.

Table 1. *Sample Items and Cronbach Alphas for Subscales of S-STEM (Unfried et al., 2015)*

Subscale	Sample Item	Cronbach Alpha
Science	"Science will be important to me in my future career"	.86
Math	"I am the type of student who does well in math"	.71
Engineering and Technology	"Designing products or structures will be important in my future jobs"	.86
21^{st} century skills	"I am the type of student who does well in math"	.90

STEM Career Interest Scale: Researchers designed a 5-item survey to descriptively examine the level of students' interest toward STEM careers. In this process, researchers benefited from STEM occupations which were categorized by Milner, Horan, and Tracey (2014, p. 645) and STEM career interest survey of Unfried, et al., (2014) (see Appendix-2). Each item represents a category of related STEM area: physical science, life science, technology, engineering, and mathematics. Each category includes from 4 to 10 sample jobs. Students were asked to rate their interest level to each STEM area and careers on a Likert scale ranging from 1 (I am not interested at all) to 4 (I am very interested). For example, the first item asked students interest toward physical science area and gave some career examples about this area such as astronomer, biophysicist, geoscientist, and physicist.

FINDINGS

Students' Perceptions of a Career in STEM

In order to answer the first research question (What is the level of students' perceptions of a career in STEM areas and does this level differ in regard to students' gender and grade level?), students were asked about their feelings regarding a STEM career. They rated their perceptions about having a STEM career as means a lot, interesting, exciting, fascinating, and appealing on a 7 point Likert scale. An average score was computed by students' responses to 5-questions of semantic test. As shown in Table 2, students' average semantic perceptions of STEM areas were ranged between 5.55 and 6.19 which are above the mid-point (4) of 7 point Likert scale. It indicated that females' and males' responses were close to each other at each grade level and they have very positive feelings toward STEM careers. Then, a two-way ANOVA was performed to examine the gender and grade level (6^{th}, 7^{th}, and 8^{th}) differences in students' STEM perceptions. No significant interaction effect was found for these variables [$F(2,245)= 1.83$, $p= .16$]. Moreover, no significant main effects for gender [$F(1,245)= 1.14$, $p= .29$] and for grade levels [$F(2,245)= .30$, $p= .75$] were found.

Table 2. *Average STEM Career Perceptions of Different Graders*

Gender	Grade	Mean	SD
Males	6	5.61	.31
	7	5.55	.13
	8	5.91	.31
Females	6	5.76	.30
	7	6.19	.13
	8	5.79	.24

Low Socioeconomic Status Students' STEM Career Interest Profiles

Students were asked to rate their interest in STEM occupations on a Likert scale ranging from 1 (not interested at all) to 4 (very interested). STEM occupations included five categories which are physical sciences, life sciences, technology, engineering, and mathematics. To ease the interpretation, we combined 'not at all interested' and 'not interested' categories into 'not interested' category, and 'interested' and 'very interested' categories into 'interested' category. Since some of the students did not answer these questions, they were not included in a category. The frequencies of students' STEM career interest in 'not interested' and 'interested' categories were presented at Table 3.

Table 3. *Frequencies of Students' STEM Career Interest*

	6th Grade (*N*=36)		**7th Grade (*N*=183)**		**8th Grade (*N*=44)**	
	Interested	**Not interested**	**Interested**	**Not interested**	**Interested**	**Not interested**
Physical Science	75%	22%	76%	23%	75%	25%
Life Science	86%	11%	67%	31%	84%	16%
Technology	75%	19%	71%	25%	66%	32%
Engineering	72%	8%	75%	22%	61%	36%
Mathematics	72%	26%	69%	23%	57%	36%

Career Plan Profiles

The third research question was aimed to descriptively examine the career plan profiles of middle school students from low socioeconomic status. In this respect, students were asked to answer to an open-ended question that "In future, which occupation do you want to work?" Students were asked to state the reason why they want to work in that occupation, too. Students' responses were categorized within five STEM areas: physical science, life science, technology, engineering, and math. As presented in Table 4, results showed that 48% of students reported occupations different from STEM field. Besides, majority of the students who stated a STEM profession, 36% of the sample, reported the occupations in the field of life science. In this field the most popular response among the students (more than half) is the medical doctor followed by nursing. The second field was engineering and about 11% of the students want to work in several engineering areas such as electrical engineering, civil engineering, and architecture. Moreover, only a few students (4%) stated science and math related occupations as their future plan. Lastly, 48% of the participants stated some occupations (such as soccer player, singer, teacher, lawyer, and police) that were not categorized under these STEM areas. Interestingly, none of the students reported an occupation in the field of technology.

Regarding the reason why students want to work in this occupation, only the answers which were in life science and engineering were examined since they were the most frequently targeted STEM occupation areas among these participants. Students' answers were investigated separately for each STEM area. In the life science area 50 of 95 students stated their reason as helping sick people or saving people's life. Another group of students (n=31), reported their interest or enjoyment to the related occupation. Remaining students either did not answer to this question or stated different reasons such as that important people in their life want them to choose this occupation. In the engineering area, 25 of 30 students stated that they would like to be an engineer because they were interested in engineering profession, in other words, they reported that they enjoyed what engineers do. Only 5 of 30 students reported different reasons for wanting to be an engineer in the future. For example, one of them reported that s/he wants to help people by creating new places for them. One of them stated that s/he wanted to contribute to the culture by his or her design. Other 3 students, who reported that they would like to be engineer in the future, explained their reason due to high salary of engineering occupation.

Table 4. *Frequencies and Percentages of Students' Career Plans*

Career	Frequency	Percentage
Physical Science	8	3 %
Life Science	95	36 %
Technology	-	0 %
Engineering	30	11 %
Math	3	1 %
Others	127	48 %

Gender and grade level difference in students' STEM career interest

On the combined categories in students' STEM career interest (we have combined 'not at all interested' and 'not interested' categories into 'not interested' category, and 'interested' and 'very interested' categories into 'interested' category) gender and grade level differences were examined. In order to investigate whether students' interest in physical sciences, life sciences, technology, engineering, and mathematics differ in terms of gender, chi-square tests for independence (with Yates Continuity Correction) were performed. Analysis results showed no significant associations between gender and career interest in physical sciences [χ^2 (1, n= 249)= 2.06, p= .15)]; gender and career interest in life sciences [χ^2(1, n= 247)= .73, p= .39]; gender and career interest in technology [χ^2 (1, n= 242)= .06, p= .81)]; gender and career interest in engineering [χ^2 (1, n= 244)= 1.37, p= .24)]; and gender and career interest in mathematics [χ^2 (1, n= 234)= 1.29, p= .26)]. Therefore, analysis results showed that females and males did not differ from one another in regard to their interest in any of the STEM occupations.

In order to investigate whether students' interest in STEM occupations differ in terms of grade level, chi-square tests for independence were conducted. Analysis results showed that there were significant differences among grade levels in terms of only career interest in life sciences [χ^2(2, n= 258)= 8.80, p= .01)]. Follow-up tests showed that the difference was between sixth and seventh grade students [χ^2(1, n= 214)= 4.78, p= .03)]. The probability of sixth grade students' being interested in a life sciences career was about 1.29 times (.89/.69) greater than seventh grade students'. Eighth graders did not differ from neither sixth nor seventh graders in terms of life sciences career interest. In rest of the STEM occupations, no grade level differences were detected. In other words, no significant associations between grade level and career interest in physical sciences [χ^2 (2, n= 260)= .07, p= .97)]; grade level and career interest in technology [χ^2 (2, n= 253)= 1.43, p= .49)]; grade level and career interest in engineering [χ^2 (2, n= 255)= 3.74, p= .15)]; and grade level and career interest in mathematics [χ^2 (2, n= 245)= 3.39, p= .18)] were found. Thus, other than career interest in life sciences, no grade level differences were detected.

Relationship between STEM Career Interest and Attitude toward STEM Areas

Initially, participants' attitudes toward STEM areas were examined. Mean scores were above the midpoint of 5 point Likert scale (for math M= 3.58, SD= .73; for science M= 3.94, SD= .83; for engineering M= 3.72, SD= .85; and for 21st century skills M= 3.90, SD= .81). These results indicated that students had positive attitudes towards STEM areas.

Canonical correlation analysis was performed to investigate the relationship between the set of students' STEM attitudes (math, science, engineering, and 21st century skills) and the set of STEM career interest (physical science, life science, technology, engineering, and math). With all four canonical correlations included, F (20, 760) = 3.93, p < .005, and with the first canonical correlation removed, F (12, 608) = 2. 32, p < .005. Subsequent F tests were not statistically significant. Therefore, only the first canonical variate accounted for the significant relationships between the two sets of variables. The first canonical correlation was .43 (19% overlapping variance), the second was .27 (6% overlapping variance) accounting for the significant relationships between the two sets of variables. Since the overlapping variance in the second canonical variate pairs was very low (under %9) it was avoided from interpreting it (Tabachnick & Fidell, 2013).

As shown in Table 5, with a cut off correlation of .30 (Tabachnick & Fidell, 2013), all of the variables in the STEM attitude set (i.e., attitude toward Math, Science, Engineering and 21st century skills) were positively and significantly correlated with the first canonical variate. Concerning STEM career interest variables, physical science, life science and engineering were found to be positively and significantly correlated with the first canonical variate while technology was not found significantly related to this canonical variate. Accordingly, the first pair of canonical variates suggested that higher level of STEM attitude was positively related with higher level of STEM career interest. Math interest (.71) and math attitude (.92) had the highest loadings among the variables within the related variable set. The coefficients obtained from canonical correlation analysis were presented in Table 5.

Table 5. *Correlations, Standardized Canonical Coefficients, Canonical Correlations, Percent of Variance, and Redundancies*

	First Canonical Variate	
	Correlation	**Coefficient**
SET 1: STEM attitude		
Math	.92	.81
Science	.49	-.25
Engineering	.43	-.06
21st century skills	.71	.57
Percent of variance	44.14	
Redundancy	8.29	
SET 2: STEM career interest		
Physical Science	.65	.42
Life Science	.32	.13
Technology	-.04	-.16
Engineering	.63	.46
Math	.71	.55
Percent of variance	28.57	
Redundancy	5.36	
Canonical correlation	.43	

DISCUSSION and CONCLUSION

The present study has two major aims; to investigate low socio economic students' career interest in relation to (1) gender and grade level and (2) STEM attitude. For the first aim of the study, students' perceptions about STEM fields, their STEM career interest, and students' career plans were examined with regard to gender and grade level. Firstly, students' perceptions about STEM areas were investigated by asking students to rate how they feel about a career in STEM areas. Results suggested that low group students' average scores were close to the highest score (7) which indicated the most positive feelings. Namely, students reported that STEM careers means a lot for them and they found STEM careers highly interesting, exciting, fascinating and appealing. To investigate whether students' perceptions about a career in STEM areas differ in terms of gender and grade level, two-way ANOVA was conducted. According to the analysis results, there was no significant difference between females and males and among the three grade levels in their STEM career perceptions. Hence, it can be inferred that low socioeconomic status middle school students have positive perceptions in having career in STEM fields regardless of gender. According to Tyler-Wood, Knezek, and Christensen (2010), determining students' perceptions about STEM careers is important to identify their career potential. At this early stage of the education, students' positive perception about having a career in STEM areas is promising for the number of people in STEM careers in future.

Regarding students' STEM career interest profile, the descriptive results suggested that majority of the students were interested in having a STEM related careers which were grouped within five categories: physical science, life science, technology, engineering, and mathematics. To investigate whether females and males differ in terms of STEM career interest, chi-square tests for independence was conducted. Results suggested that there was no significant difference between females and males. Actually, it was an unexpected result since it was hypothesized that males have more STEM career interest than females based on the relevant literature (e.g., Unfried et al., 2014). One of the reasons of this surprising result may be because of students' age. Namely, middle school students have limited knowledge about career options. Although one of the aims of the primary and middle school science curricula is to improve students' awareness about science related careers (MoNE, 2013), in-class activities may not sufficiently emphasize this issue, in practice. Thus, we suggest future studies to investigate what extend science teachers provide information about science related careers and carry out these activities in their classes. Students' socioeconomic status may be another reason for similarities between males and females in STEM career interest. Related literature suggests that financial advantage of STEM careers is one of the underlining motivations of males to choose STEM careers (Correl, 2001; Dick & Rallis, 1991). Since, our sample is from the low socioeconomic status families, the limitations of low socioeconomic status may also encourage females to be interested in high salary jobs which are mostly in STEM fields. Future studies can investigate low socioeconomic status students' career interest with more details by using qualitative research methods.

To investigate whether students' interest in STEM careers differ in terms of grade level, chi-square tests for independence were conducted. Findings suggested that there was no significant difference among 6^{th} graders, 7^{th} graders and 8^{th} graders in terms of STEM career interest in all STEM fields, except for life sciences. These findings indicated that whether students being interested or not interested in STEM career was not influenced by grade level as far as we expected. Sadler et al. (2012) suggested that pre-high school activities are important to improve students' interest in STEM careers. However, findings of the present study indicated that there was not any developmental difference in students' STEM career interest through Grade 6 to Grade 8. In other words, activities in which students were engaged during middle school are not sufficient to improve students' STEM career interest. By considering the stability in students' STEM interest level during the high school (Sadler et al., 2012), the importance of the education in middle school can be better understood. Hence, science curricula can be enriched by integrating STEM related activities to support students' interest in STEM related careers. Regarding Turkey, Sarıer (2010) suggests that each student in Turkey does not have opportunity to take a high quality education in STEM. Although science curriculum in Turkey suggests harmony of science and mathematics teachers in their coursework (MoNE, 2005, 2013), the science and mathematics courses are not linked in practice (Özden, 2007). The new science curriculum (MoNE, 2013) highly emphasizes integration of technology in students' research and inquiry activities, relating science and technology, and enhancing science career awareness among students. However, to what extent these aims are achieved in science classes need to be investigated.

Students' career plans for the future were investigated by asking the question "In future, which occupation do you want to work?" According to the students' responses, life sciences area was predominated among low socioeconomic status students who stated STEM related occupations. Social popularity may be one of the reasons of why majority of students prefer to have a life science career in the future. In Turkey, education is highly valued by society. Besides, Turkish education system is competitive. Hence, parents encourage their children to have a good career and have good life standards (e.g., Şenler & Sungur, 2009). Because of the characteristics of Turkish culture, individuals consider others' opinions while decision making. Having a career in a life science, especially being a medical doctor is very popular in Turkey, not only among students but also among parents of students. According to a research (“Career choice”, 2013) in Turkey, one of five parents expects their children to be a doctor in their future. Engineering followed life science; the second popular STEM career among the participants was engineering. Besides that, unexpectedly, no student stated an occupation related to technology. Lack of occupation knowledge may lead students to focus on widely recognized occupations. Nowadays, Turkish policy makers take actions to raise students' awareness in technology related careers. For instance, with the demand of the Ministry of Industry, Ministry of National Education has begun to consider including a new course on software coding in both middle school and high school curricula (Ülkar, 2016). On the other hand, nearly half of the students stated occupations different than STEM related professions, which was a surprising result since findings of this study also suggested that students have high interest in STEM careers and positive perceptions about STEM areas. One of the reasons of why students did not report STEM related jobs so much may be because of the lack of knowledge about various career options. This may be caused by their social environment. Our sample was derived from a population that mostly family members work in agriculture, animal husbandry or building worker. Generally, educational level of parents is low. These situations may make these students disadvantaged about being aware of STEM careers. They may need a role model for leading to prefer various STEM occupations. Since these students do not have such a support from their families, the role of schools is getting more important. Actually, in Turkey, middle school students are provided with insufficient guidance about their career plans. Moreover, the existent guidance at school is limited with the information about transition from high school to university. Although it is discussed by policy makers to extend career guidance into middle schools, this type of training is available for only eighth grade students (Yeşilyaprak, 2012).

The second aim of the present study was to investigate the relation between low socioeconomic status students' STEM career interest and their STEM attitude. The canonical correlation analysis suggested that higher level of STEM attitude was positively related to higher level of interest in STEM careers, except technology. In other words, students who have positive attitudes towards science, math, engineering, and 21st century skills tend to be interested in careers in physical science, life science, engineering and math. Math and 21st

century skills had high loadings among STEM attitude variables. Regarding STEM career interest variables, math, physical science, and engineering had high loadings. Based on these high loadings, it can be suggested that higher level of students' math and 21^{st} century skills related to higher interest in physical science, math, and engineering which are also known as difficult and less preferred careers in comparison to other STEM careers. The positive relation between STEM attitude and STEM interest also supports Lent et al.'s (2008) model which was based on SCCT theory. In this model, Lent et al. proposed that students' interest to an academic subject can be enhanced by high self-efficacy and positive outcome expectation in this subject. Similar findings were found for STEM career interest in several studies (e.g., Milner et al., 2013; Unfried et al., 2015). Therefore, in order to increase students' STEM career interest, enhancing their attitudes towards STEM fields is important, especially for low socioeconomic status students in young ages.

There are some limitations for this study. Firstly, it is a cross-sectional study, so the results do not imply cause-effect relationship. Future studies can use experimental or longitudinal designs to investigate STEM attitude and STEM career interest to set cause-effect relation. Second, the present study used only quantitative research methods to investigate low socioeconomic status students' STEM career interest. Future studies can investigate underlying reasons of low socioeconomic status students' career interest in detail by designing qualitative research. Additionally, the participants of this study were conveniently selected from rural areas of a small city and results cannot be generalized to all low socioeconomic status students in Turkey.

To sum up, as mentioned before, middle school years are important for students' interest. Thus to encourage students for choosing STEM related careers, the integration of STEM activities should be started at early levels. Besides that, according to the findings of this study, low socioeconomic status students have limited knowledge about career options. Hence, not only engaging students to STEM related activities, but also making them aware about different STEM careers may also excite their interest in STEM domains. Actually, STEM areas are popular among both students and parents in Turkey (“Career choice”, 2013). However, this popularity may come from extrinsic factors like other significant people’s desire, prestigious occupations, and financials reasons (Sarıkaya & Khorhid, 2009). However, it is important that students get aware of how science is useful in their life, how it is interesting and enjoyable. By integrating STEM activities into curriculum, the underlining reasons of students’ STEM career aspiration may become intrinsic motivation rather than external reasons like social desirability. We think that integrating STEM activities into Turkish schools has potential to educate citizens who have internationally competitive; have 21^{st} century skills and are scientifically literate.

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APPENDIX-1

Original and Turkish version of Semantic STEM survey for career interest

1. Original Semantic STEM survey for career interest (Tyler-Wood, et al., 2010, p. 350)

To me, a career in science, technology, engineering, or mathematics (is):									
1.	Means nothing	1	2	3	4	5	6	7	Means a lot
2.	Boring	1	2	3	4	5	6	7	Interesting
3.	Exciting	1	2	3	4	5	6	7	Unexciting
4.	Fascinating	1	2	3	4	5	6	7	Mundane
5.	Appealing	1	2	3	4	5	6	7	Unappealing

2. Turkish version of Semantic STEM survey for career interest

Fen, Teknoloji, Mühendislik veya Matematik alanında kariyer sahibi olmak ….									
1.	Hiçbir anlam ifade etmiyor	1	2	3	4	5	6	7	Çok şey ifade ediyor
2.	Sıkıcı	1	2	3	4	5	6	7	İlgi çekici
3.	Heyecan verici	1	2	3	4	5	6	7	Can sıkıcı
4.	Büyüleyici	1	2	3	4	5	6	7	Sıradan
5.	Çekici	1	2	3	4	5	6	7	Çekici değil

APPENDIX-2

Stem Career Interest Scale

Aşağıdaki meslek gruplarının ne derece ilginizi çektiğini işaretleyiniz.	Hiç ilgimi çekmiyor	İlgimi çekmiyor	İlgimi çekiyor	Çok ilgimi çekiyor
1. Fizik Bilimleri (astronot, atmosfer ve uzay bilimci, biyokimyacı/biyofizikçi, kimyager, çevrebilimci, yerbilimci, fizikçi)	1	2	3	4
2. Yaşam Bilimleri (tarım ve gıda bilimci, veteriner, biyolog, mikrobiyolog, eczacı, hemşire, tıp doktoru, diş doktoru, tıp ve laboratuvar teknisyeni)	1	2	3	4
3. Teknoloji (bilgisayar güvenlik uzmanı, bilgisayar ve iletişim sistemleri uzmanı, yazılım mühendisi, bilgisayar programcısı, veri tabanı uzmanı, grafiker)	1	2	3	4
4. Mühendislik (uzay mühendisi, mimar, biyomedikal mühendisi, kimya mühendisi, inşaat mühendisi, bilgisayar donanım mühendisi, elektrik mühendisi, endüstri mühendisi, makine mühendisi)	1	2	3	4
5. Matematik (matematikçi, muhasebeci, istatistikçi, maliye uzmanı)	1	2	3	4

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Students' Attitudes towards STEM Education: Voices from Indonesian Junior High Schools

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ABSTRACT

The purpose of this study was to investigate Indonesian students' attitudes towards Science, Technology, Engineering and Mathematics (STEM) through survey study. Data collected from 260 Indonesian junior high school students (47.3% male and 52.7% female) who were studying at public school in East Java province. The Attitudes Towards Science, Technology, Engineering and Mathematics (AT-STEM) questionnaire was developed with Indonesian language and validated through an exploratory factor analysis of participants' responses. In addition, the Pearson product moment was used to measure the correlation among four dimensions of scale. The results indicated that, *first*, the instrument used in this study had satisfactory validity and reliability. The construct validities of the AT-STEM were varying from .60 and .96 and explained 86.84% of the variance. Overall, the Cronbach's alpha coefficient of the instrument was .94. *Second*, the dimension of Mathematics came in the first rank and followed by Science as well as the degree of attitudes towards STEM. *Last*, the results also showed a significant interrelationship among dimensions of attitudes towards STEM.

Keywords: Attitude; STEM; Indonesia; Student.

INTRODUCTION

Education approach for students in Science, Technology, Engineering and Mathematics (STEM) has received increasing attention over the past decade (Honey, Pearson & Schweingruber, 2014). The approach is greater emphasised on these fields for improvements in the quality of curricula and instruction. In other words, STEM is a curriculum based on the idea of educating students in four specific disciplines — science, technology, engineering and mathematics — in an interdisciplinary and applied approach. Rather than teaching the four disciplines as separate and discrete subjects, STEM integrates them into a cohesive learning paradigm based on real-world applications (Hom, 2014).

Several benefits of STEM education include making students become better problem solvers, self-reliant, innovators, inventors, creators, logical thinkers and technologically literate (Morrison, 2006). STEM stimulated students becoming critical thinkers. Some studies have shown that integrating mathematics and science has a positive impact on students' attitudes and interest in school (Bragow, Gragow & Smith, 1995), their motivation to learn (Gutherie, Wigfield & VonSecker, 2000) and achievement (Hurley, 2001). Recently, another study focused on an educational strategy based on professional practices can help students make connections between mathematics, statistics, science and professional practices (Dierdorp et al., 2014). Meanwhile, the study with integrating science and technology

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education by applying "robotic science" indicated that the use of technology in different disciplines will contribute to the nation (Koç & Böyük, 2013). Moreover, the National Academy of Engineering and the National Research Council list fifth benefits of incorporating engineering in K-12 schools: improved achievement in mathematics and science, increased awareness of engineering, understanding and being able to do engineering design, increased technological literacy and interest in pursuing engineering as a career (Katehi, Pearson & Feder, 2009).

Regarding the importance of synergies between science, technology, engineering and mathematics, then students need to be stimulated towards a positive attitude about them at the beginning. While, there has been considerable research conducted about students' attitudes towards science (Osborne, Simon & Collins, 2003) and mathematics (McLeod, 1994), science and mathematics (Özgün-Koca & Şen, 2011), there is less research available about students' attitudes towards technology and engineering. Various categorisations had been developed to capture the attitudes towards STEM which can usefully be applied to students (see, for example, Tyler-Wood, Knezek & Christensen, 2010; Tseng, Chang & Lou, 2011; Faber et al., 2013; Guzey, Harwell & Moore, 2014). However, most of the studies conducted in the US, Europe, Taiwan, Turkey and others and rarely heard from developing countries like Indonesia. As Faber et al (2013) reported that the United States remains a world leader in discovery and innovation today because of STEM education already widespread. Therefore, it is important for a country to improve their creativity and competitiveness through STEM education.

In particular, the concept of STEM in Indonesia became popular in recent years, especially in higher education level. It can be said that the concept is gradually developing in Indonesia. Some researches and events were turned to this concept, such as an innovation strategy to build students' disaster literacy through STEM-D (Science, Technology, Engineering, Mathematics and Disaster) Education (Sampurno, Sari & Wijaya, 2015); a partnership program between local schools in Riau province and Honeywell about science and technology (Honeywell, 2014); and an ongoing project between Columbia University and the Institute Pertanian Bogor to improve the teaching of STEM in Indonesian high schools (Columbia Global, 2014). However, some of these programs were more emphasised on the secondary and higher education rather than the low levels of education, such as elementary and junior high school. Bottia et al (2013) also recommended that the feasible approaches for inspiring, reinforcing and preparing more of the nation's youth to choose a STEM pathway for their futures. Therefore, this study focused on junior high school student for primary potential integrating STEM education.

Based on the introduction and the aforementioned theoretical foundations, the purpose of the current study is to investigate the Indonesian students' attitudes towards STEM. To this end, the aims of this study were twofold:

1. To explore the degree of attitudes towards Science, Technology, Engineering and Mathematics among junior high school students in Indonesia.
2. To examine the interrelationships among dimensions of attitudes towards Science, Technology, Engineering and Mathematics.

METHODOLOGY

a) Research Design

Starting from July to August 2015, the author spread out the questionnaire by traditional survey method to students in three junior high schools in East Java province, Indonesia. Survey designs are procedures in quantitative research in which investigators administer a survey to a sample to describe the attitudes, the opinion, behaviors or characteristics of population (Creswell, 2012). Specifically, the survey is a useful tool to assess efficacy of STEM education programs on students' attitudes towards STEM and STEM careers (Guzey et al., 2014). Figure 1 depicts the process of survey design.

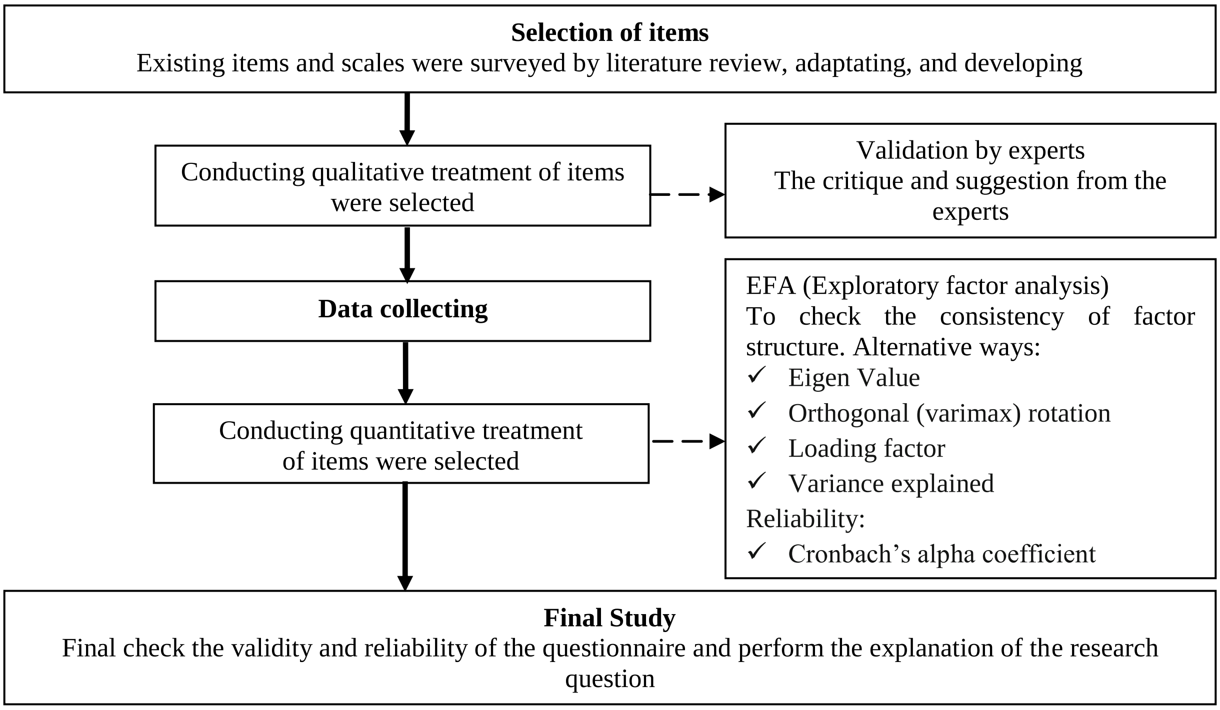

Figure 1. *The process of survey study*

b) Participants

As described in the introduction, this research focuses on the junior high school students. The participants were 260 junior high school students (aged 12–16 years) at public school in East Java Province, Indonesia. In this study, the participants consisted of 47.3% male and 52.7% female. The sample varied of demographic factors, as shown in Table 1.

Table 1. *Summary of sample demographics (N= 260)*

Background	Subtotal	
	n	%
Gender		
Male	123	47.31
Female	137	52.69
Grade		
Seventh (7)	83	31.9
Eight (8)	90	34.6
Nine (9)	86	33.1
Missing	1	0.4
Total	260	100.0

c) Instrument

The instrument used in this study was the Attitudes Towards STEM Questionnaire (AT-STEM). Derived from other attitudes questionnaires (such as Faber et al., 2013 and Guzey et al., 2014), this STEM attitudes questionnaire was examined by three experts. Originally, the instrument consisted of 27 items for AT-STEM, which used English version (see Appendix).

The instrument distributed into four crucial conceptions of STEM education, including Science (S), Mathematics (M), Technology and Engineering (T-E) and Science, Technology, Engineering and Mathematics (STEM). The items were coded on a five-point-Likert-type scale, ranging from 1 (strongly disagree) to 3 (neutral) to 5 (strongly agree). The higher scores indicated the greater attitude towards STEM education. By translating process into Indonesian and checking the content validity, the instrument feasible to Indonesian students. Two items with low factor loading were deleted and twenty-five items remained in the questionnaire. The information of validity and reliability for the scale is shown in Table 2.

d) Procedure

The data collection of this study was accomplished with printed surveys. Invitations were first distributed to the potential participants (i.e. Junior high school students in East Java Indonesia) through email, face to face requests and science teachers' assistance. This made sure that all the participants volunteered to take part in and to respond to the questionnaires. At the beginning of the surveys, the students were informed of the aim of this study and the purposes of the questionnaires. In the questionnaires, the author only addressed the intention to investigate students' perspectives and confidence about attitudes towards STEM education. However, the issue about STEM education was relatively new in Indonesia. Therefore, in the first step the researcher with supporting by three science teachers introduced and demonstrated teaching and learning process by integrating STEM education as a foundation for students' prior knowledge.

The Hydrogen fuel cell was used to integrate between formal science curricula and STEM education. The solar Hydrogen science kit guided students to invent their own clean energy applications using fuel cells and renewable hydrogen created using solar energy and water (see Figure 2). The set was equipped by a complete curriculum on renewable energy with easy experiment, manual kits and background history on the technology. The sub-topics of the experiment include: the effect of heat on solar panels, finding the solar panel's maximum power, electrolysis mode (generating Hydrogen and Oxygen from water) and fuel cell mode (generating electricity from Hydrogen and Oxygen).

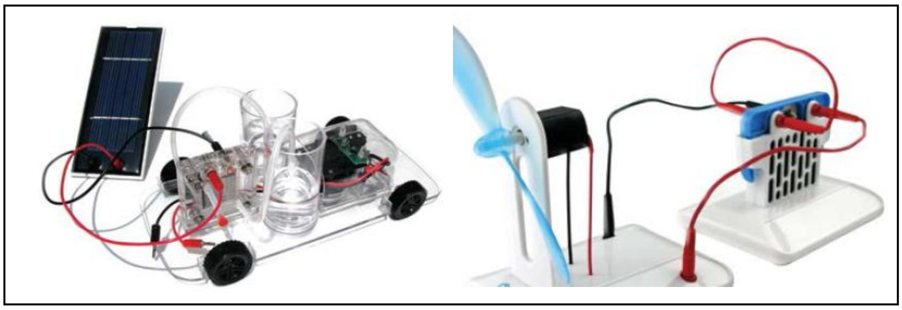

Figure 2. *The Solar Hydrogen Science Kit (Horizon Educational, 2015)*

e) Data Analysis

The Attitudes Towards STEM Questionnaire (AT-STEM) was developed with English version and translated into Indonesian language. The data analysis of this study was threefold. First, the author determined whether the data were appropriate to perform an Exploratory Factor Analysis (EFA) through Kaiser–Meyer– Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity. Hereafter, analysis of data used SPSS's software for checking the validity and the reliability of instrument. According to the validation criteria of exploratory factor analysis suggested by Stevens (2002), the retained items should preferably be weighted greater than .4. In other words, the items with a factor loading less than .4 were deleted. The principal component extraction with orthogonal (varimax) rotation was conducted to estimate the number of factors proposed in this study, which contributed to the construct validity of each instrument. Furthermore, the Cronbach's alpha coefficient for each scale of the AT-STEM instrument was calculated to ensure the reliability of each factor as well as the overall alpha coefficients of the instrument. Second, the mean and standard deviation of each dimension was used to depict the degree of attitudes towards STEM. Third, the Pearson product moment was used to measure the correlation among four dimensions of AT-STEM.

FINDINGS

a) Exploratory Factor Analysis of AT-STEM

To validate the AT-STEM instrument, an exploratory factor analysis with a varimax rotation was performed to clarify its structure. Originally, from 27 items performed the Kaiser–Meyer– Olkin (KMO) value was .87 and the result of Bartlett's test was significant (X^2 = 12972.31, $p < .001$), indicating that the samples were appropriate for factor analysis. However, two items were deleted because these items with a factor loading of less than .4 (e.g. S3: Knowing science will help me earn a living and TE3: I am curious about how electronics work). A possible reason to explain these findings is students maybe confidence that science will be important in their life, but it doesn't necessarily help them earn a living. In addition, some students feel not too curious about how electronics work rather than what makes machines work and how imagine creating new products. It can be understood that the electronic materials (e.g. robotics, complex electrical circuit) are very minimal applied in the science curriculum in Indonesia. This situation is different with another study. Koç & Böyük (2013) who applied "robotic science" in Turkey found some contributions to science and the nation.

Hereinafter, the participants' responses were grouped into the following four proposed factors—(1) science, (2) mathematics, (3) technology and engineering, and (4) STEM—and a total of 25 items were retained in the AT-STEM instrument. The KMO value was .86 and the result of Bartlett's test was significant (X^2 = 12854.49, $p < .001$), indicating that the samples were appropriate for factor analysis. The detailed descriptions and sample items of the four dimensions are presented as follows:

1. Science (S, six items): exploring the students' attitudes towards science, such as science in school, out of school, and life's work, and a career in science.
2. Mathematics (M, seven items): exploring the students' attitudes towards mathematics, such as learning mathematics, grade and choosing career in mathematics.
3. Technology-Engineering (TE, five items): exploring the students' attitudes towards technology and engineering, such as using technology, new machine, creating new product and a career in engineering.
4. STEM (seven items): summarising the students' attitudes towards integrating science, technology, engineering and mathematics, such as using creativity and innovation for future work and a career that involves science, mathematics, engineering, or technology.

The eigenvalues of the four proposed factors from the principal component analysis were all larger than one, and the total variance explained was 86.84% (see Table 2), which was validated to clarify the structure of the instrument. The dimension of STEM itself can explain the highest variance with achieved 25.78%. It means the students' attitudes can be more explored from the combination of four terms together: science-technology-engineering-maths than each factor separately. Table 2 also shows factor loading of attitudes towards STEM education designed to measure each factor were between .60 and .96, so that it meets the criteria of Stevens (2002). In addition, the reliability in terms of Cronbach's alpha coefficients for these factors were .97, .93, .99, and .98, respectively, and the overall alpha value was .94, suggesting that these factors had high internal consistency for assessing the participants' four dimensions of attitudes towards STEM.

Table 2. *Rotated factor loadings and Cronbach's alpha of the AT-STEM questionnaire*

	Factor 1: S	Factor 2: M	Factor 3: TE	Factor 4: STEM
Factor 1: Science (S), α = .97, variance explained = 21.01%				
S1	.89			
S2	.91			
S4	.93			
S5	.93			
S6	.87			
S7	.89			
Factor 2: Mathematics (M), α = .93, variance explained = 20.53%				
M1		.92		
M2		.91		
M3		.60		
M4		.92		
M5		.85		
M6		.85		
M7		.64		
Factor 3: Technology-Engineering (TE), α = .99, variance explained = 19.52%				
TE1			.96	
TE2			.96	
TE4			.95	
TE5			.96	
TE6			.95	
Factor 4: STEM, α = .98, variance explained = 25.78%				
STEM1				.94
STEM2				.96
STEM3				.95
STEM4				.91
STEM5				.91
STEM6				.94
STEM7				.93

Note: Overall Cronbach's α = .94. Total variance explained = 86.84%.

b) The Degree of Attitudes Towards Science, Technology, Engineering and Mathematics

Table 3 presents the degree of attitudes towards Science, Technology, Engineering and Mathematics among students. The dimension of Mathematics came in the first rank with a mean of (4.12) and standard deviation of (0.66) followed by Science with a mean of (3.99) and standard deviation of (0.61). Both of these two dimensions performed greater than the grand mean (3.88). Meanwhile, the technology and engineering appeared in the last rank with a means of (3.58) and standard deviations of (0.67). This result indicated that Mathematics became the dominant preference among student and following by Science compared to Technology and Engineering or STEM itself. This result represents the proportion of mathematics in junior high school curriculum greater than others.

Table 3. *Summary of the degree of attitude towards STEM*

Dimension	M	SD	Rank
Science (S)	3.99	0.61	2*
Mathematics (M)	4.12	0.66	1*
Technology and Engineering (TE)	3.59	0.67	4
STEM	3.83	0.62	3
Total	3.88	0.44	

* mean > grand mean

c) The Interrelationships among dimensions of Attitudes Towards Science, Technology, Engineering and Mathematics

The interrelationships among dimensions of STEM and STEM itself presented a varying results (see Table 4). The coefficient of correlation range from .220 to .409 that was useful for limited prediction based on the criteria of Creswell (2012). However, each dimension correlated each other at α =. 01. The result confirmed to us that most participants will find that they use a mix of these different attitudes, but some participants find they have strong tendencies towards one attitude. In other words, the students have a consistency in their attitudes regarding the component of STEM separately to the whole of STEM as an integral part of science, technology, engineering and/or mathematics. These findings address the goals of science, technology, engineering and mathematics education while providing meaningful knowledge, abilities and experiences for students.

Table 4. *The interrelationships among dimensions of STEM*

Dimension	1	2	3	4
1. Science (S)	--			
2. Mathematics (M)	.409**	--		
3. Technology and Engineering (TE)	.283**	.220**	--	
4. STEM	.250**	.344**	.300**	--

** $p < .01$

DISCUSSION

The study was designed to investigate the Indonesian junior high school students' attitudes towards STEM. Specifically, the study explored the degree of attitudes towards Science, Technology, Engineering and Mathematics, and examined the interrelationships among its dimensions. Supported by three science teachers, then the study was started by introducing and demonstrating teaching and learning process and integrating STEM education with topic "Hydrogen Fuel Cell". As stated as Stohlmann, Moore & Roehrig (2012), a support, teaching, efficacy and materials of considerations for teaching integrated STEM education was developed through a year-long partnership with a middle school. The STEM model is a good starting point for teachers as they implement and improve integrated STEM education. In the following step, a survey study was conducted to explore students' attitudes towards STEM.

In general, the findings indicated that the instrument (AT-STEM) used in this study had satisfactory validity and reliability. The instrument performed well in terms of the variance was explained (86.84%). In addition, the overall of Cronbach's alpha coefficient was .94 also indicated the high reliability scale. Therefore, the instrument can be used for further study, especially for the upper elementary school and junior high school which adopting STEM approach. For each finding based on the aims of the study will be discussed at the following part.

Turning to the first aim, the dimension of Mathematics came in the first rank and followed by Science as a component of STEM implied that Mathematics is a basic knowledge of bringing foundation to the other discipline. At the junior high school level (grade 7-9), instruction in science and technology are usually the responsibility of separate teachers. These findings also in-lined with Özgün-Koca & Şen (2011) who studied Turkish secondary school students' attitudes towards mathematics and science and found that students had generally positive attitudes towards mathematics and science courses. Mathematics was the most dominantly and favoured subject in Turkey (Özgün-Koca & Şen, 2011) as well as Indonesia (Frensidy, 2014). However, technology and engineering were leaving behind and need full supporting from science and mathematics. The science and technology standard of the NSES [National Research Council (NRC), 1996] represents content that goes well beyond typical science (Yager, 2004).

Regarding the second finding, there were significant interrelationships among the four dimensions of AT-STEM: Science (S), Technology-Engineering (TE), Mathematics (M) and STEM. In junior high school, the maths and science teacher is frequently part of a "team" of grade-level teachers who coordinate and ideally integrate instruction among the traditional academic areas. Mathematics and Science are more dominant on the curriculum content. Information and Technology (IT) teachers, on the other hand, teach one of the "specials". In many cases, students attend these specials while their academic teachers meet and plan as a team, for example, in terms of engineering, the science-physics teacher will cover the information about machine, product, engineering, electricity, electronics, and others. Thus, integration is more difficult at this level. So that is why this situation in-lined with Foster (2005) and the result of interrelationships among dimensions of STEM above which performed limited prediction each other even though there was significantly correlated in statistics. Figure 3 illustrates the interrelationships among science, mathematics, technology and/or engineering in junior high school in Indonesia based on the current situation and Table 4 above.

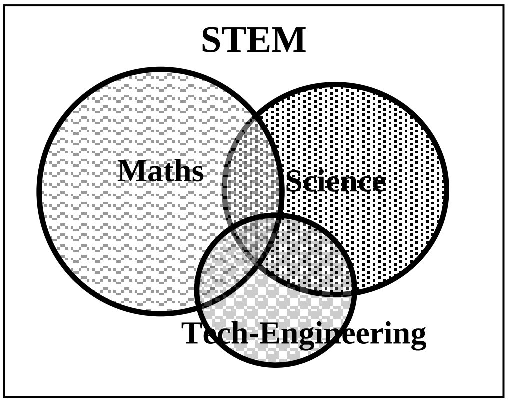

Figure 3. *The interrelationships among mathematics, science, technology and/or engineering in junior high school*

CONCLUSION and IMPLICATIONS

The result confirmed us that the instrument used in this study had satisfactory validity and reliability. The construct validities the AT-STEM were varying from .60 and .96 and explained 86.84% of the variance. Overall, the Cronbach's alpha coefficient of the instrument was .94. The dimension of Mathematics came in the first rank and followed by Science as a component of STEM. However, these instruments were developed to measure attitudes towards one of the STEM fields; thus, they follow the assumption that students learn STEM subjects only through traditionally, separated STEM education. Students' attitudes towards STEM are an important factor influencing student motivation to learn STEM subjects and pursue a STEM career (Maltese & Tai, 2011). The results also showed the significant interrelationships among dimensions of attitudes towards STEM. Surprisingly, STEM education in Indonesia still becomes a new issue in the current year. Therefore, the implications delineated contribute to the improvement of science curriculum in Indonesia and students' career.

In fact, STEM is everywhere. Our homes, our nourishment, our health, our safety, our relationships with family and friends and neighbourhoods, our jobs, our leisure are all profoundly shaped by technological innovation and the discoveries of science (Office of the Chief Scientist, 2013). STEM has and will continue to provide for everyone – to make available the new knowledge and technologies that are needed to address challenges, and to underpin new goods and services. For future study, it is important to take place the STEM education programs and to consider the 21st century skills as a foundation for STEM careers. Schools are integral to augmenting, diversifying, and equalising the STEM workforce because schools can inspire and reinforce students' interest in STEM in addition to academically prepare them to be able to follow a STEM career (Bottia et al., 2013). Therefore, the subject areas that involve mathematics, science, engineering and/or technology, and lists of jobs connected to each subject area (such as physicist, chemist, astronomer, biological scientist, mathematician, lab technician, analyst, veterinarian, etc.) need to be explored. This study also motivates K-12 schools, community colleges, and universities implement new STEM and 21st century skills programs, which is the fact that students in Indonesia have been performing below those from other countries.

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APPENDIX-1

Attitudes Towards STEM (AT-STEM) Questionnaire

Dear students,
Thanks a lot for completing this questionnaire. It is to understand your response to attitudes towards STEM. Your fill-in information will be used only for research and kept absolutely confidential. Please tick a choice according to your own perception. Thanks for your help. If you are interested in the result of my research, please give us a call.

Directions:

1. *There are five choices after the statement: Strongly Disagree (SD), Disagree (D), Neutral (N), Agree (A) and Strongly Agree (SA).*
2. *Please tick (√) the choice in the box according to your opinion.*

Thanks a lot.

Code	Items	Option				
		SD	**D**	**N**	**A**	**SA**
		1	2	3	4	5
S	**Science**					
S1	I know I can do well in science.					
S2	I expect to use science when I get out of school.					
S3	Knowing science will help me earn a living.					
S4	Science will be important to me in my life's work.					
S5	I will need science for my future work.					
S6	I would consider a career in science.					
S7	I can handle most subjects well, but I cannot do a good job with science.					
M	**Mathematics**					
M1	I enjoy learning mathematics.					
M2	I am good at math.					
M3	I am the type of student to do well in math.					
M4	I am sure I could do advanced work in math.					
M5	I can get good grades in math.					
M6	I would consider choosing a career that uses math.					
M7	I can handle most subjects well, but I cannot do a good job with math.					
TE	**Technology and Engineering**					
TE1	I enjoy learning to use technology.					
TE2	If I learn engineering, then I can improve things that people use every day.					
TE3	I am curious about how electronics work.					

TE4	I am interested in what makes machines work					
TE5	I like to imagine creating new products.					
TE6	I believe I can be successful in a career in engineering.					
STEM	**Science, Technology, Engineering and Math**					
STEM1	I would like to use creativity and innovation in my future work.					
STEM2	To learn engineering, I have to be good at science and mathematics.					
STEM3	Knowing how to use math and science together will allow me to invent useful things.					
STEM4	Science, technology, engineering and mathematics make our lives better.					
STEM5	Science, technology, engineering and mathematics are very important in life.					
STEM6	Science, technology, engineering and mathematics are good for the future of our country.					
STEM7	I would like to have a job that involves science, mathematics, engineering or technology.					

Part II: Personal Information

1. School name : ____.
2. Grade :
   - ☐ (1) VII (7)
   - ☐ (2) VIII (8)
   - ☐ (3) IX (9)
3. Gender :
   - ☐ (1) Male
   - ☐ (2) Female
4. In the future, would you like to participate in this study? Please give me your e-mail if you attend all future researching activities. Thank you for your help.

____.

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Pre-Service Science Teachers' Cognitive Structures Regarding Science, Technology, Engineering, Mathematics (STEM) and Science Education *

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ABSTRACT

The aim of this study is to reveal pre-service science teachers' cognitive structures regarding Science, Technology, Engineering, Mathematics (STEM) and science education. The study group of the study consisted of 192 pre-service science teachers. A Free Word Association Test (WAT) consisting of science, technology, engineering, mathematics and science education concepts and semi-structured interview records were utilised to reveal their opinions regarding these concepts and inter-conceptual relations were used as data collection tools. While the WAT was implemented with all of the pre-service teachers, semi-structured interviews were carried out with only eight of the pre-service science teachers. Using two data collection tools via triangulation, enabled the researchers to obtain similar and varied findings. According to the frequencies, WAT was analysed using the cut-off point (CP) method; hence, concept network maps were composed and interviews were descriptively analysed. The findings of the study revealed that pre-service teachers' cognitive structures involved STEM disciplines and science education were quite independent from each other. Also, they could not make a distinction between science concept and science education concept, nor associate 'technology, engineering and mathematics' concepts with science and science education' concepts.

Keywords: Cognitive Structure; Pre-service Teachers; STEM; Science Education; Word Association Test.

INTRODUCTION

Knowledge production and innovation have become more important than ever before for various countries since the last century. Moreover, it has become the biggest power factor for those countries. The USA, in particular, and many other countries realized how knowledge production and its contribution to development was exhibited when Russia launched the Sputnik. Then, these countries embarked on education reforms in order to keep up with the changes and developments taking place in the rest of the world (Laugksch, 2000). The most important of these initiatives has been in science education. First of all, it was found in the USA that more attention should be given to science education and that everybody should be science literate (American Association for The Advancement of Science [AAAS], 1990)

* A preliminary report of this study was presented at the XI. National Congress of Science and Mathematics Education [Ulusal Fen Bilimleri ve Matematik Eğitimi Kongresi] in Adana-Turkey (11-14 September 2014)

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However, as change and development continued rapidly in this period, the growth of scientific knowledge has brought about the development of technology and many disciplines. Considering the situation in recent years, these changes have led the structure of the problems encountered becoming more complex because change and development have become the source of the complex problems that are societal, environmental, economic and social. In this case, it has become a necessity to raise individuals who can cope with these problems, so the necessary skills individuals are required to gain have increased and become more complex. Therefore, this requirement has revealed the importance of science education. Primarily, it was stressed that science education was not enough, so knowledge in science-technology-society and environment should also be acquired (Deboer, 2000; Hollenbeck, 2006). However, it is regarded that these areas are still not enough to keep pace with the change. Especially because it was stated by the educational policy makers and educational researchers that interdisciplinary relationships are important and carrying out implementations in only one discipline in science education would not serve either national of global purposes and this has been emphasized in many research reports (e.g., NRC, 2012; Alberta Education, 2007). Furthermore, the STEM education approach, which is based on the integration of science, technology, engineering and mathematics (STEM) disciplines, is involved in education reforms and implementations have been increasing rapidly.

Similarly, when Turkey's science education goals are examined, it is possible to see the same goals and efforts. The purpose of science education is to have individuals gain life skills, which will bring solutions to the problems they encounter in their daily life, and to develop their scientific literacy levels (MEB, 2013). To achieve this goal, education systems and environments should be reorganized for the individuals to keep up with the changes and developments in order to make contributions to them. Because of the information that an individual is required to acquire, both in the knowledge and skill dimensions, in the science curriculum, which was revised in 2013. Moreover, as in the international reports, the reports which were prepared regarding Turkey's vision for the year 2023 and educational policies reveal that STEM education should be defined on our country's scale (Çorlu, 2014). Although technology and mathematics are not integrated into Turkey's science education, they are included in science education. But, the integration of engineering into science education is a new idea. In this direction, it seems very early to mention education standards determined for K-12 engineering education or learning outcomes, as defined regarding disciplines in the national context. In addition to this, STEM research studies are very rare in the studies, which have been carried out in Turkey (Bozkurt, 2014; Ercan & Şahin, 2015). But in the Report on STEM Education in Turkey (Akgündüz, Aydeniz, Çakmakçı, Çavaş, Çorlu, Öner et. al, 2015, p.20), it was emphasized that STEM education is a necessity for Turkey. For this reason, teachers in particular and pre-service science teachers, who will be the teachers in the near future, should be trained for the adoption and implementation of STEM education. This is a new teaching approach in Turkey, so they should be supported because a qualified science teacher should be aware of scientific developments and changes which will occur in the light of these developments and they should have the knowledge, competency and qualifications to aid their students to gain knowledge, skills, attitudes and values in this field. In order to actualize this, teachers and pre-service teachers, who are going to use STEM education in their lessons, should understand STEM disciplines and nature very well because teachers transfer their understanding and perceptions to their students (Palmquist & Finley, 1997). Therefore, revealing the pre-service teachers' cognitive structures regarding STEM and science education is important in the development of a course and for the transfer their understanding to the students regarding the following issues: how they understand or conceptualize STEM disciplines, how they are required to conceptualize them, how they establish relationship between these disciplines and how STEM disciplines will be integrated into science education. Therefore, it is important to examine their cognitive structures (for STEM and science education). It is thought that the results of this study (the cognitive structures of pre-service science teachers) will provide guidance on teaching intervention. Then, with information regarding these interventions, teachers can develop knowldege and skill in the STEM disciplines. Also, the cognitive structure of pre-service science teachers represents their perceptions of the integration of the STEM disciplines.

Cognitive structure is a form of structured information and shows the relationship of concepts in memory (Shavelson, 1974). Although it is difficult to explain an individual's cognitive structure, their ideas about key concepts provide important data to discover their cognitive structure (Gilbert, Boulter & Rutherford, 1998). Moreover, revealing cognitive structure does not only discover an individual's conceptual knowledge, or ideas, but also it helps them to understand the transitions between concepts and relationships (Tsai & Huang, 2002). Pre-service teachers' cognitive structures regarding STEM disciplines and their conceptual understanding are important when considering their teacher training.

In this regard, the purpose of this study is to reveal pre-service science teachers' cognitive structures and their understanding of STEM disciplines and science education. Regarding this purpose, answers will be sought for the following questions: "What are the pre-service science teachers' cognitive structures regarding science, technology, engineering, mathematics and science education like?" and "What kind of relationship do the pre-service science teachers establish between STEM disciplines and science education?"

METHODOLOGY

Phenomenology, which is one of the qualitative research methods, was used in the study to describe the existing situation. Phenomenological design focuses on the phenomenon or particular situation which we are aware of but where we do not have in-depth and detailed understanding. In phenomenological design studies, the purpose is usually to reveal individual perceptions related to a phenomenon and their interpretations (Yıldırım & Şimşek, 2011).

The study group of the research consisted of a total of 192 pre-service science teachers (freshman N=51; sophomore N=52; junior N=44 and senior N=45) in the Department of Primary Education, Faculty of Education, in a middle-sized state university in the northeast of Turkey. The study was carried out during the fall term of the 2013-2014 academic years.

a) Data collection

The data of the research study was gathered via the Word Association Test and semi-structured interviews.

Word Association Test (WAT)

The techniques used for the investigation of cognitive structures are free word associations, controlled word associations, topic trees, concept network maps, and flow charts. This study used a free word association test (WAT), which is one of the methods used to reveal individuals' cognitive structures and the relationship between the concepts in this structure and to determine whether the relationship between the concepts in the long-term memory are adequate and meaningful (Snow & Lochman, 2012:8; Bahar, Johnstone & Sutcliffe, 1999); it has been used by many researchers (e.g. Ercan, Taşdere & Ercan; 2010).

When planning a WAT, the following points should be considered carefully: each concept, which is related to the subject should be put on separate pages, if they are on the same page, they should be displayed consecutively and at least 10 times, and a space next to the word should be given for pre-service science teachers to write down the concepts that come to their minds. Bahar and Özatlı (2003) explained that the reason why the key concepts were written one under another was to prevent students from moving away from the key concept.

While implementing a WAT, students are asked to write the concepts they recall associated with any concept, consecutively, regarding their cognitive levels between 30 seconds and one minute and the reasons are explained like this:

> *It is stated in the literature that an ordered response given for any key word by a student from his long-term memory asserts relations between the concepts in his cognitive structure and this shows semantic proximity. Regarding semantic proximity or semantic distance effect, if the two concepts are very close to each other in terms of distance, they have a very close relationship in semantic memory. Moreover, during the recalling process, because cognitive investigation will be much faster, the responses associated with both concepts will be much quicker* (Bahar & Özatlı, 2003).

The WAT in this study includes five key concepts from science, technology, mathematics, engineering and science education. Each concept was written one under another and repeated 10 times on one page and a page layout was designed as shown in the example.

- Engineering…………………
- Engineering …………………
- Engineering ………………… (10 times)

During the implementation of the test, the pre-service teachers were asked to write the related words they recalled about the given key concepts in 40 seconds and the time was controlled by the researchers. At the end of 40 seconds, the students were asked to move on to the next key concept and the test was completed in that way.

Semi-Structured Interviews

Semi-structured interviews were carried out with eight pre-service teachers, two volunteer teachers from each grade. The aim of the interviews was to reveal pre-service teachers' views regarding how they explained and associated "science, technology, engineering, mathematics, and science education concepts". Each interview consisted of six questions. The first researcher carried out the interviews face-to-face and individually and each interview lasted approximately 10 minutes.

b) Data analysis

For the analysis of the responses obtained from the word association test, the total number of the responses given to each stimulus word, whether the given responses had a relation with the stimulus and the overlapping between the response lists, which was a measure of semantic proximity between the two stimulus words for an individual, must be taken into consideration (Preece, 1976). Concepts that are created in this context are associated with the other concepts to give the integrity of the cognitive structure and concept networks are composed (Tsai & Huang, 2002).

In this study while the WAT was analysed, the concepts written by each pre-service teacher for each key concept were determined one by one and a frequency table was composed to determine how many different responses were given and how many times these responses were repeated for which key concepts. The Cut-off Point (CP) technique suggested by Bahar et al. (1999) was used to elaborate and evaluate the concepts, which were associated with key concepts in concept network maps. In this technique, in the frequency table, fewer than 3 or 5 words for the most frequently given response word for any key concept in a word association test was used as a cut-off point and the responses were found to have higher frequencies than this response frequency were written in the first part of the network map.

Then, the cut-off point was periodically decreased and the process continued until all the key words appeared on the network map. Because of the large number of participants in this study, the cut-off point was determined to be 40 and the concept networks were composed with a 10-frequency interval. As the cut-off point increased, the frequency of repetition of the concept decreased and this means that its frequency reduces. Therefore, the evaluation was that very few participants recalled that word.

Semi-structured interviews were firstly transcribed and then they were analysed descriptively. The pre-service teachers, who were interviewed, were coded in order as, PT1 (first pre-service science teacher), PT2, PT3, PT4, PT5, PT6, PT7, and PT8 and their views were presented. For supported word associations, the results presented the interested views of the pre-service science teachers as quotations.

In order to provide the validity of the results, two researchers conducted the analysis and network maps were created as common. The process of analysis was explained in detail; also the findings were supported by quotations from the interviews.

FINDINGS

This section includes the findings, which were obtained from the analysis of the data collected via the data collection tools and these findings were supported by the views of the pre-service science teachers.

Generally, the first cut-off point (CP) was determined to be 40 and above, to create a concept network map. The following cut-off points were decreased three times. The concept network maps for each cut-off point level are given below.

Figure 1 presents the repeated concepts that were determined as 40 and above, regarding STEM and science education.

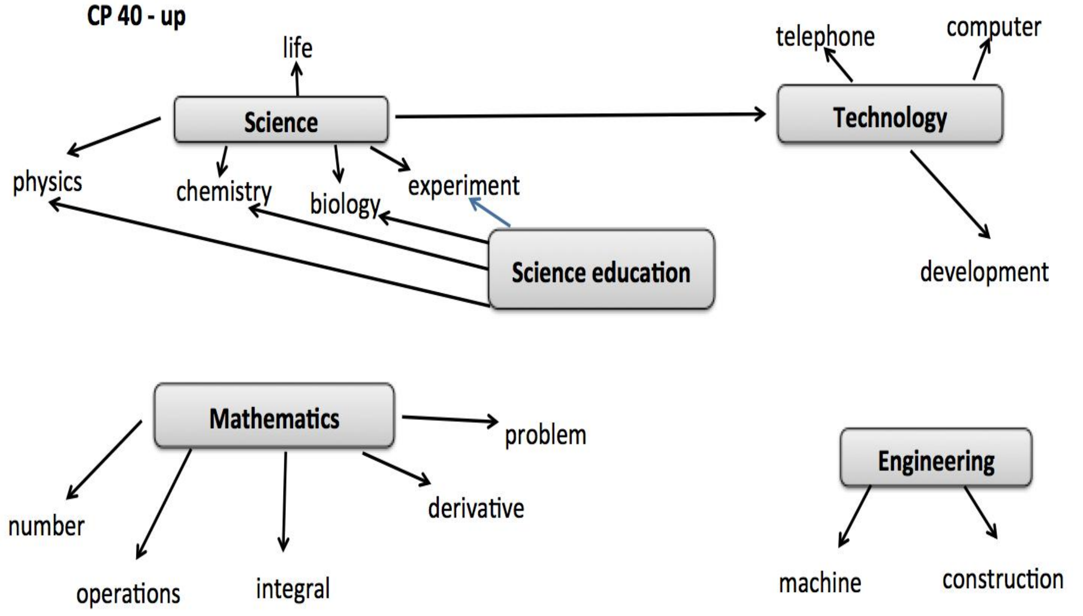

Figure1. *Concept network map created for the concepts with a cut-off point of 40-upwards*

When Figure 1 is examined, it is seen that in the concept network map, which was created with CP 40 - upwards, shows that the pre-service teachers associated science with life, physics, chemistry, experiment and technology concepts, they associated mathematics with numbers, operations, derivatives, integrals and problem concepts; technology was associated with science, development, computers and telephone concepts; engineering was associated with machines and construction concepts; and finally, science education was associated with physics, chemistry, biology and experiment concepts.

Similarly, PT2 explained their views on science, as *"…Science explains the events happening in our life. For example, how we stand on the Earth. This is physics, chemistry, and biology… In fact, it is everything…".* PT6 explained their views on technology, as *"… technology covers all of the gadgets and tools which we use, like computers, tablets, telephones, calculators…. all these things were created by using science… ".* PT7 explained their views on mathematics, as "*Mathematics is derivative, integral, operations, geometry, trigonometry, and limited. It is about calculation.…"* PT 4 explained their views on mathematics, as *"Science education is the teaching of science, chemistry and biology to students by the teachers…".*

It was found that pre-service teachers were unable to establish a relationship between science education, technology, engineering and mathematics concepts. Also PT6 explained their views on engineering, as *"Engineering is construction, food, electricity, trade, machines and computers. Usually, they draw and introduce what they are going to produce. The other workers do what they draw. …. A food engineer focuses on how food is processed with which technique."*

Figure 2 presents the repeated concepts that were determined between 30 and 39, regarding STEM and science education.

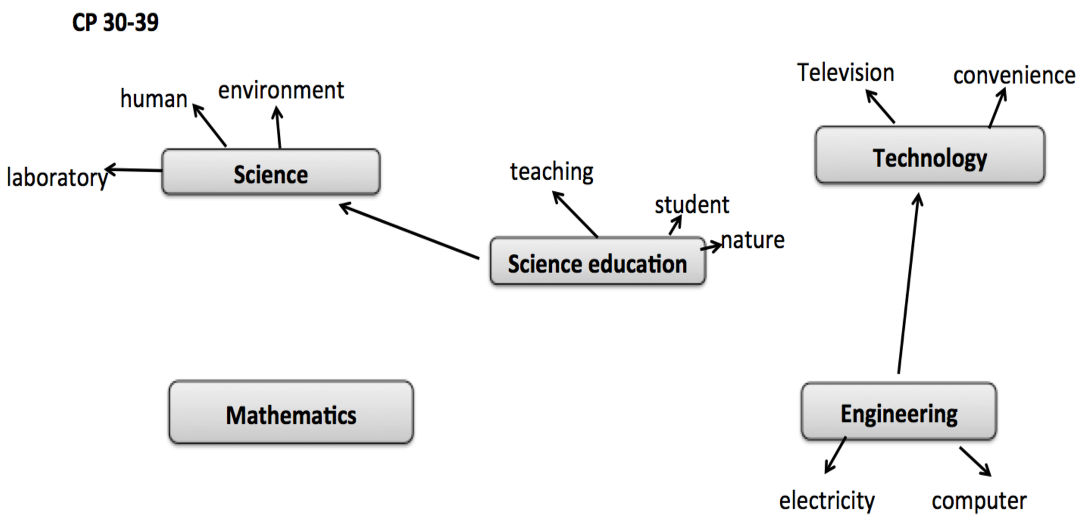

Figure2. *Concept network map created for the concepts with a cut-off point of 30 -39*

When Figure 2 is examined, it is found that, in the concept network map created with CP 30-29, the pre-service teachers associated science with environment, human and laboratory concepts; technology with television and convenience concepts; engineering with technology, electricity and computer concepts; and science education with science, nature, teaching and student concepts and they were different from the concept network maps formed at higher cut-off points.

Similarly, PT8 explained their views on the network of engineering and technology, as *"… technology enables us to do our work easily without it becoming too difficult. To exemplify, telephones, computesr, and television facilitate communication. In fact, lifting jacks, bulldozers, and load pullers in construction are the technologies used by engineering…".* PT5 explained their views on network mathematics and technology: *"…mathematics is numbers and operations. It helps us to calculate something. In fact, we can say that it is not only calculation… It is all of the tools we use, like computers, tablets, telephones, calculators … these are the things, which are created by using science…".* PT2 explained their views on science education, as: "*Science education is whatever science is… ".* Also, PT4 explained their views on engineering, as:*"Engineering is what engineers do. For example, a civil engineer constructs buildings, an electrical engineer works on power* *connections, a mechanical engineer designs and develops machines."* Also, PT3 explained their views on the networks of all concepts *"...I think that there is no relation between engineering and science or science education…. Engineers use technology and mathematics. In other words, they are similar…".*

Figure 3 presents the repeated concepts that were determined between 20 and 29, regarding STEM and science education.

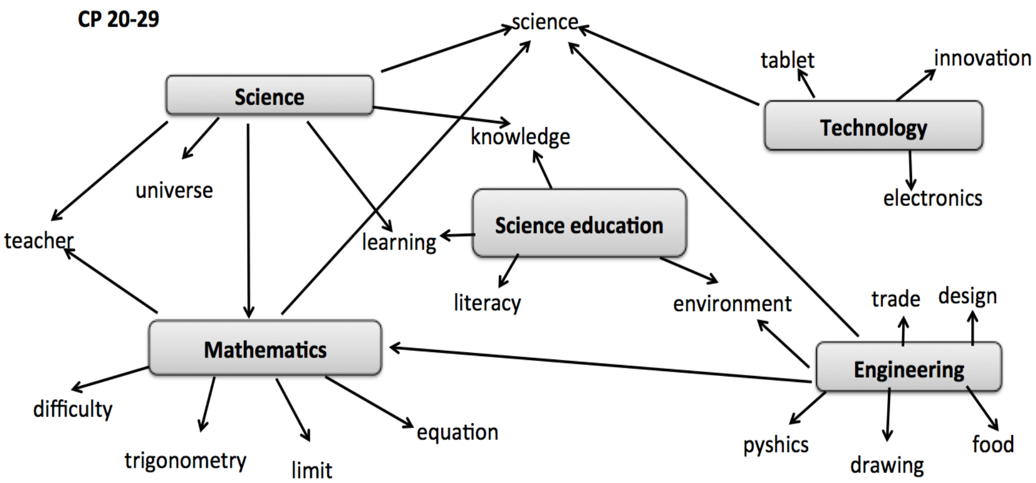

Figure3. *Concept network map created for the concepts with cut-off point 20 -29*

When Figure 3 is examined, the concept network map created with CP 20-29, reveals a different pattern from the concept network maps, which were formed at higher cut-off points. The pre-service teachers associated science with learning, knowledge, teacher, and universe concepts; technology with science, tablets, electronics and innovation concepts; engineering with the concepts of trade, design, food, drawing, physics, mathematics and environment; mathematics with concepts of difficulty, trigonometry, limits and equations, and science education with knowledge, learning, literacy and environmental concepts. Moreover, while science was associated with mathematics directly and with teacher concepts, science education was associated with knowledge. In addition, it is observed that engineering was associated with science education and environment, and directly with mathematics and science.

Similarly, PT2 explained their views on matematics, as *"...mathematics is used in science, technology and engineering to lift the materials to be used for construction. But people are not aware of it…"*

Figure 4 presents the repeated concepts that were determined between 10 and 19, regarding STEM and science education.

When Figure 4 is examined, it is found that from the concept network maps formed at upper cut-off points, the concept network map formed with CP between 10 and 19 associated all of the concepts with more concepts. While the pre-service teachers associated science and technology with microscopes, they established a relationship between science and science education with observation concepts. Technology was associated with science education and with benefit concept. Engineering and science education were associated with the concept of school. Moreover, mathematics was associated directly with technology and science education was associated with lesson concept.

PT1 explained their views on network of all concepts, as *"…We use technology while teaching science. We also perform arithmetic operations…"* Also, PT8 explained, *"We teach science in science education. We can also use technology. But, scientists use science to discover technology. Engineers use technology, too. Mathematics is used both in engineering* *and mathematics. But, engineering is not used in science education. Maybe it can be given as an example from daily life. As I said before, a forklift truck used to lift and move materials to the construction and standing in the balance can be a daily life example when explaining equilibrium. In fact, all of them are related to each other. But this relation is not an indispensable relation.".*

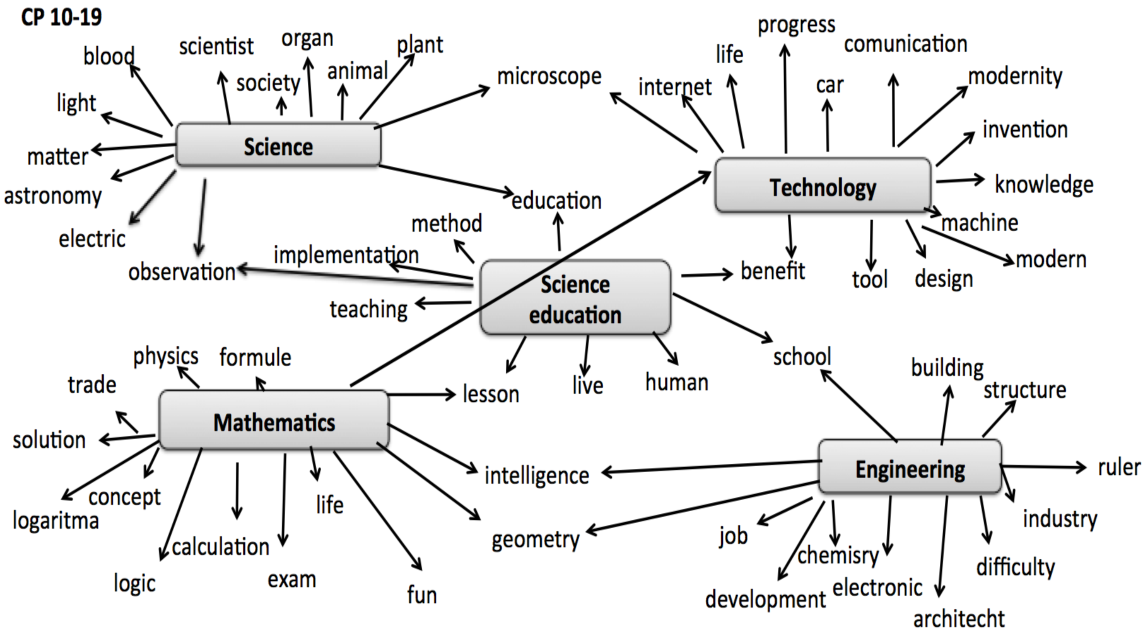

Figure4. *Concept network map created for the concepts with a cut-off point of 10 -19*

CONCLUSION and DISCUSSION

It is important to understand the nature of individuals' opinions in order to discuss their views about science and learning effectively (Finson & Others, 1995; McDuffie, 2001). The ideas of students who have the required qualifications to become a scientist in the early periods of their education and who generate opinions about science and learning, frequently depend on the messages received from out of school settings (Jones, Howe & Rua, 1999). At the end of the study, the pre-service science teachers' statements obtained from both the WAT and the interviews, revealed that they could not adequately differentiate between science and science education and they explained them as physics, chemistry, biology, experiments, learning and nature. The Turkish Language Association defined science as "the common name given to physics, chemistry, mathematics and biology", and the "implementation of data obtained from physics, chemistry, mathematics and biology at work and on a building site." (URL). Similar expressions to this definition were encountered with the pre-service teachers' views. Events and phenomena we encounter in our life, are closely related to science. Science depends on the generalizations attained as a result of the investigation of nature and an attempt to predict events, which have not come to light yet, observations and experiments. While the pre-service teachers were describing science in the interviews, they defined it as the investigation and understanding of all the events and phenomena in our life and, similarly, they expressed science education as the teaching of it. Moreover, when pre-service teachers' cognitive structures regarding science and science education were examined, they associated science with the content knowledge of science education (cells, electricity, human beings, etc.), with the environment, which they use while learning or teaching science (laboratory, class, etc.,) and with some equipment and tools they use (microscope).

Technology makes our lives easy with the materials developed, thanks to the combination of knowledge and concepts obtained from different disciplines, such as science, mathematics and culture (Doğru & Şeker, 2012). In other words, it cannot be thought of as inseparable from other disciplines. However, it was revealed that pre-service teachers explained technology as electronic tools and the convenience they gave, as well as the development, and they did not associate technology with many other disciplines. Çepni, Ayas Akdeniz et al. (2005:7-8) defined the goals of technology and they focused on facilitating life and its stresses, which should be done according to the laws of nature. Moreover, other studies revealed similar results and found that individuals recall technological devices when talking about technology and they tried to define technology with these products (Durukan, Hacıoğlu & Dönmez-Usta, 2016).

It is important to understand the relationship between science, technology, other disciplines and society and the results of this relationship, in order to achieve the goals of science education (Hançer, Şensoy & Yıldırım, 2003). One of the other disciplines is mathematics. There is no science field where mathematics is not used, but it is mostly used in physics and science (Aksu, 2008). In STEM education, mathematics is as important as the other disciplines in terms of the skills, which individuals are required to gain. Thus, mathematics should be defined as knowledge, skills, beliefs, dispositions, habits of mind, communication abilities and problem-solving skills, which an individual needs in order to engage effectively in quantitative situations occurring in life and work (MCATA, 2000).

However, it was revealed in this study that pre-service teachers defined mathematics as numbers and operations. On the other hand, stood out in the interviews was that there were some pre-service teachers who explained mathematics with regard to target goals and who explained its importance and how it was used with other disciplines. But, there were no pre-service teachers who expressed concepts or views regarding mathematics' relation to real life. Thus, because it is important to develop an understanding of the cognitive structures of pre-service teachers who are going to give STEM education, considering the nature of mathematics and mathematical literacy, it was revealed that there is a strong need to be in communication and cooperation with these teachers working in this discipline. It is important to discover individuals' and students' views on the engineering discipline to understand their views on the engineering profession and to develop career awareness related to the STEM education approach (Knight & Cunningham, 2004). Engineering is defined in the literature as a complex initiative, which generates achievable solutions via using creativity, science and mathematics in order to meet the needs and desires of people (Wulf, 1998) and a profession which has a problem-solving process (Petroski, 1996). It is emphasized in the study of Petroski (1996) and in the reports published by NAE (2010) and NAGB (2010), that design is very important in the process. Pre-service teachers mostly explained engineering as machines, construction and the product of professions related to electronics in this study and, similarly, it was found in the literature that students stated that engineering was related to mechanics (Oware, Capobianco & Diefes-Dux, 2007). Moreover, many research studies have stated that many pre-service science teachers' perceptions of engineering and the engineer, focus on engineering products and engineering branches (Marulcu & Sungur, 2012). It can be stated that daily experiences and the environment have an important effect on the rise of this condition. Although there are a lot of engineering products around us in daily life, students, teachers and pre-service teachers do not understand what engineers usually do (Frehill, 2007). Knight and Cunningham (2004) stated that students, who were aware of studies on engineering, obtained most of the information from sources like the media. Therefore, the importance of teacher training cannot be ignored to prevent this limited perception, which will occur within the students, the founders of the future. Thus, these results may be a guidance to explain the nature of engineering, so that this limited perception of the pre-service teachers can change and they can understand STEM education.

Understanding STEM disciplines and the relationship between STEM and science education is important in order to keep up with the times. The findings of the study revealed that while there was a strong relationship between the pre-service teachers' cognitive structures and science and science education, there was a weak relationship between science and technology, technology and engineering and mathematics and science, and there was scarcely any relationship between science and mathematics. In fact, although the relation with mathematics is stressed in science education curricula, pre-service teachers could not express this relation with the concepts in the word association test. However, in the interviews they expressed their opinions regarding the importance of mathematics, in order to learn particularly physics and chemistry from science disciplines. They stated these views as if mathematics existed in the nature of science. This result supports the fact that pre-service science teachers are unable to use the knowledge in their disciplines within the context of other disciplines (Çorlu & Çorlu, 2012).

Technology is an indispensable part of science (Ortakuz, 2006). But, in the literature it is revealed that in their cognitive structures, pre-science teachers can build a weak relationship between science and technology and this relationship is only at the level of technological product (Erduran, Avcı & Akçay, 2014); they could not easily distinguish between science and technology; they viewed technology as a sub-discipline of applied sciences; and what they understood from technology was only technological products (Aydın & Taşar, 2010). However, the individuals who were aware of the relationship between science and technology understood the effect of these disciplines on social life (Bridgstock, 1998). Moreover, when STEM was not popular, Science-Technology-Society-Environment was emphasised in the Turkish Science Education Curriculum (MEB, 2005) and students received training according to this curriculum. However, the pre-service teachers who received this education were not able to state any concepts in the WAT, considering these gains and also they could not mention this relationship in their opinions. On the other hand, Ayvacı and Şenel-Çoruhlu (2012) found different results in their studies from this study and stated that science teachers could not explain the relationship between science and learning technology independently and they considered science and technology concepts to be equal, but not science and learning. This concept of considering science to be equal with the other disciplines was called "Myths of Science" by Mc Comas (2000). It can be interpreted that the existence of this condition within pre-service teachers and students can result from the fact that these concepts are used wrongly or interchangeably in daily life. Moreover, it can be stated that the definitions of these concepts have a similar situation in the dictionary of the Turkish Language Association and the people who read these definitions in this dictionary may have misconceptions about these concepts (URL).

Ayvacı and Şenel-Çoruhlu (2015) determined in their studies that teachers used technology in their lessons with the purpose of introducing the importance of technology for the society and signifying its effects on our life. Although the pre-service teachers mentioned technology to teach science in this study, what drew our attention was that there were no concepts related to technology in the word association test. This result shows that pre-service teachers should acquire technological pedagogical content knowledge (TPCK) to use educational technologies for STEM education (Grable, Molyneux, Dixon & Holbert, 2011). Moreover, the function of the technology discipline, mentioned in STEM education, does not only involve educational technologies. It should be addressed as the production of technology, the use of and the development of technology. Therefore, it is very important to understand the nature of the disciplines in STEM education and, at this point, it is a requirement that pre-service teachers and teachers should be trained. These results may lead to training being given to the pre-service teachers.

In the Turkish science education curriculum (MEB, 2013), the gains intended for the engineering discipline and engineering design process are not included under the name of the discipline, but under the knowledge and skill gains. But, it was revealed in this study that the pre-service science teachers could not build a relationship between science education and engineering in their cognitive structures and views. It was found in the literature that students and pre-service teachers could not explain the meanings of science, technology, engineering and design concepts and they could not associate between these concepts (Hsu, Purzer & Cardella, 2011). Indeed, cognitive structures towards engineering, perceptions and ideas have an effect on students' attitudes towards technology and science (Knight & Cunningham, 2004). It is thought that a negative attitude towards science will also indirectly lead to a negative image regarding engineering (Sherriff & Binkley, 1997).

When the literature which examined individuals' views on engineering was examined, it was found that as many people, including teachers, did not have enough information about engineering (Akaygün & Aslan-Tutak, 2016), and its impact on society, and it was ineligible in students' career choices (Kimmel, Carpinel & Rockland, 2007). When considered from another point of view, even if no one chooses a career in engineering in developed societies; everyone has to have science literacy, technology literacy and engineering literacy. Furthermore, it was seen that students restricted engineering only to the concepts like mechanics and construction and they could not develop a positive attitude towards engineering (ASEE, 2003). The studies conducted determined that interdisciplinary science education, and particularly engineering design-based learning, were effective to eliminate these wrong perceptions and negative attitudes (Reynolds, Mehalik, Lovell & Schunn, 2009). Moreover, the implementation of pilot studies intended for engineering design-based learning increased the participant pre-service teachers' desire for integration of the engineering discipline into science education (Hacıoğlu, Yamak & Kavak, 2015).

In conclusion, the data of this study suggests that future teachers' cognitive structures regarding STEM concepts and science education concepts are independent of each other; especially their perceptions of engineering, which are far from their perceptions of science, technology, mathematics and, most importantly, science education. This study's results indicate that teachers, who can solve some 21st century problems and who aware of nature of disciplines and the relationship of disciplines, should be further educated. In accordance with these results, it is suggested that the science education curriculum, including STEM activitiesshould be further designed. It should be be given to teachers pre-service and in-service training about STEM education and especially EDBSE.

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STEM Education Program for Science Teachers: Perceptions and Competencies [*]

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ABSTRACT

This study focused on the professional development activities carried out at Sinop University during the summer of 2015. The purpose of the study is to investigate the effects of the professional development program on the participating science teachers' perceptions and competencies as they relate to STEM education. 24 science teachers were participated the program which was organized to promote their acquisition of the competencies necessary for the development and implementation of original activities suitable for STEM education. The study was carried out through qualitative paradigm. One of the data sources used was to "Teachers' Perceptions on STEM Education Questionnaire". STEM education teaching plans which were developed by teachers during the program were the other data sources used by the study. Findings from the TPSEQ suggest that the professional development program positively affected teachers' views of STEM education. Additionally, after the professional development program, participating teachers made suggestions for the (engineering) design based science instruction for the adaption of STEM education. It can be suggested that in-service training programs should be developed for teachers to raise their awareness of the necessity of STEM education and to enhance their competencies in planning, implementation and evaluation of an instructional process suitable for this approach.

Keywords: STEM Education; Interdisciplinary Education; Science Education.

INTRODUCTION

We live in a century in which developments in the fields of science, technology, engineering and mathematics affect almost every part of our modern life (Brophy, Klein, Portsmore, & Rogers, 2008; NRC [National Research Council], 2012; NGGS [Next Generations Science Standards], 2013). The impact of technological innovation brought about by developments occurring in the fields of science and technology and economic growth is getting bigger and bigger. It is necessary to adapt to these developments, which are occurring at an overwhelming speed and which are exercising influences on countries (International Technology Education Association [ITEA], 2007). This encourages countries to train the engineers and scientists of the future (Miaoulis, 2009) and to improve the literacy of the society in these fields (Miaoulis, 2009; Roehrig, Wang, Moore & Park, 2012).

In recent years, at the root of the reform movements in the field of education was concerned with the restructuring of the educational programs and was directed at the integration of science, technology, engineering and mathematics disciplines (STEM) at K-12

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level (Asghar, Ellington, Rice, Johnson & Prime, 2012; NAE, 2010; NAE and NRC, 2009; Williams, 2011;) demonstrating that the issue has been addressed by the policies developed by countries.

STEM education invests efforts to integrate the disciplines of science, technology, engineering and mathematics by establishing connections between real-life problems; that is, the problems are multi-disciplinary. On the basis of the implementation of these disciplines to real-life problems, borders between the disciplines should be abolished. Each STEM discipline brings a different competency and viewpoint but as in real life, for a successful team, teamwork is the key term (NAE & NRC, 2009; Wang, 2012). This approach points out integrated education programs capitalizing on the knowledge and skills of every discipline (Roberts, 2012). However, given the current elements of education programs, it is clear that adoption of such an approach requires the restructuring of many elements ranging from the training of STEM teachers, changing the structure of education programs from the revision of measurement-evaluation methods and the cost and time of making such big changes stand as an barrier in front of this reform (Bybee, 2010; NAE & NRC, 2009; NRC, 2012). Though America and many European countries have already started to make these changes required by STEM education, research suggests different approaches for the implementation of STEM education within the context of current circumstances (Bybee, 2010; Dugger, 2010; Sanders, 2009). These approaches suggest different combinations of the disciplines such as putting the main emphasis on science and mathematics and keeping technology and engineering secondary, embedding each discipline into another or incorporation of all the other STEM disciplines into one of them. The approach most suitable for meeting the expectations from STEM education is the one entailing the incorporation of the others into one of the STEM disciplines; for example, integration of mathematics, engineering and technology into the science program.

The professional development of teachers is important to STEM education. Teacher professional development programs will need to provide learning opportunities for teachers themselves in order to deepen their conceptual understanding, engage in scientific and engineering practices, and develop an appreciation of science as a way of knowing in a community of knowledge builders (NRC, 2012). Research has identified that professional development is important in STEM Education (Apedoe, Reynold, Ellefson ve Schunn 2008; Capobianco, 2011; Capobianco, 2013; Cuijck, Keulen, Jochems, 2009; Felix, 2010; Hsu, Purzer, Cardella 2011).

This study focused on the professional development program carried out at Sinop University during the summer of 2015. The purpose of the study is to investigate the effects of the professional development program on the participating science teachers' perceptions and competencies as they relate to STEM education.

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METHODOLOGY

The current study aims to investigate the effects of the professional development program on the participating science teachers' perceptions and competencies as they relate to STEM education. The study was carried out through qualitative paradigm

a) Study Group

The study group of the current research is 24 science teachers (14 females, 8 males) determined by means of purposive sampling selection method. Initially, a web site was designed to inform the participants about the professional development program. The program was publicized on social networking sites subscribed to by science teachers and the link to the website was shared. Teachers made online applications to the program. The applications were classified according to criteria including the length of time an individual has been teacher, the city in which the school is located and whether or not there had been previous participation in a similar program. Following these considerations selection was made among the teachers in such a way as to construct a heterogeneous sample in terms of the selection criteria. The science teachers constituting the study group are from seven different regions of the country and have a length of service ranging from 1 year to 15 years. None of the teachers have participated in a similar program before.

b) Context of the Study

A nine-day professional development program was organized to promote the science teachers' acquisition of the competencies necessary for the development and implementation of the original activities suitable for STEM education. The professional development program [STEM Education Approach: Strengthening of Science Classes through Interdisciplinary Ties] was supported by TÜBİTAK. The program was conducted at Sinop University between 21-29 August 2015. The date of the program was the last period of the teachers' summer holiday. The program consisted of theoretical and applied activities designed to promote the teachers' understanding of the nature of STEM and its' implementation of it in their science classes. While STEM Educations' Theory and Implementation, STEM Education and the Characteristics of Future Teachers, The Nature of Science and Engineering and The Applicability of STEM in Science Education were the theoretical activities of the program. Robotic applications and calculative thinking, the use of probes, science instruction through lego pieces, designing an environmentally friendly living space, designing a solar vehicle, fixing of a coordinate with GPS, generating water hardness and intensity maps, deterioration and storage conditions of water products and design-based science implementation were the applied activities in which the teachers actively participated. The activities were conducted by 15 specialized and experienced academicians from 7 different universities.

c) Data Collection and Analysis Process

The data of the current study were collected through "Teachers' Perceptions on STEM Education Questionnaire" developed by the researchers and STEM teaching plans developed by the participants.

Teachers' Perceptions on STEM Education Questionnaire (TPSEQ)

In this questionnaire, there are five questions asked to elicit what the participants know about STEM education, why they think that such an approach is needed, its importance for our country, how STEM education can be applied in classes and the extent to which they consider themselves competent in the implementation of STEM. The data collected with this questionnaire were qualitatively analyzed by using content analysis and comparative analysis techniques together. Each teacher numbered their forms (The form of the first teacher was numbared as Ö1). Initially the responses of each teacher given to the questions were revised in such a way as to allow comparative analysis. The responses of every teacher to the each question on the form were separately analyzed and coded. Two researchers individually constructed their lists of codes individually and similarities and differences between the lists were identified. The differences were revised and when necessary, the opinions of a third expert was sought. The final list of codes was constructed on the basis of words, whole sentences or paragraphs and after making comparisons between the codings, categories were formed on the basis of the predominant themess and thus the coding list was simplified and its final form was determined (Bogdan & Biklen, 2007; Gay, Mills & Airasian, 2006). One category obtained through the above-mentioned analysis process and a series of codes listed under this category is given in Table 1 below.

Table 1. *Sample category and codes*

Category	Code
STEM-oriented Skill Development	Interdisciplinary inquiry skill Interdisciplinary problem solving skill BSB Decision-making skill

How the codes constructed as a result of the analysis of the pre-service teachers' responses and presented in Table 1 were attained is exemplified below:

Sample Category: STEM-oriented Skill Development,

Sample Code: Creativity in STEM areas

Teacher Response: *"…When these areas are integrated, an individual can come up with original things while developing something because I think, when the individual can integrate mathematics, technology and engineering, he/she can improve his/her creativity and think more comprehensively…"*

STEM Teaching Plans

On the last day of the program the teachers were asked to develop STEM teaching plans in order that an in depth analysis could be carried out of any changes to their opinions regarding their competencies in developing, teaching and conducting STEM education processes in their classes. The teachers were divided into five groups and they were given 180 minutes to determine the objectives from the science course teaching program. The teachers were asked to develop their teaching plans in line with Design-based Science Education, one way of conducting STEM education in science classes. The teaching plan prepared by the 2nd group is presented in the Table 2.

Table 2. *Teaching Plan Prepared by 2nd Group*

Unit: Matter and Heat The aim of this unit is to ensure students comprehend heat conduction and insulation, heat insulation technology', contribution to family and the national economy, fuel types, and the environmental impact of the fuel used for heating purposes. **Suggested Time:** 8 one-hour lessons **Learning Objectives:** Classifies the matters according to heat conduction. Discusses the importance of heat insulation according to family and the national economy and the effectiveness of sources. States the criteria of heat insulation materials' electing. Improves the alternative heat insulations materials.
Design Challenge: Students will be expected to design a building for Istanbul city. The designs' success criteria are maximum energy efficiency, the lifetime of materials, and the total cost of design. *"Rubric will be prepared to evaluate the design."*
Mini Design Challenge: We are investigating the energy efficiency *"The aims of this activity is for students to understand, design and discuss the most effective heat insulation for buildings and why heat insulation is important"* **Mini Design Challenge:** Designing an Insulator *"In this activity, the aim is to design an effective insulation for a cup of cold soda using different materials such as cotton, aluminum foil, wool etc., gaining an understanding of how different materials can facilitate or slow heat transfer."* **Mini Research:** Heat insulation materials for building… *"There are plenty of cheap and common insulation materials available on the market today. Many of these have been around for quite some time. Each of these insulations have their own advantages and disadvantages. The choice of insulation material can be very important and in this activity students investigate the properties of heat insulation materials. They will consider differences including price, environmental impact, flammability, and other factors.*

The teaching plans prepared by the teachers were analyzed on the basis of the criteria developed by considering the design based science instruction and education plan development steps proposed by Wendell et al. (2010, p.6) and the features to be possessed by design problems defined by Crismond (2001). These criteria are as follows:

- *8-10 science (and engineering) objectives intended to be incurred in students need to be determined.*
- *A comprehensive engineering design task that will allow conducting scientific research related to learning objectives needs to be determined.*
- *The design tasks should include sub-tasks that will constitute the real life context.*
- *The design task should be able to be conducted with materials known and easy-to-use.*
- *The design task should allow more than one design solution.*
- *The design task should be supportive to cooperative work.*
- *The design task should be suitable to be conducted by repeatable steps so that design products can be improved and enhanced.*
- *Activities to prepare students for the design task should be determined (mini design/ mini research).*

The teaching plans were presented by the groups and three science education experts experienced in STEM education evaluated the presentation on the basis of the above-given criteria and then the teachers were given feedback. The evaluations were video-recorded. In order to establish the reliability, the same teaching plans were reevaluated five weeks later and the same results were obtained.

FINDINGS

Perceptions about STEM Education

TPSEQ was administered to the teachers before and after the program and comparisons were made on the themes and the categories and codes subsumed under these themes on the basis of the analysis of their responses. The data gathered in this way will be presented separately under the themes of “Reasons for the Necessity of STEM Education, Adaptation of STEM into Education System, Perceptions about the Barriers to Implementation of STEM Education and The Proficiency Perceptions of Teachers about STEM Instructional Process Planning, Implementation and Evaluation.

Perceptions about the Reasons for the Necessity of STEM Education

From the teachers’ responses given to the first and fourth questions in TPSEQ, it was attempted to determine their perceptions about the reasons for the necessity of STEM Education. The findings obtained as a result of the analysis of the responses given to these questions are presented in Table 3.

As can be seen in Table 4, before the program, the teachers viewed developing positive attitudes towards STEM areas (f=12), enhancing creativity (f=11) and interdisciplinary inquiry (f=6) skills and improvement of academic achievement (n=7) as important reasons for the necessity of STEM education. After the program, it was found that none of the teachers consider academic achievement as an important reason for the necessity of STEM education. After the program, the teachers put greater emphasis on the necessity of STEM education for improving the creativity in STEM areas (f=18), interdisciplinary problem solving (f=9) and inquiry skills (f=7) and technology-utilization (f=6). Thirteen of the teachers mentioned developing positive attitudes towards STEM areas and five of the teachers mentioned lack of motivation as reasons for the STEM education after the program and the frequencies of these two reasons are very close to each other before and after the program. After the program, the teachers added two more reasons for the necessity of STEM education that are having a say in scientific developments (f=15) and increasing the level of development of a country (f=5) and they indicate that the teachers developed some ideas about the societal contribution of STEM. Another change observed in the perceptions of the teachers as a result of the program is that STEM education is necessary for people desiring a career in engineering (f=5).

Table 3. *Teachers' Perceptions about the Reasons for the Necessity of STEM*

Category	Codes	Pretest f	Posttest f
Improvement of STEM Knowledge	Improvement of STEM academic achievement	7	-
Skill Development	Interdisciplinary inquiry skill	6	7
	Interdisciplinary problem solving skill	1	9
	Creativity in STEM areas	11	18
	Technology-utilization skill	1	6
	Scientific process skills	1	2
	Decision-making skill	-	1
Affective Behaviors Development in STEM areas	The need for a generation having positive attitudes in STEM areas	12	13
	Lack of motivation in STEM areas	3	5
Societal contribution of STEM	Having a say in scientific developments	-	15
	Increasing the level of development	-	5
Career Development in STEM Areas	Training scientists	1	-
	Training engineers	-	5

Some of the opinions expressed by the teachers in the pretest and posttest about the reasons for the need for STEM are as follows:

Ö2-Pretest: "Unfortunately, our country can't keep up with the technological developments in the world, let alone producing these technologies. Individuals who are far away from science literacy and scientific thinking are educated, there are still individuals experiencing difficulty in using technology; therefore, I think that STEM education should be put into practice in classes"

Ö3-Pretest: "In my opinion, given that children's interest in science is gradually decreasing, STEM education is of great importance for our country to create a generation interested in science"

Ö5-Pretest: "I think that STEM education is of a vital importance for our country because we have not been able make a great stride in the field of science for years. In this regard, one of the key points to be considered is that science education should be in integration with other disciplines as it is in the real world. That is, they should be provided with opportunities to make interdisciplinary comparisons…"

Ö11-Pretest: "Science, technology, engineering and mathematics are indispensable for thinking brains. In my opinion, our country needs students liking these disciplines. By means of STEM education, I think that a generation interested in these disciplines can be created."

Ö1-Posttest: "STEM intends to educate individuals who can produce, solve problems, conduct analysis and are literate in the related disciplines. We need STEM to have qualified engineers, scholars, teachers and society in general. In the long run, STEM will make important contributions to the development of our country."

Ö2-Posttest: "… In my opinion, the most important objective of it should be to eliminate negative attitudes in the fields of science and to endear these fields…"

Ö7-Posttest: "Within the context of STEM education, training focusing on the production of solutions to problems is given. Students learn science by encountering and finding *solutions to problems. In this way, skills required to think and inquire are developed in science-related disciplines."*

Ö15-Posttest: "I think that STEM education will yield important benefits for our country in the long-term. Teaching children how to question and design will positively affect both their personal lives and their achievements in academic fields. Thus, children will be confident enough to find solutions to their problems. Given that one of the important problems in our country is production, innovative production efforts could be invested as a result of such education."

Perceptions about the Adaptation of STEM to the Education System

The teachers' perceptions about how to adapt STEM education to the education system were elicited through the first and second questions in TPSEQ. The purpose of the third question is to determine the opinions about how it can be implemented in the current conditions (education programs in our country, teacher training, measurement and evaluation methods etc.).

Findings related to the teachers' perceptions about how to adapt STEM education to the education system are presented in Table 4.

Table 4. *Teachers' Perceptions about how to Adapt STEM Education to the Education Program*

Category	Codes	Pretest	Posttest
		f	f
Adaptation of the current conditions to STEM education	Development of STEM instructional program	5	-
	STEM teacher training	5	-
Adaptation of STEM education to the current conditions	Connection of mathematics to science courses	5	-
	Connection of technology to science courses	3	-
	Connection of engineering to science courses	5	-
	Out-of-school project works	-	2
	Cooperation between teachers	-	2
	Engineering-focused science courses	-	18

When Table 4 is examined, it is seen that before the program, the teachers suggested that a separate STEM instructional program should be developed (f=5) and STEM teacher training be conducted (f=5) but after the program they gave up this suggestions. Some of the teachers believe that STEM education should be implemented without making radical changes in the current conditions. These teachers stated that this adaptation could be achieved by incorporating mathematics (f=5), engineering (f=5) and technology (f=3) into science courses before the program. After the program on the other hand, none of the teachers mentioned such an integration and they mostly mentioned engineering-focused science courses (f=18). While few teachers pointed out that cooperation should be made between teachers for the integration of STEM education under the current conditions (f=2) and such an integration could be achieved by means of out-of-school projects (f=2).

Findings related to the teachers' perceptions about STEM implementation under the current conditions (instructional program, teacher training, measurement-evaluation etc.) are presented in Table 5.

Table 5. *Teachers' Perceptions about how STEM Education can be adopted to the Education System in the Existing Conditions*

Category	Codes	Pretest f	Posttest f
Suggestions for Teachers	Cooperation between the concerned teachers	7	21
	In-service training for teachers	12	8
	Teachers' becoming open to development	6	4
Suggestions towards Course Process	Interdisciplinary relationships while teaching the subjects	1	1
	Daily life context	1	-
	Integration of technology	1	1
	Product-focused	1	-
	Design-based science	-	14
Suggestions for Out-of-class Activities	STEM workshops	1	3
	Science festivals	1	-
Other Suggestions	Student-centered	3	1
	Activity pool suitable for STEM	7	5

As can be seen in Table 5, it is seen that prior to the program, the teachers mostly thought that in-service teacher trainings should be given (f=12), cooperation between teachers should be increased (f=7) and teachers should be open to personal development (f=6) for the implementation of STEM education under the existing conditions. Another important element pointed out by the teachers for the STEM education is the construction of the activity pool suitable for STEM (f=7) before the program. After the program, more emphasis was put on the cooperation between teachers (f=21). Prior to the program, the teachers were able to make very few suggestions related to what should be done during the instructional process and made more general suggestions in relation to teacher training. However, following the activities at the program, most of the teachers made suggestions regarding instructional process and stated that design-based science education could be adopted (f=14) and integration of technology, engineering and mathematics into science courses can be achieved. This may indicate that the program contributed to the teachers' competencies in relation to in-class implementations.

The findings presented in Table 4 show that before the program, the teachers thought that the adaptation of STEM into the education system can be achieved by making changes in the education program and teacher training system or within the context of the existing conditions. Following the program, almost all of the teachers made suggestions for the adaptation within the context of the existing conditions and this may indicate that as a result of this nine-day training program, the teachers started to think that the adaptation can be achieved without making radical changes when teachers take some responsibilities.

Some of the opinions stated by the teachers in the pretest and posttest about how to adapt STEM education to the education system under the existing conditions in general are as follows:

Ö8-Pretest: "Course plans complying with STEM education should be developed … If this is to be done under the existing conditions, we should be trained"

Ö9- Pretest: "If we are expected to do this under the existing conditions, then the starting point for STEM education should be science education. As it involves mathematical skills, technology and engineering, it can be easily implemented in science courses. First, plans should be developed for courses, setup needs to be designed well. …Of course, first we need to understand the logic of STEM well; thus, we should be trained. Teachers may cooperate for the effective implementation of STEM."

Ö10- Pretest: "I do not think that STEM disciplines are completely disconnected. Science makes use of mathematics to a great extent. But, I do not know what will happen when the *subjects taught in courses are not parallel to each other… In my opinion, STEM training programs should be organized and we need to participate in them."*

Ö12- Pretest: "We can connect it with technology, by using the tablets given to students, by showing that tablets are not only for playing games or taking photographs but they can also be used to study and research. We can download books into tablets…"

Ö1- Posttest: "For us to integrate STEM education into our schools, first teacher training programs should be revised on the basis of STEM education and teachers who can implement this approach should be trained. In addition to this, by means of in-service training programs, teachers can be trained for the implementation of this approach. Besides training teachers, education programs can be revised to adjust them to this approach. Science teachers should create connections with other disciplines and can develop their own course programs in line with this approach.

Ö7- Posttest: "We can adapt it first by constructing the required infrastructure in our schools. Then, cooperation among teachers should be established. Training of science teachers is of great importance for this integration …"

Ö11- Posttest: "…Teachers should be educated about STEM by means of in-service training programs or such projects. At the same time, teachers should be in contact with each other; we can share our course plans."

Ö17- Posttest: "We conduct science courses by assigning design tasks to students; we can develop teaching plans for this purpose. But first we need to get in-service training."

Findings related to the Teachers' Perceptions about the Barriers to Implementation of STEM Education

The teachers' perceptions about the barriers to implementation of STEM Education were attempted to be elicited by analyzing the responses given to the first question in TPSEQ and are presented in Table 6.

Table 6. *Teachers' Perceptions about Barriers to Implementation of STEM Education*

Category	Code	Pretest	Posttest
		f	f
Teachers	The profile of a teacher not open to new ideas	3	-
Students	Student readiness	-	1
Teaching program	The content of the teaching program is not suitable	6	-
Teacher education	Improper teacher qualifications	10	7
Measurement and evaluation approach	Centralized exams	2	3
Others	Technical facilities	2	4
	Cost	6	-
	Time	2	4
	Difficulty in integrating the knowledge and skills of different disciplines	2	3
	Prejudiced parents	1	-

As can be seen in Table 6, both before (f=10) and after the program (f=7), the teachers viewed the biggest barrier to implementation of STEM Education as improper teacher qualifications. Other factors believed to be barriers to implementation of STEM Education were the structure of the teaching program (f=6) and costs (f=6) before the program but the teachers gave up seeing them as be barriers after the program. This might be because of the experiences of the teachers during the program; as a result of these experiences they started to believe that adaptation of STEM could be achieved under the existing conditions and its cost would not be too high.

The Proficiency Perceptions of Teachers about STEM Instructional Process Planning, Implementation and Evaluation

The proficiency perceptions of teachers about STEM instructional process planning, implementation and evaluation were attempted to be elicited through the analysis of the responses given to the fifth question of "TPSEQ" and are presented in Table 7.

Table 7. *The Proficiency Perceptions of Teachers about STEM Instructional Process Planning, Implementation and Evaluation*

Field of competency		Yes	Partially	No
Planning	Pretest	-	6	18
	Posttest	6	8	-
Implementation	Pretest	-	8	16
	Posttest	20	4	-
Measurement-evaluation	Pretest	-	6	18
	Posttest	18	6	-

When Table 7 is examined, it is seen that when compared to how they perceptions' before the program, the teachers started to feel more confident about planning, implementation and measurement-evaluation dimensions following the program. This might have resulted from the active participation of the teachers in many activities related to STEM education during the program.

Some of the opinions stated by the proficiency perceptions of teachers about STEM instructional process planning, implementation and evaluation in the pretest and posttest about as follows:

Ö4-Pretest: "The most important challenge is the shortage of teachers competent enough in these fields; moreover, the content of education programs is not suitable."

Ö6-Pretest: "The challenges may stem from the teacher's not being open to different approaches. Or even if it is adopted by the teacher, lack of equipments or shortcomings in infrastructure may lead to some other problems. Another problem can be incompliance between educational programs and STEM education."

Ö10-Pretest: "The existing teachers have been educated through traditional methods and their being closed to new things. Time can be another problem. Cost is an important barrier considering the present state of education in the country. Moreover, our education program is not suitable for the integration of STEM."

Ö2-Posttest: "Time-induced problems, technical possibilities, readiness level of students, qualifications of teachers"

Ö5-Posttest: "Some challenges can be encountered in the adaptation to the science course due to qualifications of the teacher. Moreover, physical conditions are important."

Ö8-Posttest: "The barriers to implementations of STEM education might be lack of information about this educational process on the part of teachers and parents' prejudices in relation to teacher-student-parent synchronization."

Ö21-Posttest: "…The biggest problem is the centrally-administered exams…"

Findings related to Teaching Plans

The findings obtained by analyzing the teaching plans prepared by the teachers according to criteria formed on the basis of Wendell et al. (2010, s.6) and Crismond (2001) are presented in Table 8.

Table 8. *Findings Related to the Teaching Plans Prepared by the Teachers*

		1st group	2nd group	3rd group	4th group	5th group
8-10 science (and engineering) objectives intended to be incurred in students need to be determined.	Yes	√			√	
	Partially		√	√		√
	No					
A comprehensive engineering design task that will allow conducting scientific research related to learning objectives needs to be determined.	Yes	√	√	√	√	√
	Partially					
	No					
The design tasks should include sub-tasks that will constitute the real life context.	Yes	√	√	√	√	√
	Partially					
	No					
The design task should be able to be conducted with materials known and easy-to-use.	Yes	√	√	√	√	√
	Partially					
	No					
The design task should allow more than one design solution.	Yes	√	√	√	√	√
	Partially					
	No					
The design task should be supportive to cooperative work.	Yes	√	√	√	√	√
	Partially					
	No					
The design task should be suitable to be conducted by repeatable steps so that design products can be improved and enhanced.	Yes	√	√	√	√	√
	Partially					
	No					
Activities to prepare students for the design task should be determined (mini design/ mini research).	Yes	√	√	√	√	√
	Partially					
	No					

When Table 8 is examined, it is seen that the design-based science instruction plans prepared by the teachers as a way of achieving the integration of STEM into science courses are quite adequate in terms of the set criteria. While the teaching plans of the two of the groups (1st and 4th groups) meet all the criteria, the teaching plans developed by the others (2nd, 3rd, and 5th groups) are accepted to be partially adequate as they include science objectives fewer than 8. This finding shows that the teachers feel confident to a great extent about planning an instructional process suitable for STEM education.

RESULTS, DISCUSSION and SUGGESTIONS

While the teachers regarded STEM education as necessary to enhance academic achievement in these disciplines prior to the program, they did not consider it so after the program. The teachers believe that STEM education is needed to improve creativity, problem solving, inquiry and technology-utilization skills in and developing positive attitudes towards these disciplines. This was the case both before and after the program but more strongly after the program. Teachers had conducted activities in which they actively participated in relation to STEM education and they more strongly believed in the necessity of STEM education for the development of some skills. This finding concurs with the findings reported in the literature. As stated by Morrison (2006), through STEM education, students are enabled to improve their self-confidence, problem solving, technology-utilization skills and discovery skills, to be more innovative and technology literate, to think critically and reasonably. Marulcu & Sungur (2012) indicated which skills of the pre-service science teachers could be developed via the science course designed through an interdisciplinary integration built on engineering design approach and found that it could improve their three-dimensional thinking, creativity and reflectivity, scientific thinking, problem solving, versatile thinking, imagination and drawing. As a result of the program the teachers started to believe that STEM education has some societal contributions to make including having a voice in scientific development and improving developmental levels. Due to the impact of the rapidly advancing technological innovations of countries it was considered necessary in order to raise the awareness of science and careers (ITEA, 2007). Moreover, in the literature, research argues that awareness of science and career can be enhanced through the integration of STEM disciplines (Apedoe, et. al., 2008; Bozkurt, 2014). In this respect, increasing awareness of the teachers in terms of the necessity of STEM education as a result of the program is of great importance given that teachers play an important role in the education system.

Before the program, the teachers thought that the adaptation of STEM into the education system can be achieved by making changes in the education program and teacher training system or within the context of the existing conditions. Following the program, almost all of the teachers made suggestions for the adaptation within the context of the existing conditions. In reality, the current structure of schools and education programs is not suitable for a separate STEM course in terms of its objectives, content, instructional activities and evaluation methods (Bybee, 2010; NAE & NRC, 2009; NRC, 2012). The teachers' expressing opinions about changing and revising all of these elements for STEM education indicate that it will be difficult to carry out in the short-term due to time and money concerns and nearly half of the teachers before the program were of this opinion. Following the program, almost all of the teachers stated that adaptation should be conducted within the existing conditions and this indicates their belief that teachers should take responsibility in this respect. This finding is supported by the opinions expressed by the teachers about the barriers to implementation of STEM education emphasizing the importance of teacher qualifications. Both before and after the program, the teachers emphasized the importance of developing teacher qualifications and cooperation between teachers. It is apparent that the teachers are cognizant of their responsibilities.

After the program, the teachers made suggestions for the design-based science instruction (Wendell, et. al., 2010) for the adaption of STEM education within the current conditions. In fact, as engineering design process that can be defined as the production process of technologies requires the use of basic engineering knowledge and skills and the principles of science and mathematics, it naturally ensures the integration of STEM disciplines (Cantrell, Pekcan, Itanı & Velasquez-Bryant, 2006; NAE & NRC, 2009;). Although the teachers were provided with opportunities to participate in different sample activities for STEM integration throughout the program, they suggested design based science education for the instructional process. Arafah (2011) conducted a study to investigate the changes taking place in the participating teachers' perceptions of engineering as a result of a three-day seminar program given about engineering design process to science and mathematics teachers and reported that the teachers' interest in the integration of engineering, technology, science and mathematics was increased at the end of this three-day program.

After the program the teachers also indicated that they felt competent about the planning, implementing, evaluation and evaluation of an instructional process in which the adaptation of STEM education is achieved because they were able to prepare teaching plans integrating STEM disciplines. Yasar Baker, Robinson-Kurpius & Roberts (2006) revealed that the teachers did not feel competent or felt inadequate while conducting instruction on design, engineering and technology. In a similar manner, in the current study, it was found that before the program, the teachers felt they were inadequate in achieving the integration of these disciplines. Sungur Gul & Marulcu (2014) found that after participating in activities about engineering design and the uses of legos for three days, the science teachers acquired basic information of engineering and were able to give some examples for engineering approach in science education; however, they could not internalize the process enough to use engineering design process to teach science concepts. Similarly, Arafah (2011) reported that though the interest of teachers in the integration of engineering, science, technology and mathematics was increased, they still felt inadequate. Unlike the studies of Arafah (2011) and Sungur Gül & Marulcu (2014) within the current study, a 9-day intensive program allowing teachers to actively participate in the activities was implemented and this long and intensive program may have led to teachers feeling more competent.

It can be recommended that in-service training programs should be developed for teachers to raise their awareness of the necessity of STEM education and to enhance their competencies in planning, implementation and evaluation of an instructional process suitable for this approach.

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The Effect of Stem Education on Pre-Service Science Teachers' Perception of Interdisciplinary Education

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ABSTRACT

In both Turkey and the other countries, disciplines in curricula emphasize interdisciplinary approach under the heading of "related with the other courses". STEM education is one of these approaches. One major problem faced by STEM education is the shortage of professional programs which guide teachers about the relationship between STEM disciplines and how to teach it in class. This study was carried out to investigate the change in pre-service science teachers' perspective of interdisciplinary relation after giving them pre-service education on interdisciplinary STEM education. Case study research model was used in the study. The study was conducted with 32 pre-service science teachers in the third grade in Recep Tayyip Erdogan University, Faculty of Education during the fall semester in the 2015-2016 academic year. In the scope of this study, science pre-service teachers were given pre-service education on interdisciplinary STEM approach; pre-test and post-test data were collected by applying the STEM-WAT and STEM surveys to the participants; and the collected data were analyzed with descriptive analysis. According to the pre-test results, the participants were able to relate science education to various disciplines prior to the STEM education. In the post-test results, despite a decrease in the number of disciplines related to natural sciences, an evident increase was reported in the number of relations with certain disciplines such as Mathematics, Technology and Engineering. Before the STEM education, pre-service teachers were thinking of relating teaching Natural Sciences to just Mathematics in their future classes. After the STEM education, they were reported to think of relating their teaching with Mathematics, Technology and Engineering. Moreover almost all pre-service teachers think of benefiting from relation of natural sciences with other disciplines in their classes. They thought that such relation would be useful for both individual and social development of students and instruction.

Keywords: Interdisciplinary Education; STEM; Pre-Service Education.

INTRODUCTION

Today, the economy of the world increasingly takes a structure based on knowledge, and countries continuously renew and increase their capacity to create innovation and technology in order to survive and obtain advantages in the global economy.

Turkey is also investing rapidly in industry and technology to increase competitiveness in this global race.

The success of countries in this area depends on a large number of qualified and well-trained personnel in Natural Sciences, Technology, Engineering and Mathematics, the STEM

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areas. As a result, we have to increase the number of successful students trained in the STEM areas not to lag behind in this race.

However, international and national assessments indicate that Turkish students have a lower level of performance in science, technology, engineering and mathematics fields and their interest in those areas is decreasing and they do not prefer these areas much for their future career (Marulcu and Sungur, 2012; Marulcu and Hobek, 2014, Url-1; Url-2). When the results of the Trends in International Mathematics and Science Study (TIMSS) status determination are analysed, Turkey was on the 33rd rank with the overall score among 38 countries when it first participated in 1999, then in 2009, it became the 42nd out of 55 countries, and lastly in 2015, Turkey was even below Greece on the 41st rank, which was facing with many crisis, among 76 countries (Url-3). Thus, Turkey cannot be said to be successful in TIMSS exam. Due to the significant relationship between attitude and academic achievement, we tried to find out at what extent this fact reflects on students' career choice. In a study carried out by Istanbul Aydın University (2014), distribution of the first 1000 students entering numerical fields between the years 2000 and 2014 was investigated by percentage of placement in STEM fields at university entrance exams. In 2000, the rate of placement in STEM fields was 85%, but it decreased to 27% in 2010, then increased to 38% back in 2014. Across all numerical fields in 2014, 81.39 % of the students who were placed in STEM fields were males, while the rate of females was only 18.61%. The failure of the students in STEM fields and the shortage of selecting the STEM professions reflect on economy. The research carried out by TUSIAD (Turkish Industrialists' and Businessmen's Association) (2014) shows that only 19% of the labor force in STEM fields in Turkey (manufacturing and network industries, retail and service sector) are comprised of individuals graduating from STEM fields (% 64 are males and 34% are females). In addition, according to the report, Turkey will face a crisis in STEM fields in the future, the labour demand in STEM areas will increase even more than in previous years within next 10 years. However, the demand will be hardly met with the existing or future labour force, so there will be a need to import labour from abroad (Koçel, 2004; Özsoy, 2015).

The interest in fields of STEM is described as positive approaches of individuals towards natural sciences, technology, engineering and mathematics subjects. Thus, this interest becomes an encouraging factor for these people to build a career in a field of STEM (Buxton, 2001). However, students tend to lose their interest in natural sciences, technology, engineering and mathematics fields until they reach high school and college levels. One reason for the loss of interest could be the discrepancy between in the dominant understanding of STEM education in primary education and secondary and high school. As students are inclined to perceive the outside world holistically, interdisciplinary teaching of STEM topics (Science of Life) is realized to some extent in primary education. However, it is mostly replaced by teaching of the same subjects (Physics, Chemistry, Biology, Geometry, Mathematics etc.) with a disciplinary approach rather than interdisciplinary at secondary and high school levels. It is a fact that human beings' attempts to find solutions to everyday life or their ways of communicating with others are not limited with the specific knowledge and skills about a particular discipline. Questions and answers asked in everyday life often fall under more than one discipline. Therefore, information and skills in the science or mathematics education may be unauthentic if not presented in such a context. Under these circumstances, it seems inevitable that students have da ifficulty in discipline-based teaching and eventually lose their interest in those courses (Yıldırım, 1999). The results of the above-mentioned STEM-related researches by Istanbul Aydın University (2014) and TUSIAD (2014) seem to be supportive of this case. In addition to this, interdisciplinary teaching can help solve this problem that could be brought by disciplinary education as it is more suitable for students' natural learning process and the way of perceiving the world (Harrel, 2010). It is emphasized in related literature that students' participating in activities where STEM subjects are discussed with an interdisciplinary approach makes the STEM topics more meaningful and increase the interest shown towards STEM fields at an early age (Dabney et al., 2012; Raju and Clayson, 2010; Tindall and Hamil, 2004). The research carried out by Dewaters (2006) revealed that students are satisfied with lessons in which STEM topics are discussed with an interdisciplinary approach and those lessons help to solve such problems in the course of daily life. Also, Bingölbali, Monaghan and Roper (2007) found out that implementation of project-based learning activities integrated with STEM has a significant effect on students' positive attitudes towards STEM and their future career choices. Maltese and Tai showed (2010) that senior students from secondary schools which perform STEM-based instruction have a three times higher tendency for orientation to STEM disciplines in the next period than those not having gone through such an education. As another example, Cho and Lee (2013) concluded that students' creativity (creative problem solving and creative personality) and learning levels improve as a result of the lesson plans developed according to STEM education. An essential feature of interdisciplinary STEM teaching is availability of learning activities dependent on problems or conditions. Learning abstracted from everyday life, which is one of the main characteristics of traditional science teaching, leaves its place to learning closer to everyday life in the context of STEM interdisciplinary teaching. In fact, many natural sciences subjects that students must learn in class have an interdisciplinary aspect. Suppose that interdisciplinary teaching is performed around the concept of "Electric Energy". Such a topic will be most likely to be interesting and important to students since it is closely related to their daily lives. In such an educational process, the topic of "Electric Energy" could be considered from various aspects and different disciplines could be exploited to support the teaching. For example, courses like Physics, Chemistry, Biology, Technology, Engineering and Mathematics may contain information related to this topic and such information can be taught within the framework of "Electric Energy" concept. . A conceptual structure based on this model that performed by the reserchers of this study seen in the Figure 1. Here, an exhaustive list of examples can be given for any sub-topic or questions that could be included under each discipline.

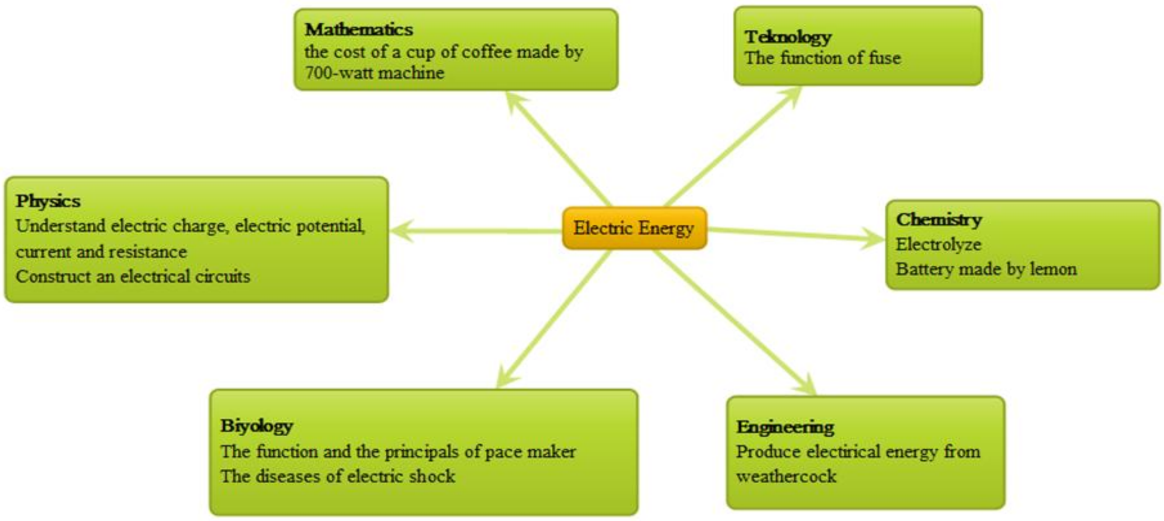


Figure 1: *Conceptual structure of electric energy with disciplines*

As seen in the figure above, students can receive STEM education based on an efficient and effective interdisciplinary approach naturally depending on the teachers' ability to relate their major to the knowledge and skills from other disciplines (Nadelson et al., 2013). According to Osborne et al. (2003), the quality of a teacher constitutes the most important factor in students' maintaining their career choice in STEM areas. However, as teachers are not often encouraged to relate their subject area to other disciplines, they just try to convey information to learners about their respective subjects, not attaching much importance to the extent to which knowledge and skills learned in these courses are applied to other courses or how they are associated with other courses. As a result, separate knowledge and skill groups are emerging in schools. Wang et al. (2011) argue that one of the major educational problems of the K-12 STEM education is the minimum amount of professional programs to guide or help teachers about the relationship among STEM disciplines and how to teach this relationship in the class. Research results about effectiveness of the STEM teaching curricula also support the above mentioned case. Researches demonstrate a number of obstacles to teachers' inability to associate their own fields with other areas (natural sciences, math, technology and engineering fields). These include a reluctant co-operation with teachers in other disciplines, teachers' inadequate information about effects of the STEM approach, teachers' not seeing the STEM approach as a method to increase students' achievement in their discipline, school's structural limitations, shortage of educational materials and so on (Pinell et al., 2013; Raju and Clayson, 2010; Nadelson et al., 2013; Shahali et al., 2015; Han et al., 2015; Siew et al., 2015). The result revealed that teachers learn more about the relationship among sciences, technology, engineering and mathematics disciplines, integrated STEM instructional strategies and STEM concepts, they feel more comfortable in teaching STEM (Nadelson et al., 2012; Stohlmann et al., 2013; Halim et al., 2014;). A professional development workshop approach for pre-service and in-service teachers is one way of creating teachers' awareness of science teaching through a STEM approach (Han et al., 2015). In this regard, the present study intends to reveal the changes in pre-service science teachers' perception of the relationship among natural sciences, technology, engineering and mathematics disciplines as a result of the STEM education program developed for them.

METHODOLOGY

This study, which intends to determine whether the STEM education helps pre-service science teachers comprehend the relationship among natural sciences, technology, engineering and mathematics, was conducted as Case Study. This research method was preferred in order to study one single variable deeply instead of a limited number of variables, to gather the data from the environment in a systematic way, and to provide an understanding of what facts need to focus in future research owing to the outcomes (Cepni, 2007). During implementation of the study, pre-service science teachers were given an education based on an interdisciplinary STEM approach. Both before and after the education, the STEM Word Association Test (STEM-WAT) and STEM Survey were administered as a pre and post-test data collection tool. The obtained data were analyzed with descriptive analysis method.

a) The Programme of Pre-service Education

STEM education course is a 9-week pre-service education programme developed by the STEM Coordination of Recep Tayyip Erdoğan University (RTEU-STEM) for pre-service science teachers. The course was carried out in the RTEU-STEM laboratory from November 16, 2015 to January 8, 2016. The purpose of the STEM Education was to emphasize the relationship and integration among natural sciences, technology, engineering and mathematics disciplines so as to create a familiarity among pre-teachers with the STEM approach, to ensure an in-depth understanding of the relationship among STEM disciplines, and to develop a positive attitude and belief for the use of this relationship in future science teaching classes. During the education programme, the participants in groups of four participated in five sessions involving Suspended Bridge Design, Amusement Park High-speed Train Design, Cockhorse Programming, Shopping Mall Door Design and Communication Technology Design comprising of activities in compliance with problem-based teaching method. Also in the scope of Free Activity Design, they developed engineering design models to address their own set of problems and exhibited these models in the exhibition hall of the faculty for the other teachers and students from their own department. In these events, engineering design process was used as a teaching strategy to establish the relationship among the disciplines of natural sciences, technology, engineering and mathematics (See Appendix 1 for sample activity plans and problems).

b) Participants

The study was carried out with 32 third-grade students taking the Instructional Technology and Material Development course in Department of Science Teaching, Faculty of Education at Recep Tayyip Erdogan University during the fall semester in 2015-2016 academic year. The data collection instruments were applied to the 42 students registered in this course. Some of the respondents just answered the pre-test, while some others answered the post-test only; some others did not answer the surveys completely. To obtaine meaningful data, the answers given by 32 participants that attended the course and answered the whole survey were analyzed. The demographics of these participants are listed below in the Table 1.

Table 1: *Demographic characteristics of participants*

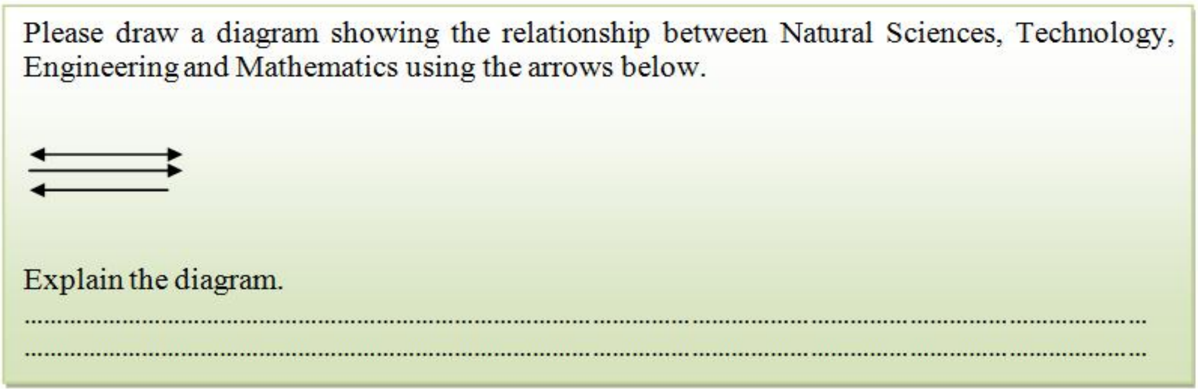
Demographic characteristics		n	%
Gender	Female	21	66
	Male	11	34
Type of high school graduated from	Science high schools, Anatolian high school, Super lycee	6	19
	General high school	22	69
	Vocational high school	4	12
The rank among the choices in the SPE (Student Placement Exam) exam	1-3	15	47
	4-10	10	31
	11-30	6	19
	Not remember	1	3
The field in the high school graduated from	Numerical	28	88
	Equal Weight	2	6
	Verbal	2	6
The level of self-confidence in science teaching	Very high	3	9
	High	20	63
	Medium	8	25
	Low	0	0
	Very low	1	3
The level of enthusiasm for science teaching	Very high	14	44
	High	13	41
	Medium	4	12
	Low	0	0
	Very low	1	3
The level of interest while studying science	Very high	5	16
	High	15	47
	Medium	11	34
	Low	0	0
	Very low	1	3

c) Data Collection Instruments

In this study, STEM Survey and STEM-WAT which were developed by the resarchers of this study were used as data collection instruments.

The STEM survey consists of 5 pre-test questions and 7 post-test questions. The scope of these questions is the ability to relate natural sciences to other disciplines, as well as to evaluate the STEM education offered. Data analysis was performed on the answers given for three relevant questions. The open-ended questions included "the other disciplines they could relate to natural sciences discipline", "whether or not they are thinking of using the relation between natural sciences discipline and other disciplines in the context of science teaching lesson" and "Please describe the relationship among Natural Sciences, Technology, Engineering and Mathematics disciplines by using arrows". These questions were selected assuming that they directly serve the purpose of this study. Moreover, to enhance reliability of the findings, the question "What is natural sciences?" was investigated in terms of the relation with the disciplines.

The open-ended question requiring respondents to describe the interdisciplinary relations with arrows is as the following in Figure 2:


Please draw a diagram showing the relationship between Natural Sciences, Technology, Engineering and Mathematics using the arrows below.

Explain the diagram.

....

....

Figure 1: *The last question of the STEM Survey*

As seen from the Figure 2, the respondents were asked to make drawings and provide an explanation about the diagram. Attention has been paid to participants to draw and explain the diagram. Forty-five seconds were given for answering the question.

The word association test (WAT) shows the number of response words produced for each keyword before and after teaching. In this technique, the number of response words produced for each keyword is one of the first methods used to evaluate the data (Shavelson, 1974). The number and quality of words given by students for each keyword can determine whether or not the concept was understood by looking at the number of responses given for the keywords in the memory (as response words increase, it can be said that understanding increases, too), and word type (whether it is related to the keyword) (Bahar, Nartgün, Durmuş and Bıçak, 2006).

The word association test (WAT) on each page contains keywords, and respondents are expected to write the words recalled by each keyword in the gap at the bottom of the keywords. In this study, the keywords selected in pre-test in the STEM-WAT were chosen as Natural Sciences, Technology, Engineering and Mathematics keywords. The keyword of STEM was added in the post-test. A sample page layout used in the implementation is given below in Figure 3:

Natural Sciences --
Natural Sciences --
Natural Sciences --
Natural Sciences --
Natural Sciences --
Natural Sciences --
Natural Sciences --
Natural Sciences --
Natural Sciences --
Natural Sciences --

Figure 2: *A sample page layout used in WAT*

The students were provided with descriptions regarding the WAT, and thirty-five seconds were given for each of the concepts. Then, the students wrote the words thought to be associated with the keyword. The keyword was written under the other one leaving a blank to prevent the risk of a chain response (Bahar and Özatlı, 2003). If the respondent does not return the keyword while writing each word, they can write the words brought to mind by the concept provided as response, instead of the keyword, which may interfere with achieving the objectives of the test. The time given to the students for the keywords in every page was checked. At the end of the allotted time for each keyword, the students were asked to go to the other concept, and the operation was repeated until all keywords are run out.

d) Data Analysis

The first three questions in the STEM Survey were analyzed with content analysis, while the last question was analyzed with classification of the drawings. During content analysis; the transcribed version of the interview was examined several times, important dimensions were determined considering the literature for the purposes of this research, and codes were generated from those dimensions. As a result of examination of the generated codes, their relations with each other were elicited and classified, and the common themes were found. These transactions were made with Nvivo package program. The compliance obtained from analysis of the data separately coded by two researchers was compared for reliability of the coding. Also, since the interview data were turned into a research report initially on the basis of description of the current situation, direct quotes were used in order to reflect the perspectives of the participating students and to portray the described situation more vividly in the mind of the reader. In addition, pseudonyms (P1, P2, …., P32) were replaced with the participants' real names in order to hide their identitis.

The STEM-WAT was analyzed by examining in detail the responses given for the word association test in the pre-test and the post-test. First, the frequency table was prepared to indicate how many different words were used by students for natural sciences, technology, engineering, mathematics and STEM keywords. The number of generated response words is one of the methods used in the evaluation of the data in this technique. The number and nature of words associated with a concept can be used to determine if that concept was understood because a better understanding of the concept depends on other words associated with it. Then, the frequency of the words used for each keyword was calculated. For analysis of the WAT results, not only the frequency and types of the key words but also the number of common words allocated for key words and the order of listing them are also important. This in turn helps to analyze the semantic proximity between keywords and allows us to map it. The mapping can also be made using data in the frequency table. Bearing these frequencies in mind, separate concept networks have been formed for pre-test and post-test. While creating the concept networks, the cut-off point (CP) technique developed by Bahar et al. (2006) was used. In this technique, initially the most frequently mentioned response is determined for each. The frequency of the response is considered to be the upper limit. 3-5 points below the highest frequency is used as a cut-off point. Determined cut-off points are written on the left side of the table. Concept networks are created starting from the first cut-off interval. Then, the cut-off point is pulled down at regular intervals and the process continues until all of the keywords appear in the concept network. In this study, the upper limit is set at 26 and above, and the concept network is created as 5 interval starting from here. The relations occurring at each cut-off interval are shown in different colours. Each interval drawn in the analysis phase of the data was examined individually because the answer word related to the keywords can be a product of connotation at the level of recalling with a non-significant relationship with keyword (Nartgün, 2006). Also, the interval will be more complex and upper level than a single-word answer.

FINDINGS

The results are presented in two sub-headings as the results obtained from the word association test and those obtained from the survey. The first sub-headings is devoted to the survey results regarding pre-service teachers' thoughts on relations between natural sciences and other disciplines. Under the second sub-heading, the findings obtained from the word association test showing the pre-service teachers' cognitive structures related to natural sciences, technology, engineering, mathematics and STEM.

STEM-Survey Results

For the question "What other disciplines do you relate natural sciences discipline to? Briefly explain how you perform this relation," responses were taken from participants both before and after they receive STEM education. The results are presented below in Figure 4.

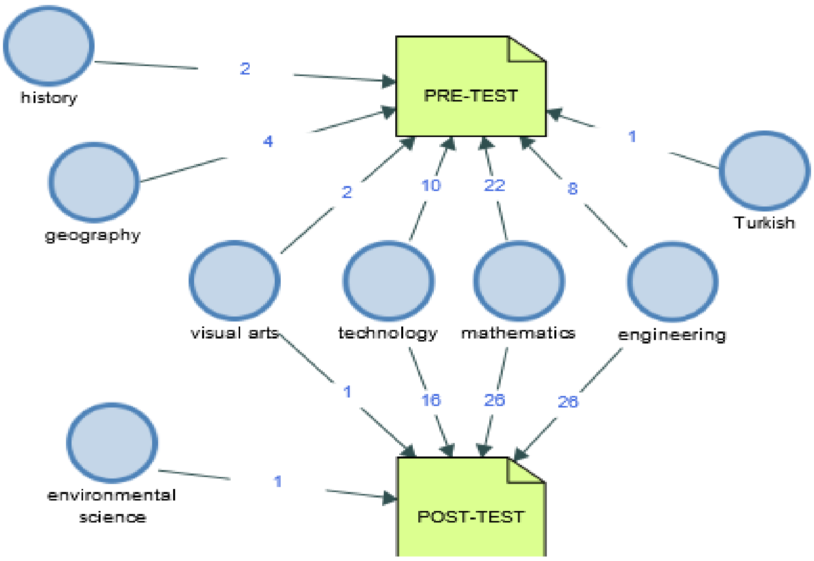


Figure 4: *The opinions of the pre-service teachers about the disciplines that were related to natural sciences*

As seen in the Figure 4, respondents listed the disciplines in a descending order of relation with natural sciences. According to the pre-test and post-test, the disciplines related to natural sciences were reported as mathematics, engineering, technology and visual arts, respectively. Apart from these, in pre-test, relation was made with geography, history and

Turkish, while attributions were also made to the environmental science in post-test with Turkish. It was seen that more relation was drawn by pre-service teachers in post-test, whereas pre-test revealed an increased diversity in disciplines compared to post-test. The obvious difference in the number of those who made relations in post-test compared to pre-test and inclusion of the difference of STEM fields may be the result of STEM education they received. The decreased diversity of disciplines and increased focus on STEM areas could be explained with the education.

In statements relating natural sciences to other disciplines, it is emphasized that the relationship between natural sciences and mathematics is at the phase of arithmetic operations and formulas: "…physics and chemistry consist of numeric data. The majority including biology to some extent has operations with numbers". The relationship between natural sciences and technology was demonstrated with technological devices such as tools made in natural sciences lesson and technological devices used during teaching of natural sciences lesson such as projector and computer. The pre-service teacher P24 stated in pre-test that: "we can take advantage of natural sciences to make technological tools or we can teach natural sciences by using technology." As for the relation with engineering, a similar relationship was found implying that engineers of the future are trained with the tools developed in natural sciences lesson: "…if the relation between natural sciences and math is in the right way and built on the solid foundation, we can bring up engineers and produce robust and useful technologies. (P3:post-test)" Its relationship with history is considered from two perspectives as the process which scientific knowledge has gone through and lives of scientists. The response given by P22 includes both perspectives: "The life of scientists, what kind of a scientific method has been implemented, and natural sciences can be better comprehended in reference to how scientific discoveries and scientific inventions were made in natural sciences." The relation of natural sciences with Turkish was stated as "the ability to transfer scientific knowledge" (P10:pre-test), while the relationship with visual arts was expressed by "much better instruction can be achieved by supporting with visuals". In addition, although it was noted that natural sciences is associated with other disciplines such as geography and environmental sciences, no statement was provided about this relationship.

In general, the relationship between natural sciences and other disciplines is understood to be dealt with at two dimensions. First, all disciplines are interrelated, and natural sciences is one of these disciplines. This was argued by P26 in pre-test indicating a chain relationship among the disciplines: "Natural Sciences, which is a discipline in relationship wih mathematics, technology, engineering and a number of other subjects, is developing hand in hand with them. This relationship continues in parallel with the interaction. For example, the development of natural sciences also affects technology, and technology affects engineering in turn. It continues as a chain ring." Secondly, natural science is a basic discipline and other disciplines help it: "When it is not enough alone, natural sciences discipline will benefit from other disciplines, mainly maths, geography and so on. (P6:pre-test)", "…technology and mathematics disciplines constitute natural sciences. (P27:pre-test)", "We, of course associate natural sciences discipline with physics, chemistry and biology. In addition to these, we may associate it with mathematics and even with all disciplines. (P5:pre-test)" The second opinion attempted to be changed in education system can be considered as a reflection of the education received by teachers during their education from kindergarden to university. Also, a very small number of participants were found to perceive and report that natural sciences as a discipline is unrelated with physics, chemistry and biology: "As a priority, of course, we associate the natural sciences discipline with physics, chemistry and biology. (P6:pre-test)"

As another question seeking support for the above-mentioned results, the participants replied the question "What do you think natural science is?" The answers provided for this question were analysed in terms of "what disciplines associate with natural sciences" in accordance with the purpose of the study. Below are given the disciplines mentioned by respondents describing natural sciences in reference with other disciplines along with respective frequencies (see in Figure 5).

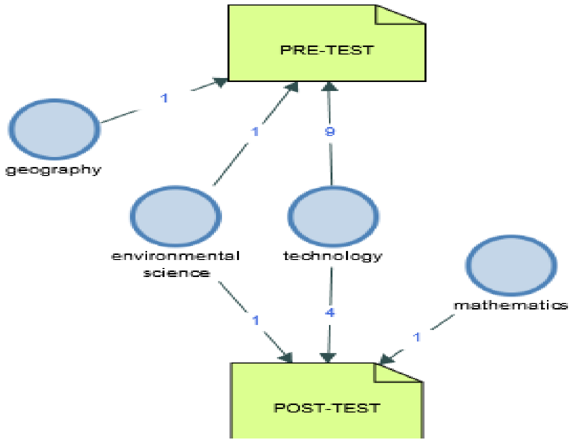


Figure 5: *The disciplines mentioned by the pre-service teachers in the definition of natural sciences*

As Figure 5 suggests, natural sciences is found to be associated relatively less with the other disciplines and mainly associated with technology in post-test. It can be inferred from the respondents' definitions that they began to perceive natural sciences as a field that facilitates observing the nature and smoothing life as a result of the STEM education: "learning and using the knowledge in everyday life (P5:post-test)", "life itself (P2:post-test)", " all natural events we observe (P4:post-test)": In the education, models of the everyday machines such as amusement parks, bridges and doors, and their working principles have been learned. In this education, natural sciences perceptions of the pre-service teachers may have been influenced in relation with making sense of life. On the other hand, it is understood from the definitions that the majority perceive physics, chemistry and biology as natural sciences branches, while a few pre-service teachers hold the misconception that these are the branches that make up natural sciences: "There are many disciplines in the natural sciences field. Natural Sciences discipline proceeds under the influence of physics, chemistry and biology disciplines (P23:pre-test).

Another question asked to participants "Would you consider to benefit from this relation for your course as a pre-service science teacher? Why?" was replied as the following.

As seen in Figure 6, almost all of the pre-service teachers stated that they intend to take advantage of the relation between natural sciences and other disciplines in the scope of their own lessons. In addition to those stating that they do not intend to do so without proposing a justification, there were also pre-service teachers who did not state their opinion or provide any answers for this question.

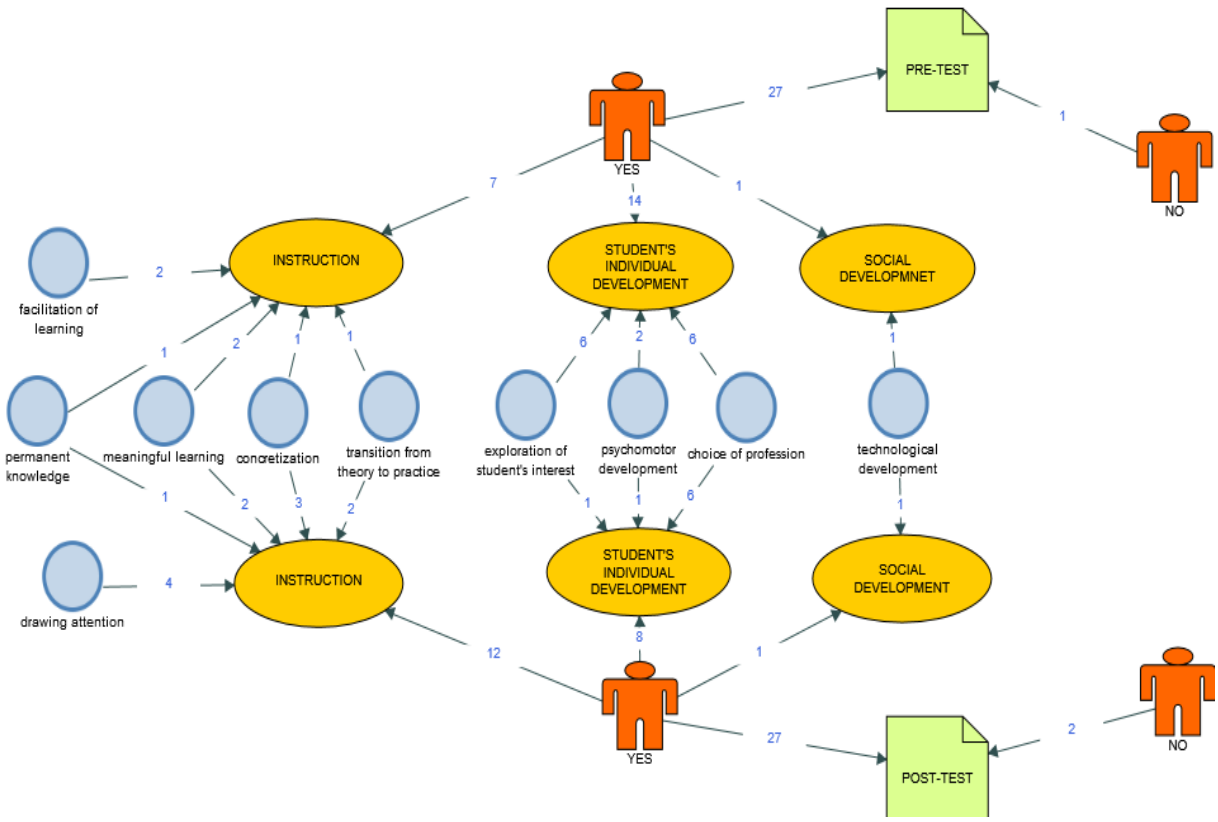


Figure 6: *The opinions of the pre-service teachers about teaching natural sciences related to the other disciplines*

The pre-service science teachers who are planning to relate natural sciences to other disciplines in their lessons believe this relation will make a contribution concerning with instruction, to individual development of students and social development. In the scope of the instructional contribution, they were seen to refer to realization of meaningful learning, concretizing of the topic, transition from theory to practice, permanent knowledge, facilitation of learning, and drawing student's attention to the lesson. Preservice teachers expressed their opinions in this regard as the following:

"...in most areas, it ensures meaningful learning by borrowing support from other fields. (P16:post-test)",

"In order to make the theoretical information transmitted to students more concrete, we take the advantage of these relationships and give examples, in this way, we make these examples concrete in the teaching area. (P6:post-test)",

"...with content knowledge, we are putting theory into practice. (P11:post-test)",

"combination of intertwined disciplines increases the efficiency. Permanent information would be gained. (P1:pre-test)",

"...if lectured together with all lessons, namely if associated with other lessons, it becomes easier for students to understand. (P26:post-test)",

"More attention could be drawn to the course by awaking curiosity about the course area by using areas such as engineering and technological development. (P20:post-test)"

The respondents indicated the contribution for students' individual development in terms of psychomotor development, exploration of their interests, and choice of profession. Preservice teachers expressed this view in the following way:

"...I benefit from the other disciplines for each student's interests. I can manage this by doing experiments and applying activities to develop hand skills. (P15:post-test)",

"... I can get them to switch to different professions. (P32:post-test)",

"When I become a teacher in the future, I will have students with different capabilities and interests in different areas. Therefore, I benefit from other disciplines for each student's interests. (P15:post-test)",

"The purpose of the course of natural sciences is to divert students to natural sciences. Experiments and observations are the first steps in a scientific research. I can think of my students as scientists and I would like to train them as individuals who do research for natural sciences and help natural sciences. For this, I would like to benefit from the relation among these four disciplines. (P32:pre-test)"

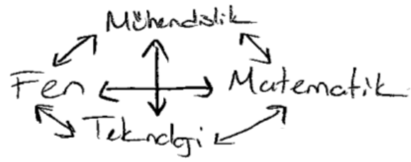
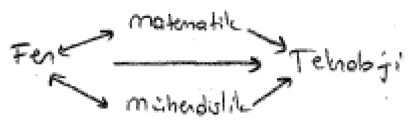
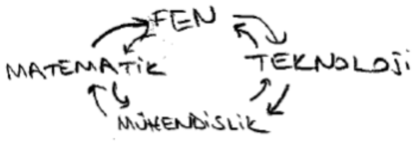
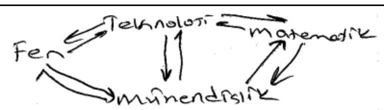
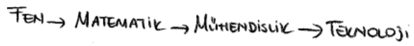
As for the contribution to the social development, the respondents stated it in relation with technological development:

"...From their relationship with each other, new inventions and various tools are obtained from the field of medicine and so on. (P31:post-test)"

"…if the relation between natural sciences and math is in the right way and built on the solid foundation, we can bring up engineers and produce robust and useful technologies (P5:pre-test).

The last but not the least, the preservice teachers' answers to the question "Draw a diagram showing the relationship among Natural Sciences, Technology, Engineering and Mathematics and explain" are summarized in Table 2.

Table 2: *The diagrams showing the relationship among Natural Sciences*

Relations	n		%		Example
	Pre-test	Post-test	Pre-test	Post-test	
All disciplines are interrelated	8	10	25	31	
Natural Sciences is related with other disciplines	6	8	19	25	 
All disciplines are circular related	1	5	3	16	
Engineering is related with other disciplines	8	2	25	6	
All disciplines are chain related	1	2	3	6	
Other	8	5	25	16	
Total	32	32	100	100	

Preservice teachers provided the following explanations in their description of the drawings: “Thanks to mathematics, which is under the influence of natural sciences, and thanks to engineering, solutions that make life easier are produced so as to develop technology.”, “They all influence each other”, “Natural Sciences is the main concept which covers all the other concepts. All constitutes a whole interrelated with each other.”

Results from Word Association Test

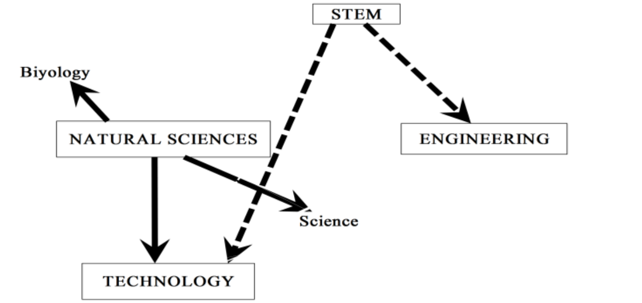
On the basis of the keywords and the related words in the STEM-WAT, the concept networks generated according to the pre-test and post-test data are presented in Figure 7. The concept networks in Figure 7 were prepared according to the cut-off technique developed by Bahar et al. (1999).

In Figure 7, the responses given by the preservice teachers are presented with the concept networks that were created using the cut-off technique. As a result;

1. For the cut-off point at and above 26, no key concept was yielded from pre-service teachers’ cognitive structures in the pre-test. However, the post-test reveals the formation of relations among Natural Sciences, Technology and STEM-related key concepts. Of these, the unidirectional relationship between STEM → Technology and STEM → Engineering as well as the bidirectional relationship between Natural Sciences↔Technology seem particularly outstanding. Remarkable outlook of relations rather than words in preservice teachers’ cognitive structure indicates that they attribute meaning to them in their memory.

2. Between the cut-off point in the range of 21 and 25 in the pre-test, Natural Sciences and Mathematics were seen to emerge as two separate concepts in pre-service teachers’ cognitive structure. Moreover, the first link was created by the relation of the concept of Natural Sciences with the term of Technology. Also, Natural Sciences and Mathematics have brought to mind the words “science” and “number”, respectively. In the post-test, although the key concepts and relationships between them started to emerge, relations rather than words continued to be on the forefront in pre-service teachers’ cognitive structure. As one examines the established relationships, it can be seen that STEM is linked with all the disciplines (STEM→Natural Sciences, STEM→Technology, STEM→Mathematic and STEM→Engineering). It is a remarkable finding that although STEM calls for all the disciplines, none of them seems to call for STEM. In terms of relations between disciplines, it is seen that unidirectional relation is established as Engineering→Natural Sciences and Engineering→Technology, while there is a bidirectional relationship as Mathematics↔Engineering. On the other hand, according to the analysis of the words associated with key concepts, it can be said that words related to natural sciences were often produced. The words are seen to be branches of Natural Sciences (physics, chemistry, biology). Hence, it can be suggested that a conceptual change occurred in pre-service teachers in a positive direction about uncovering the relationships between concepts, not the number of words produced.

3. Between the cut-off point in the range of 16 and 20 in the pre-test, a slight increase was seen in the number of words produced and the number of relations offered. Although Natural Sciences, Mathematics and Engineering seem to be perceived as science by pre-service teachers, the same attribution was not made to technology. Also, natural sciences was associated with “experiment” by the participants. Just as Mathematics recalls numbers (cut-off point at 21-25), looking at the “experiment” connotation of natural sciences, these

<table>
<tr><th></th><th>PRE-TEST</th><th>POST-TEST</th></tr>
<tr><td>CP: 26-</td><td></td><td>
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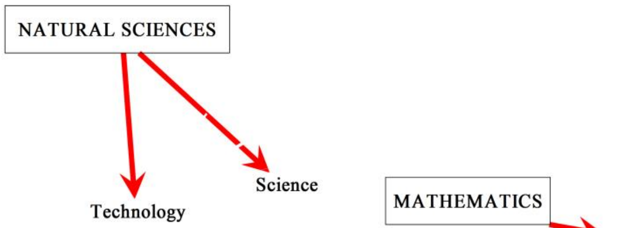
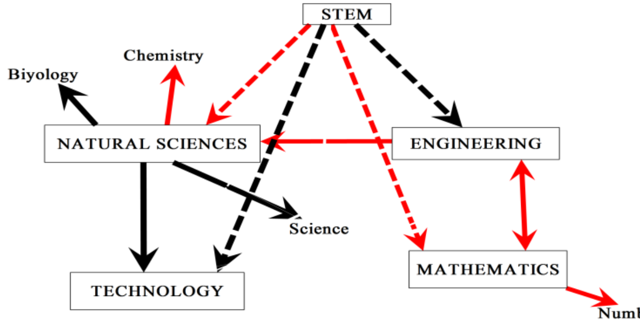
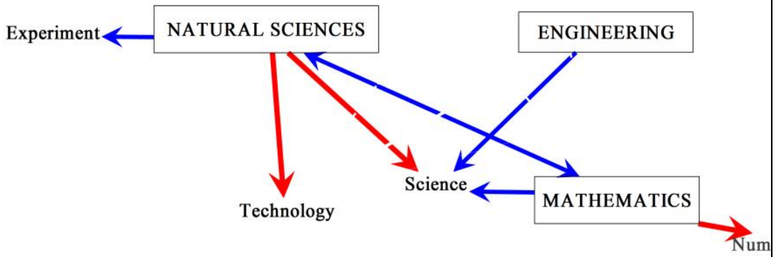
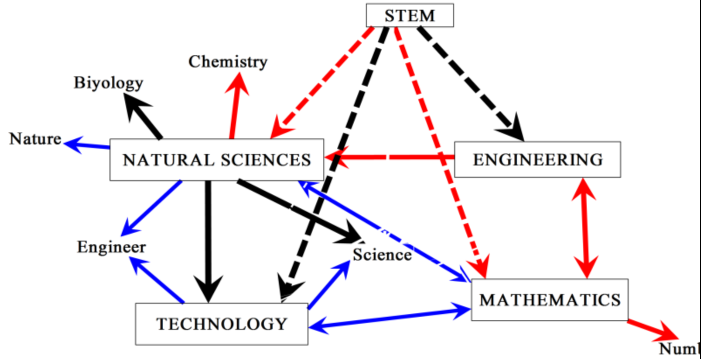
<tr><td>CP: 21-25</td><td>
</td><td>
</td></tr>
<tr><td>CP:16 -20</td><td>
</td><td>
</td></tr>
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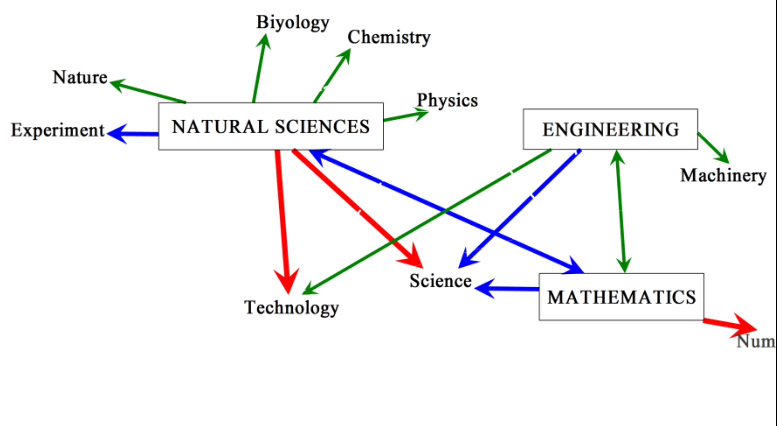
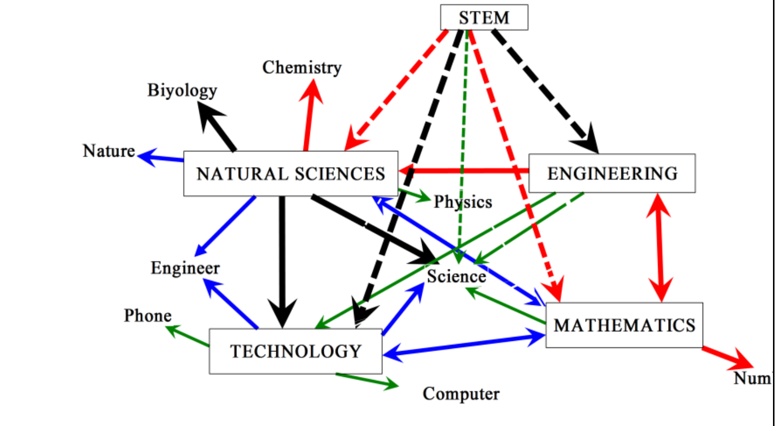
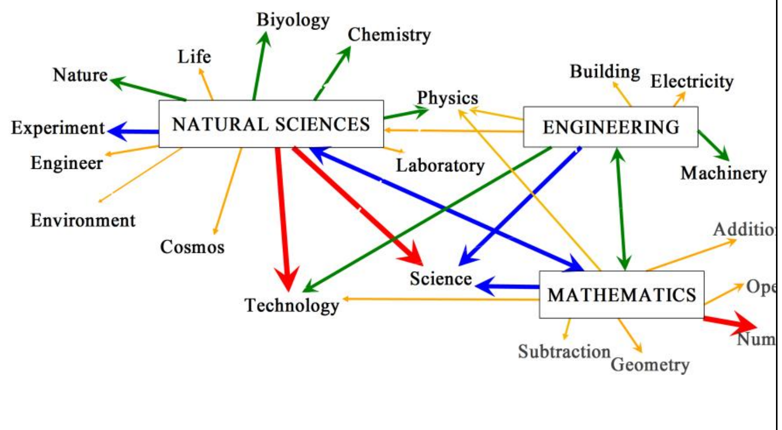
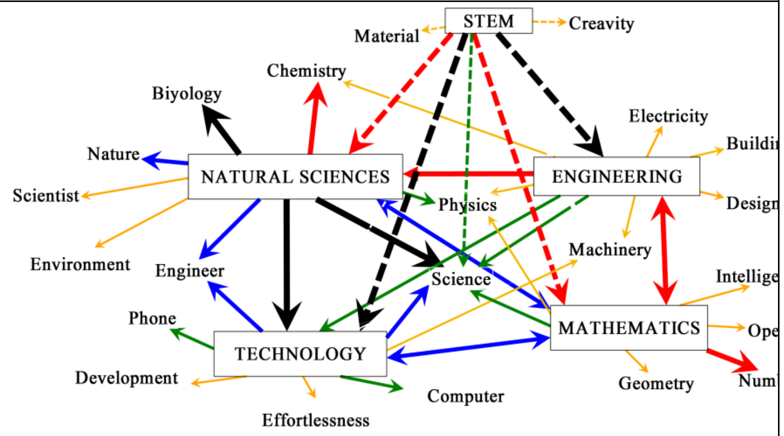
CP: 11-15		
CP: 6-10		

Figure 7: *The cognitive structures of pre-service teachers*

concepts (Natural Sciences and Mathematics) can be said to be identified with the words they are first associated. On the other hand, a bidirectional relationship was indicated between natural sciences and mathematics. In the post-test, all the key concepts emerged and the relationships between these concepts and the number of words associated with these concepts continued to increase. A bidirectional relationship is seen between Natural Sciences↔Mathematics and Mathematics↔Technology. At this stage, it is interesting that relations are observed between all concepts except forEngineering→Natural Sciences and Engineering→Technology. Despite the lack of the relation of natural sciences and technology with engineering (Natural Sciences→Engineering and Technology→Engineering), a link was established between the two concepts by associating Natural Sciences and Technology with the term engineering. Apart from that, when viewed relative to the number of words produced, it is understood that natural sciences recalls a greater number of words to the minds of the pre-service teachers compared to other key concepts.

4. Between the cut-off point in the range of 11 and 15 in the pre-test, a drastic increase was seen in the number of words and relationships associated with the concepts of natural sciences, but mathematics was seen in comparison to the others. In natural sciences, field-specific words began to emerge (physics, chemistry, biology, nature). Establishing relationships between key concepts continued. On one hand, a bidirectional relationship was found between Mathematics and Engineering (Mathematics↔Engineering); on the other hand, Engineering was seen to be associated with Technology (Engineering→Technology). In the post-test, the quality of the words produced seems more noteworthy than the relations made. Field-specific phrases, which had been seen in natural sciences only, began to appear in other key concepts as well. Technology was noted to call for computer and phone, while engineering called for construction. Another finding is that all of the key concepts are defined as natural sciences. Pre-service teachers seem not only to be aware of the fact that Natural Sciences, Technology, Mathematics and Engineering are branches of natural sciences, but also to perceive STEM as a type of natural sciences. However, here it can be said that the participants hold a wrong impression that STEM is a field of natural sciences.

5. Between the cut-off point in the range of 6 and 10 in the pre-test, it is seen that the key concept technology was not obvious in the network concept yet, resulting in the lack of emergence of all the key concepts. The words generated regarding key concepts seem to be field-specific. Natural sciences was linked with life, environment, universe, laboratory, and engineers; Engineering with Natural Sciences, electric, construction, and physics; lastly, Maths was linked with geometry, operation, addition and subtraction.On the contrary, it was seen that the participants did not recall technology even on the last rank. Moreover, no concept which could evoke the concept of technology was mentioned. It is strange that despite the currently experienced age of technology, the preservice teachers seem not to have enough connotations in mind about technology. In addition, the finding that they do not regard technology as natural science seems to support the inference above. Investigation of the established links lastly reveals unidirectional relationships as Engineering→Natural Sciences and Mathematics→Technology. Also, the concept of engineering was determined to be associated with physics, and there was an established link between Engineering and Natural Sciences. In general, very little connection can be mentioned between the associated words and the key concepts. As the links are examined, outward networks are seen. In other words, it may be said that the preservice teachers just think the words associated with key concepts with keywords are unique to that area, being unaware that the same words could be related with different areas. In the post test, five key concepts were seen with more complicated and intertwinted relationships. In addition, a larger number of links were seen to be established between the associated words and the key concepts. Those links were found to

reveal an inward structure. In this case, it could be argued that the students noticed the possibility to associate the concepts associated with a specific field with other areas as well. Besides, the relationship between the key concepts is seen to be expanded further. For instance, by expressing that Natural science, Mathematics and Engineering concepts are related with physics, another connection was found among these three fields. Similar relationships were noted with chemistry in the context of Natural Sciences and Engineering, and with machinery in the context of Technology and Engineering. As regards to the key concepts, the number of words associated with specific areas continued to increase. (Uses such as Mathematics-operation, geometry, intelligence; Natural Sciences-scientist, environment; Engineering, electric, design; Technology-development, convenience were seen).

Overall assessment of the Word Association tests results demonstrates that the relationship among the concepts of Natural Sciences, Technology, and Mathematics was branched and independent in the pre-test. Despite the higher number of concepts in the pre-test compared to the post-test, limited relationship was reported between them by respondents.Contrarily, post-test results show a decrease in the number of concepts, while the relations increased significantly. In addition, the concept STEM is seen to be linked with Natural Sciences, Technology, Engineering and Maths in the post test. The relationship among the key concepts of Natural Sciences, Technology, Engineering and Mathematics implies that initially the participants' cognitive structure was partially independent before the implementation. After the implementation, the pre-service teachers could draw links between the concepts revealing the interrelation among them.

The pre-service teachers' responses to the WAT, which were discussed in detail in the concept netword above, are summarized in the following Table III.

Table 3: *The frequency of the pre-service teachers' responses to the Word Association Test*

Key Concepts	**Frequency of the responses**	
	Pre-Test	**Post-test**
Natural Sciences	86	83
Technology	115	94
Engineering	103	95
Mathematics	88	80
Total	392	352
STEM	-	101

As seen from the Table III, in this study, the total number of words in the WAT was noted as 392 before the course, but 352 after the course. Also, in both pre-test and post-test maximum words were noted for Technology and Engineering, whereas the concepts of Natural Sciences and Mathematics covered the least words. Besides, the number of words specified in pre and post-test was approximately equal in Natural Sciences and Mathematics; a higher number of words was found to be allocated for Mathematics and Engineering during pre-test than in post-test.

Given the different number of words produced in the table, it is understood that the total number of keywords decreased in comparison of post-test (352) to pre-test (392). Beside, the decrease was seen in the number of words associated with each of the keywords after the STEM education. Frequency tables and the concept networks built on them reveal that quality and significance of the given words increased as a result of the education, and the reduction in the level of students' knowledge can be said to be more than the decline in the number of words produced actually.

CONCLUSION and RECOMMENDATIONS

In both Turkey and other world countries, studies on interdisciplinary approaches can be found in academic curricula of many disciplines under the heading of "associating with other courses". However, most researches suggest that teachers lack experience in research on the relationships and connections between the disciplines of a particular curriculum (Jacobs, 1989; Mason, 1996; Aybek, 2001; Karacaoglu, 2008; Bümen, 2005). In order to produce a solution to this problem caused by interaction of disciplines, a number of education approaches were introduced, one of which is the STEM approach that integrates the disciplines of natural sciences, technology, engineering and mathematics. STEM is a learning approach by which basically student-centered and collaborative learning is emphasized and the four disciplines are taught simultaneously in real-life situations rather than teaching of them separately and in different areas (Herschbach, 2011; Israel, Maynard and Williamson, 2013, Hom, 2014).

Before the STEM education, the pre-service science teachers could also associate science subject with various courses; but it could be said only a few of them do so. It is understood that these relations mostly include Biology, Physics, Chemistry, Earth, Sky and Environmental Sciences, Health and Natural Disasters, which are referred to as basic knowledge about natural sciences in the science curriculum (MEB, 2013). After receiving the STEM education, a marked increase was recorded in the number of relations with other courses in spite of the reduction in the number of associated disciplines. This growth includes the STEM fields. The decrease in discipline diversity against increased focus on STEM fields may be a result of the interdisciplinary STEM education they received in this study. The pre-service teachers pointed out that natural sciences subject could be associated with Turkish, history, visual arts, geography and environmental science besides STEM fields.

When we look at their projections on interdisciplinary science teaching in their future classes, the reflection of this relationship could be felt. The pre-service teachers just noted mathematics to associate with science teaching in the future prior to the STEM education. Other interdisciplinary studies particularly report relation between natural sciences and maths disciplines (Czerniak et al., 1999; Pang and Good, 2000). This might have been resulted from the frequent application of mathematics to natural sciences and the relation between mathematics and real life often observed in natural sciences. Dugger (2010) thinks that in this trend, as he called "STEM", technology and engineering are both pushed into the background. This approach, which places very little emphasis on technology and engineering, seems very unlikely to help individuals establish a proper relationship among STEM disciplines (Bybee, 2010). Contrary to these results, the pre-service science teachers in this study could associate Natural sciences with Mathematics, Technology and Engineering after they were given interdisciplinary education as a combination of mathematics, engineering and technology in the context of science class (See Figure 8). These relations were in Mathematics as "making arithmetic operations and using formula in natural sciences course", in Technology as "the tools made in natural sciences course and technological devices used in science classes such as projector and computer", and in Engineering as "developing instruments in natural sciences course". This result can be explained with the fact that integration of STEM disciplines was realized in the framework of engineering design problems during the pre-service course (Roth, 2001; Wendell, 2008; Daugherty, 2012; Strong, 2013). Since Engineering Design Process (EDP), as the production process of technology, requires to use basic engineering knowledge and skills as well as natural sciences and mathematics principles, it naturally ensures relationships of STEM disciplines with each other.

From overall assessment of relations between natural sciences and other disciplines drawn by pre-service teachers, it is seen that they address such relation from two aspects: "All disciplines are interrelated and natural sciences is one of these disciplines" and "Natural

Sciences is the basic discipline, and other disciplines help it" (see p.11). The diagrams made by pre-service teachers to show the relationships among the four disciplines support this result. The first aspect was supported by drawings implying that all disciplines are related, disciplines are cyclical and there is a chain-like relation among them. The other aspect (Natural Sciences is the basic discipline, and other disciplines help it) was supported by drawings suggesting that Natural Sciences is associated with other disciplines. This result seems consistent with the multidisciplinary relation approach in STEM education. In STEM, teaching is performed by harmonization of the contents of four abovementioned disciplines or placing one of them in the focus to teach its content by means of the other three disciplines (Moore et al., 2013). However, the second aspect reveals that the axis course approach remains unchanged, even though the changes made to the curriculum (MEB, 2013) were intended to change this understanding.

Another conclusion of the present study suggests that almost all pre-service teachers think of benefiting from relation of natural sciences with other disciplines in their classes; but they seem to be hindered in practice. This result shows similarities with the study by Aladag and Sahinkaya (2013). No concrete change has been reported following the STEM courses, possibly because the interdisciplinary STEM courses mostly offer activities to elicit the relationship among the four disciplines. Other studies also indicate the need for pedagogical content knowledge as well as sufficient subject area knowledge to be able to have interdisciplinary skills (Aybek, 2001; Frykholm and Glasson, 2005). It is known from many studies that science teachers graduate without having adequate pedagogical content knowledge (Aydın and Boz, 2012). Other probable reasons for this situation are reported in the literature. For example, pre-service teachers are taught lessons which provide really a few relations with other disciplines throughout their secondary education. Alternatively, little emphasis can be placed on interdisciplinary relation to improve both pedagogical content knowledge and subject area knowledge in the courses they have taken during undergraduate education. Also, it is noted that despite the updating of the curricula, integrity of the disciplines is not highlighted remarkably at the required extent in courses within the existing education system; rather, disunited teaching of the contents is sustained.

On the other hand, the pre-service teachers who are thinking of associating natural sciences with other disciplines in their future classes, hold the belief that such relation would be useful for both individual and social development of students. In terms of teaching benefits; the participants mentioned realization of meaningful learning, concretizing of the topic, transition from theory to practice, permanent knowledge, facilitation of learning, and drawing student's attention to the lesson. The respondents exemplified the contribution to students' individual development and psychomotor development, exploration of their interests, and choice of profession. In this regard, STEM course could have made contribution to pre-service teachers' developing positive attitude towards interdisciplinary STEM approach. In a similar study on pre-service teachers associating social studies with mathematics lessons, it is reported that the relation is significant as it helps to internalize the concepts, addresses topics at different dimensions, increases the effectiveness of learning, ensures permanent learning, increases the interest in the course, provides meaningful learning, brings a different perspective to happenings, draws cause-and-effect relationship, notices the relationship between the contents of different courses, and associates the knowledge with real life (Aladag and Sahinkaya, 2013). The results of this study are in parallel with the present study.

As seen above, while the pre-service teachers expected contribution from interdisciplinary relation to individual development prior to the education, they thought that it would contribute to their teaching skills as a result of the education. The most important reason could be their awareness of the change in their instructional knowledge as a result of the education they received. Whereas the justifications indicated by prospective teachers were somehow superficial before the education on interdisciplinary relation, they gained a little more depth. Mansur (2009) argued that although the teachers have a positive attitude towards a new approach, they might have a negative attitude towards the applicability of this approach in the classroom. It might be because they lack concrete experience although they have an idea about this approach. Here the need becomes apparent to support relational comprehension of pre-service teachers for their professional development relating to their own discipline as well as other disciplines to be associated. It seems essential that interdisciplinary relationships be referred in teacher education programs and in-class activities.

For the purpose of equipping teachers, as practitioners of interdisciplinary curriculum, with knowledge and skills, teacher education programs offered in education faculties must include courses supporting integrated teaching knowledge, classroom applications and activities. To this end, it is recommended to collaborate with faculties of engineering and science and arts so that teacher education can be both diversified and enriched. Furthermore, pre-service teachers should be given the opportunity to take courses from faculties of science and arts, engineering and technology as well as faculty of education and therefore they should be encouraged to have a rich life experience (Corlu, 2012; Corlu, 2013).

Other recommendations would include providing adequate education for pre-service teachers at undergraduate level. Finally, works and studies could be included in “School Experience” and “Teaching Practice” courses in order to eliminate handicaps faced in practice.

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APPENDIX-1

A sample of worksheets

BRIDGE

Turkish scientist Aziz Sancar, with his "DNA repair study", making a decisive contribution on medical world, receives Nobel Prize, dedicated this award to Anıtkabir. At the same time, he wants to pay off his fidelity to his hometown, where he grew up in Savur, Mardin. For this purpose, by giving a great contribution on fixing and enhancements of the country roads, he is planning to build a bridge to relaxing traffic. So, he needs some help from the experts and he contacts with an expert team in the field of Physic, Maths, Engineering and Technology. You undertook this essential task.

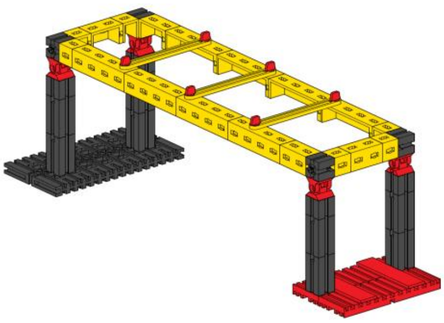
A bridge has four characteristic specialities,

- Being safe
- Being long
- Being cheap
- Being aesthetic

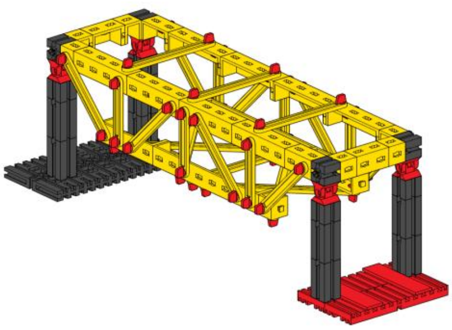
Before starting on building the bridge, you have drawn three different plans of the bridge. By doing prototypes of this drawings,make a decision on the theme of the characteristic property of it.

PROTOTYPE 1:

- Do same experiment with placing different weigths on the bridge.
- What can you say about the stability of it? Draw and name the static parts of the bridge.



PROTOTYPE 2 :



- Do same experiment with placing different weigths on the bridge.
- What can you say about the stability of it? Draw and name the static parts of the bridge.

PROTOTYPE 2:

- Do same experiment with placing different weigths on the bridge.
- What can you say about the stability of it? Draw and name the static parts of the bridge.

- In which areas and what aims can this bridge be used? Give answers with justifications.
- At the end of your assesment, according to these criterias, which model did you choose? Why?