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# Prerequisites for Elementary School Teachers before Practicing STEM Education with Students: A Case Study*

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**ABSTRACT**

**Purpose:** Implementing STEM education in the early grades is a more effective way to encourage creativity, problem-solving, and innovation. There is a need for elementary teachers to implement STEM education to integrate and contextualize science, technology, engineering, and mathematics (STEM) in their teaching. This research aims to examine the prerequisites for elementary teachers before practicing STEM education with students.
**Research Method:** This study is a case study and implementations were undertaken with six teachers over 13 weeks and were delivered in theoretical and practical ways. Open-ended pre-test and post-test, interviews, diaries of both researcher and participants, worksheets, lesson plans, assessment tools and engineering design process (EDP) reports were used as multiple data sources to triangulate findings. Thematic analysis was utilized using open coding and cross coding of data.
**Results:** Several codes emerged from the analysis that were grouped under five salient themes as follows: understanding STEM, instructional gains of STEM education for teachers and benefits of STEM education for students, instructional prerequisites for teachers and conditions of schools to perform effective STEM education.
**Implications for Research and Practice:** Theoretical and practical integrated STEM education can be planned in a long-term manner for the education program of elementary school teachers consisting of problem-based, inquiry-based and project-based learning enriched with content knowledge integrated STEM practices.



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## Introduction

In the 1990s, the National Science Foundation (NSF) in the United States of America supported the abbreviation SMET (1990) as educational policy, including the science, mathematics, engineering and technology disciplines at the regional level, emphasizing integrity rather than integration. Later, the term STEM began to be used despite objections due to comparisons with the definitions for the body of a plant or stem cells (Byee, 2013). The inclusion of STEM both as a definition and on curricula at national and international levels was of different importance in the 1990s due to the foundation of STEM schools, research centers, and inclusion on teacher education programs and in the educational policy plans of countries. When we examine definitions related to STEM education, in addition to the effects of STEM education on students, there are details related to implementation. Hence, Chute (2009) defined STEM as an education system where students produce solutions to problems encountered in real life and create opportunities, while Sanders (2009) identified STEM education as the purposeful integration of various disciplines used in solving real-world problems. STEM education ensures the development of many features, such as student's self-confidence, problem-solving, gaining life experiences, innovation, spatial skills and invention, and critical thinking (Baenninger and Newcombe, 1989; Morrison, 2006; Wai, Lubinski and Benbow, 2010).

The next generation of science standards ([NGSS], 2012) presents the goal of the framework for K-12 science education as:

> "Ensuring that by the end of 12th grade, all students will have some appreciation of the beauty and wonder of science, possess sufficient knowledge of science and engineering to engage in public discussions on related issues, be careful consumers of scientific and technological information related to their everyday lives, be able to continue to learn about science outside school, and will have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology" (p. 14).

STEM education, in addition to preparing scientific and technical instincts used more often over time with the increasing integration of technological research and development, also aims to create a more knowledgeable society with scientific and technologic literacy (NAS, 2014). When we look at definitions related to the implementation of STEM education, it is defined as adopting the perspective that these four disciplines are one unit. Thus, they should be taught as one cohesive entity (Breiner, Harkness, Johnson and Koehler, 2012). It is expected that students at the K-12 level will be able to engage in scientific research about the main science concepts and undertake engineering design projects based on the emphasis that engineering is included in STEM education (NGSS, 2013). STEM education aims to train individuals to be successful engineers by directing them to work with others in different disciplines who have communication skills, can find the best solutions to problems, think systematically, and have ethical values and creativity (Bybee, 2010; Dugger, 2010; Guzey, Tank, Wang, Roehrig and Moore, 2014; Mann, Mann, Strutz, Duncan and Yoon, 2011; Rogers and Porstmore, 2004). The general outputs of the STEM education highlighted in the engineering design section of engineering courses applied at the K-12 level is to increase students' success and motivation according to the National Research Council (NRC, 2012) report. Students develop their motivation for learning, science and mathematics, and solving problems at a better level (Furner and Kumar 2007; Stinson, Harkness and Stallworth, 2009) as they develop conceptual learning, higher-order thinking skills and engineering design skills (Fan and Yu, 2015). As seen in these explanations, integration of disciplines included in STEM is stated to contribute to the engineering and the importance of engineering in STEM education, the required skills for occupations in the future, and that even if occupations in the STEM field are not chosen, it contributes to raising scientifically and technologically literate citizens. In light of all this, we can define the STEM concept in summary as:

> "Instead of separate teaching of the science, technology, mathematic and engineering disciplines forming the basis of STEM, it is an applied teaching method targeting science and mathematics learning of 21st century skills with technology integration ensuring connections between engineering-based science and mathematics concepts in the process of producing products providing solutions to problems or desires occurring in daily life."

Within the many gains of STEM education, the research in the literature reveals that learning science should begin in elementary school in order for students to succeed in high school (Belden, Lien and Nelson-Dusek, 2010).

A student's interests, fundamental knowledge and skills concerning STEM mainly develop during early grades. Antony Murphy (2011) who is executive director of the National Center for STEM Elementary Education at St. Catherine University indicated that

> *Children at birth are natural scientists, engineers, and problem-solvers. They consider the world around them and try to make sense of it the best way they know how: touching, tasting, building, dismantling, creating, discovering, and exploring. For kids, this isn't education. It's fun! Yet, research documents that by the time students reach fourth grade, a third of boys and girls have lost an interest in science. By eighth grade, almost 50 percent have lost interest or deemed it irrelevant to their education or future plans. At this point in the K–12 system, the STEM pipeline has narrowed to half. That means millions of students have tuned out or lack the confidence to believe they can do science* (Murphy, 2011, para. 4- 5).

The implementation of STEM education in the early years ensures the development of not only mathematics skills and general knowledge in science and social studies but also reading skills that are fundamental for the scientifically literate people of the future (Brenneman, 2014). Also, to eliminate gender differences in the STEM field, starting STEM education in the early years was endorsed by Xie, Fang and Shauman (2015) and Belden, Lien and Nelson-Dusek (2010). The focus is not on achievement, but on the process of engaging the student in learning and thus, forming an interest in STEM. It is recommended that rather than a separate engineering education program, integrated STEM education is applied at the K-5 level since it focuses on the key knowledge and skills for 21st-century citizens (Lamb, Akmal and Petrie, 2015; NGSS, 2013). While Tseng, Chang, Lou and Chen (2013) observed that project-based learning activities integrated into STEM significantly affect students' positive attitudes towards engineering, the positive attitude that emerges is mostly in the form of engineering, then science, thirdly technology and finally mathematics. They stated that they were ranked. Researchers defending the integrated approach in STEM education have proposed that students' interest, motivation and success in lessons increases with topics, including problems encountered in daily life; as a result, this situation is expected to increase the academic success of students in addition to increasing the number of students planning careers related to STEM in the future (Gulhan and Sahin, 2016; Honey Pearson and Schweingruber, 2014; Stohlman, Moore and Roehrig, 2012). Engineering design in STEM education encourages students to engage in more formalized problem-solving in which they define a problem using criteria for success and constraints or limits of possible solutions. Students research and consider multiple possible solutions to a given real-world problem (Purzer, Goldstein, Adams, Xie, C. and Nourian, 2015; Moore et al., 2014a; English, Hudson, and Dawes, 2013; NGSS, 2013; Mehalik, Doppelt and Schun, 2008; Diefes-Dux, Hjalmarson, Miller, Lesh, 2008; Cunningham and Hester, 2007). Within the advantages of engineering education in STEM integration, there were arguments about the integration of four disciplines concerning how integration will be planned. The main problem lies in the definition of STEM education are being the combination of science, technology, engineering, and mathematics in one class. However, according to Stohlmann et al. (2012, p. 30), "in general, integrated STEM education can involve multiple classes and teachers and does not always have to involve all four disciplines of STEM." Hurley (2001) and Byee (2013) presented many different forms of integration, giving the advantages and disadvantages of each form. Byee (2013) indicated that no one approach is best and Morrison (2006) also pointed out the needs for transdisciplinary integration. Bryan, Moore, Johnson and Roehri (2015) identified three forms of integration considering content and context; (a) content integration where learning experiences have multiple STEM learning objectives, (b) integration of supporting content where one area is addressed (e.g., mathematics) in support of the learning objectives of the main content (e.g., science) and (c) context integration where the context from one discipline is used for the learning objectives from another. In this research, in the research- and inquiry-based 5E learning model, the Life-STEM topics of the brain and stomach were chosen. In the 5E learning model, topic content is learned practically in the engage, explore, explain sections, while the engineering design process (EDP) is applied in the extended section. In the extended stage, technology, physics (helmet design) and chemistry (acid, choosing material against acidity) are integrated.

STEM education positively affects the academic success of students in future experiences, is effective in choosing an occupation in the STEM fields and develops positive attitudes to mathematics and science lessons, so this requires changes for teachers who will provide this education (Daugherty, Carter and Swagerty, 2014) and their education programs (Wyss, Heulskamp and Siebert, 2012). However, the application of new teaching methods in the classroom rather than traditional models or the existing professional development models used by teachers has been discussed for a long time. Furthermore, even the teachers that were involved in education programs of new teaching methods were unable to keep using them over a long time in practice since they did not assimilate these strategies (Ebert-May, Derting, Hodder, Momsen, Long and Jardeleza, 2011; Henderson et al. 2012). Elementary school teachers need STEM education to integrate and use engineering in the teaching, learning, and assessment of their content (Guzey et al., 2014). During the education of teachers, various researchers have documented the many difficulties that have been encountered in presenting STEM education. A summary of these problems is outlined below with the implications of many studies: **a) Lack of enough time**: Generally, there is not enough time allocated for the application of engineering practices and teachers believe that engineering is just another addition to their heavily loaded science curriculum (Czajka and McConnell, 2016; Guzey, Tank, Wang, Roehrig and Moore, 2014; Lee and Strobel, 2010; NRC, 2013). Teachers specifically consider the weekly plan that allows the students time for engineering practices (Dorph et al., 2011) and also other non-formal education and STEM practices that would need to be implemented out of school to improve students' positive attitude and beliefs toward science (OECD 2012). **b) Need for an integrated curriculum:** The curriculum needs to be flexible (Jardine, 2006) rather than rigid (Pinar, Reynolds, Slattery, and Taubman, 2000). Integrated programs in teacher education (Berlin and White, 2010; Offer and Mireles, 2009) have been implemented or are planned, but problems found were the lack of the development of supporting curricula materials and instructional models for STEM integration (Stohlmann et al. 2012). **c) Lack of adequate content knowledge and skills**: Elementary school teachers need content knowledge for both science and mathematics and for the integration of engineering, they also need knowledge and skills (NRC, 2013; Guzey et al., 2014; Czajka and McConnell, 2016)**.** Furthermore, in addition to mathematics and science background, they need engineering and technology education (Debiase, 2016) and their lack of STEM content knowledge affects their self-efficacy to practice STEM in the classroom (Bencze, 2010).The problem is dealing with the teacher education programs or elementary education curriculum. Thus, teachers are reluctant to undertake many science activities in class giving their reasons as the level of conceptual knowledge (Chaney, 1995; Darling-Hammond, 2000; Druva and Anderson, 1983), level of education (Furtak, 2005; Ingersoll, 2003), experience (Wenglinsky, 2000) and habits of primary teachers (Abd-El-Khalick et al., 2004) and level of self-confidence (Harlen and Holroyd, 1995; Kind, 2009). **d) Overcrowded classrooms**: Engineering is not accessible to a large number of students (Douglas et al., 2004). **e) Insufficient tools and technical facilities of schools**: Tools and resources available to students are essential in providing multiple learning strategies that support student learning in the class (Puntambekar and Hubscher, 2005) and the classroom environment is also associated with students' achievement and attitudes (Fraser,1998). Interactive lectures encourage students to engage in practices, understand more concepts, generate better explanations, and increase their productivity working with classmates (Eslinger, White, Frederiksen and Brobst; 2006; Krajcik and Delen; 2017; Metz 2004; Wolf and Fraser; 2008; White and Frederiksen 1998). Dorp et al. (2011) commented that kits rather than hands-on instructional materials were preferred by teachers and schools because these kits can be rotated through the classes in accordance with the order of units in the curriculum. **f) Need for assessment tools**: Currently, there are not enough assessment tools that teachers can use to measure student outcomes and the effectiveness of STEM applications in schools (Lee and Strobel, 2010; Dorp et al., 2011; NRC, 2011; NRC, 2013). Using multiple-choice questions in systemic measurement exams to measure the academic achievement of students rather than skills, scientific literacy, and cognitive development of students restricts teachers from implementing STEM practices. Thus, restricted content is presented by the teachers. **g) Teachers' beliefs, confidence and efficacy:** The factors which affect primary teachers when teaching science are self-efficacy which is the combination of feelings and beliefs about their knowledge, abilities and experience (Van Aalderen-Smeets, Molen and Asma, 2011) and self-confidence in their science knowledge, skills related to daily lives of individuals, and familiarity with science (Appleton, 2002; Mulholland and Wallace, 1996). Even though short professional development interventions can effectively influence relatively stable constructs, such as teacher confidence and efficacy (Nadelson et al., 2013), it is the teacher's belief concerning STEM disciplines and integrating engineering into science and math that has the strongest effect in terms of whether STEM can be successfully implemented in their classroom (Czajka and McConnell, 2016; Wang, 2012). The results of research in the USA found that there was a positive impact on the levels of efficacy, confidence, and attitudes from two years of a STEM teaching program (Nadelson, Callahan, Pyke, Dance and Pfister, 2013). **h) Inadequate practices**: Children already have a great deal of knowledge about the natural world, including concepts related to physics, biology, psychology, and chemistry but both the breadth of the curriculum and teacher's practices are not sufficient to develop skills in science (Brenneman, 2014) and teachers need to adopt STEM, which is based on integrated practices (NRC, 2013; Radloff and Guzey, 2017). **i) Integrated STEM education:** Teachers need an integrated STEM curriculum and samples of integrated STEM practices (Jardine, 2006; Stohlmann et al., 2012) and successful integration requires the teachers to understand the subject matter (Pang and Good, 2000).

STEM refers to a purposeful integration of the various disciplines, and STEM education aims for individuals to gain 21st-century skills that are required to solve real-life problems. Therefore, in elementary school teacher education programs or in-service teacher training programs, content-rich lectures engaging problem-based and project-based learning are needed to influence students' interest, content knowledge, and skills in STEM fields (Daugherty et al., 2014). Also, Roehrig, Moore, Hui-Hui Wang and Park (2012) implied that integration could be implemented most successfully when mathematics and science teachers work together in a single classroom (co-teaching) and in multiple classrooms (a common theme). Therefore, elementary school teachers teaching both science and mathematics can apply STEM efficiently while integrating art, music and other disciplines. This paper mainly aims to determine the prerequisites for elementary school teachers before practicing STEM with their students. STEM education consisted of theoretical and practical lessons that were applied to six novice elementary school teachers considering their requirements in the processes of education over 13 weeks. The main integrated STEM practices focus on the biology of the brain and stomach. The research results referred only to the first part of the continuing teacher education program and did not take into account the teachers' practices with students.

The problems in this study are:

1- Are there any changes in teachers' understanding of STEM?

2- What are the instructional gains of STEM education for teachers?

3- What are the prerequisites to implement effective STEM education?

4- What are their opinions about the benefits of STEM education for students?

## Method

*Research Design*

The adopted research model was a case study consisting of six elementary school teachers, attending an elementary school teachers' master's program, which included a Science and Nature Course as an elective course. Yin (2009) defines a case study as an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident (p. 18). The use of qualitative methods in case studies has the ability to bring a deep understanding of a case and to provide intrinsic knowledge and details regarding a problem or issues of interest to a researcher (Stake, 1995).

*Research Sample*

The teachers explained the reason for selecting this course as their need for a deep understanding of science concepts, the requirement of new teaching methods in the classroom with changing student attitudes and skills and finally because they wanted to learn about STEM to apply the system in their schools since they would be teaching within the new curriculum in which STEM is integrated with engineering practices (MoNE, 2018). Briefly, the elementary school teachers were willing to learn about STEM and implement it in their classrooms. This research focuses on the results of 13 weeks of their education program. The participants continued with their professional education program and engaged in classroom teaching, which included STEM education practices. For the anonymity, pseudonyms were used for each participant: Danny, Nagi, Aida, Jenny, and Lisa were participants in this research who are working as elementary school teachers. Their brief data are shown in Table 1.

**Table 1**

*Brief Explanations about Participants with Alias*

| Alias | Experience | Age | Department of graduation |
| --- | --- | --- | --- |
| Danny | Three years in public school | 28 | Science Education |
| Nagi | Two years in private school | 26 | Elementary education |
| Aida | Two years in private school | 37 | Vocational high school teacher education program |
| Jenny | Part-time teacher at a private school | 24 | Newly graduated from elementary education |
| Lisa | Three-months experience in a public school | 24 | Elementary education |
| Sera | No experience | 23 | Newly graduated from elementary education |

*Implementations*

The implementations were carried out over 13 weeks within three hours each week in the Education Faculty Master Program of a Foundation University. Before practicing STEM activities, theoretical knowledge required by teachers determined by the pre-test, and observations of the researcher (diary notes, worksheets of teacher) were given to participants. For example, the Programme for International Student Assessment [PISA] and Trends in Mathematics and Science Study [TIMSS] were not included in the planned STEM education program. The identification and integration model of STEM disciplines was explained theoretically according to the recommendation by Wang, Moore, Roehrig and Park (2011) to develop a theoretical STEM integration framework that describes how STEM integration could be put into practice. The other problem that was detected on pre-test results was the incompetence about teaching strategies, methods and learning models used in the STEM practices. Therefore, problem-based learning explained with theoretical knowledge was used and the group designed examples for 3$^{rd}$ and 4$^{th}$-grade students based on the curriculum level and were related to questions. For example, 'Can we produce a telescope for everybody?' and 'How can we prevent the decay of food in a refrigerator?'. Again, the same treatment was administered for theory and examples of practices with project-based learning, inquiry-based learning, situated learning and the 5E learning model. According to Wang et al. (2011), two major foci of STEM integration were mentioned of problem-solving by developing solutions and inquiry. Therefore, in this research, main STEM practices about the brain and stomach were practiced with inquiry-based learning enriched by contents in the first three steps of the 5E learning model and in the elaborating step EDP was applied for the problem which is mostly seen in Turkey (epilepsy) of integrating technology (appendix). The technology was chosen as an example of integration because of the advice of Hsu, Purzer, and Cardella, (2011). They conceived the unfamiliarity of elementary school teachers about the usage of technology in engineering design. Also, Brush et al. (2008), Kurz and Middleton (2006) and Watts-Taffe et al. (2003) reported the insufficient usage of technology by elementary school teachers. Before the main activities, the engineering design process (EDP) and its applications in science and mathematics were explained through video, diagrams and discussion later about two activities; Activity 1: space shuttle and Activity 2: Building a bridge. They completed EDP reports containing a step-by-step account, drew their design, and wrote up their results. At the end of the session, we compared the possible benefits of EDP and the possible difficulties involved with practice in the classroom. Later, the 'Brain and Helmet' (appendix) and 'Artificial Stomach' life-STEM activities were carried out and teachers were introduced to the design program, Solidword, developed by a software engineer. They used a 3D printer to produce their prototypes for the bicycle helmet or artificial stomach. In the last two weeks, teachers prepared lesson plans and activity notebooks (worksheets) for classroom applications depending on the elementary education curriculum, and their lecture plans and activity drafts were evaluated. Finally, the details about how to assess students for STEM activities were explained by giving many examples of specific measurement tools during the whole process. The teachers prepared their assessment tools as homework. Finally, teachers presented their assessment tools, and their products were evaluated with explanations and sampling of better solutions.

### *Data Sources*

In this study, more than one type of qualitative data was gathered during the whole intervention period to perform an in-depth investigation of the impacts of STEM education on teachers. Multiple data sources were collected through an open-ended pre-test and post-test, teacher interviews (questions are given in Table 3), diary notes of the researcher, worksheets, lesson plans, assessment tools, diaries of teachers, and EDP reports. 'The aim of gathering qualitative data based on different sources is to eliminate the risk of the researcher's systematic error' (Maxwell, 2008) and to discover a theory about completion of the research based on systematically obtained data (Glaser and Strauss, 1967). In addition, a key strength of the case study method involves using multiple sources and techniques in the data-gathering process (Soy, 1997, p. 2).

**Table 2**

*Open-ended Questions on Pre-test and Post-test*

| |
|---|
| 1- Which disciplines are included in STEM? |
| 2- Can you draw a diagram that explains the relations between the disciplines in STEM? |
| 3- What is STEM education? Can you briefly explain it? |
| 4- What are the skills of the 21st century? |
| 5- Which teaching approaches can be used in STEM education? |
| 6- Why are STEM integration interventions required in an education system? |
| 7- Can STEM be applied in the education system? |

**Table 3**

*Interview Questions*

| |
|---|
| 1- What was your initial expectation for this STEM course? |
| 2- What kind of awareness have you gained? |
| 3- What is the most influential activity in this STEM teaching process? |
| 4- Was there a change in your perception when identifying the concept of engineering? |
| 5- How your experience of technology had an impact on you? |
| 6- Which type of assessment tools will be useful to measure the impact of STEM on students? Can you produce these tools? |
| 7- Can you apply STEM practices in your classroom? |

### *Data Analysis*

In this case study, the long-term interaction between the researcher and participants, the long-term observations of the researcher through continuous data gathering during the 13-week implementations, and the use of different data sources for triangulation were considered as proving the reliability of the research (Creswell, 2012). In addition, the participants' main role, pre-test results, questions and responses were considered during the implementation in this research (Stake, 1995). Data analysis was undertaken during the process by the researcher and one of the external inspectors, not at the end of research; therefore, for any unexpected result, it could be considered that the implementation plan needed to be changed (Patton, 1980, 1990). Thematic analysis was chosen. Because many different data sources were used, answers to research problems were not directly related to one or two data tools, and themes were explained within data (Braun and Clarke, 2006). Thematic analysis as an independent qualitative descriptive approach is mainly described as 'a method for identifying, analyzing and reporting patterns (themes) within data' (Braun and Clarke, 2006, p. 79). Ten Have (2004) indicated that the researcher finds out attitudes, behavior and real motivation of studied people. Therefore, in the research, the focus of research problems was examined through the detailed outcomes of elementary school teachers' STEM education with flexible perspectives.

In the beginning, all data were transcribed by the researcher, codes, then themes were produced by eliminating data with a few samples by two experts who specialize in STEM education other than the author. Validity and reliability were provided by generating themes, and multiple data sources require the preparation, organization, and assessment of the interaction of the data on multiple levels (Creswell, 2007, 2012). At this point, the theme 'prerequisites of elementary school teacher' was the most discussed theme. Because although the research question was trying to find prerequisites for teachers to practice STEM, they also mentioned requirements for conditions in school to apply effective STEM. Therefore, we divided requirements to apply effective STEM education into two themes as follows: prerequisites of teachers and conditions to implement STEM in schools. Furthermore, the other most discussed code was EDP. In the beginning, teachers did not know the meaning of the letter E in the synonym STEM, and through the implementations, they learned what EDP is. However, when practicing, they learned the steps of EDP, such as designing and testing. Therefore, we placed EDP under the two themes explaining differences in detail. Themes and codes and samples of codes were checked and discussed many times to provide the reliability of the analysis, and the reliability of the codes for all data groups was determined using the Miles and Huberman (1994) formula:

$$\text{Reliability} = \frac{\text{number of agreements}}{\text{number of agreements + disagreements}}$$

The reliability was calculated as an average of 90%. This result indicated that the codes of the research were reliable. The final results of the thematic analysis are summarized in Table 4 below to understand themes, codes and examples from data sources.

**Table 4**

*Themes, Codes and Examples*

| Themes | Codes | Samples from participants |
|---|---|---|
| Understanding STEM | defining stem<br>learning approaches and learning models<br>STEM integration<br>learning EDP | **Aida:** The most efficient part of the implementations was the engineering bicycle-helmet session through learning |
| Instructional gains of STEM education for teachers | teamwork<br>brainstorming<br>technology competencies<br>learning science concepts<br>self-belief<br>self-confidence<br>EDP steps<br>communication | **Serra:** Integrating mathematic in STEM will provide easy understanding of mathematical concepts.<br>**Nagi**: The engineering design part of education was the most enjoyable and now I understood some physics laws and rules.<br>**Lisa:** Technology is difficult for me; for example, I learned the PowerPoint application only two years ago; so, the technology part was not interesting for me and I think I cannot implement this part in my teaching.<br>**Jenny**: I learned the correct meaning of the centrifugal force. |
| Benefits of STEM for students | choice of job<br>creativity<br>long term memory<br>critical thinking<br>asking questions<br>problem-solving | **Aida:** If I had learned the Solidword program before, I would have been a designer, but now I will use the program to design toys to avoid paying more for imported toys. |
| Instructional prerequisites of teachers to use STEM with students | contextualizing problems from daily life<br>produce assessment tools<br>integration practices | **Lisa**: I couldn't apply STEM without a mentor and without the support of an advisor.<br>**Danny**: Teachers should work together to design activities.<br>**Serra**: The curriculum should be regulated to support integrated STEM education |

Table 4 Continue

| Themes | Codes | Samples from participants |
|---|---|---|
| Conditions of schools | curriculum<br>mentor<br>materials<br>overcrowded classroom<br>time | **Danny**: Insufficient materials may be a problem in my classroom, but I believe that I can use simple materials.<br>**Jenny**: How could I evaluate so many students with the observation rubric? |

## Results

In this section, all the themes will be explained with multiple data sources as pieces of evidence for the discussion in light of the literature.

### *Understanding STEM*

At the beginning of the implementation, Aida and Danny knew all the disciplines in STEM, but Nagy appeared to have no idea about the STEM disciplines, and Lisa wrote the word 'mechanic' instead of mathematics. Jenny wrote that STEM included science and mathematics, whereas Sera defined science as studying everything. At the end of the implementations, all the teachers correctly defined the STEM disciplines. However, when we compared their figures to determine whether they understood integrated STEM, none of them could correctly explain integrated STEM with their drawings. The teachers' drawings are shown in Figures 2 to 5.

**Figure 2**. *Danny and Sera's STEM Integration.*

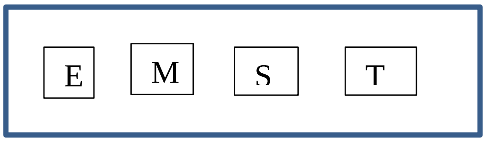



**Figure 3**. *Jenny's STEM Integration.*

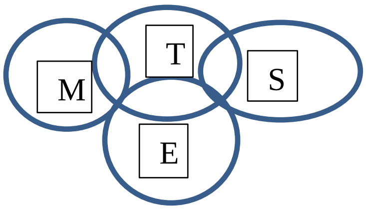



**Figure 4**. *Aida's STEM Integration.*

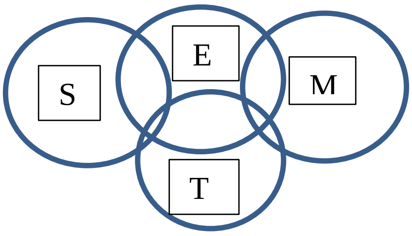
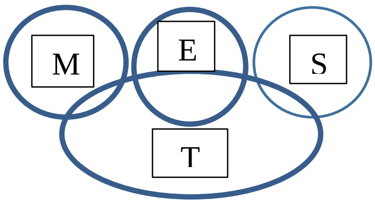



**Figure 5.** *Lisa's STEM Integration.*




The extracts below from the teachers' diary notes and the interviews reveal the way the teachers understood STEM integration. **Serra** stated that *the most interesting part of implementations was the engineering practices; now I can easily adapt the engineering design process in mathematics, art and science, I could also integrate literature, such as stories into* *the lessons.* Aida drew the engineering part at the center of her figure because of her background, having graduated from a technical teacher education program and the science department of a high school. She explained in her interview that *the most beneficial part of STEM is practicing EDP because it improves the creativity of students and they can connect engineering with science and mathematics with problems in daily life and there is a product at the end of EDP.* In his response in the interview, Danny said, "*I heard and read something about STEM before the implementations, and I expected that I only needed to practice STEM, but I then realized that I had many misunderstandings and I didn't know the steps of EDP. The most efficient part of the implementations was the engineering bicycle-helmet session through learning how we can apply [engineering] in practice.*" There appears to be no problem with the drawings of the teachers probably because they had the opportunity to practice and we can see that they mostly enjoyed the EDP part of activities. When we look at the data about the usage of learning approaches, which can be used during STEM practices, Aida, Lisa, and Nagi did not give a response in the pre-test, Danny gave hands-on activities as a method, and Serra defined brainstorming as a method. Jenny defined teaching techniques, such as problem-solving and brainstorming in STEM education. Furthermore, from the diary notes of the researcher '*the teachers' main problem is that they knew what problem-based learning or project-based learning was, but they could not apply this theoretical knowledge into the practice of a given topic, and they were unable to differentiate the main differences between problem-, project- and inquiry-based learning and situated learning*. However, at the end of interventions, they used various terms in the post-test; problem-based learning, project-based learning, inquiry-based learning, learning by doing and living, constructivist approach, 5E model, active learning, discovery, situated learning and meta-cognition.

### *Instructional Gains of STEM Education for Elementary school Teachers*

In this part, we selected words and sentences from at least two examples from the participants' statements as codes to determine the improved skills of teachers during interventions. The first example relates to the steps of the EDP cycle**.** The review of the reports about the EDP cycle practices revealed that the teachers designed an imagined model of a bicycle helmet and an artificial stomach, but after testing of their prototypes, they did not make any changes to the design. During the interviews, they were asked the reason for not redesigning the models. The responses from five of the teachers were as follows: *We don't need to draw it again because we know the parts which should be changed or improved (*Danny). *We realized that we have no ability to draw because we tried it, especially for the bicycle helmet, but couldn't do better than before (*Alice). Serra commented that *engineering parts were the most interesting part of the course because there was a product at the end and thinking step-by-step to produce a model improved our critical thinking abilities*. Thus, Serra referred to one of the aims of STEM education, which is to think systematically (Bybee, 2010a; Dugger, 2010; Duncan and Yoon, 2011; Guzey et al., 2014; Roehrig and Moore, 2014; Morrison, 2006; Rogers and Postmortem, 2004). In an interview, Lisa was also affected by the engineering part of the course, saying that *engineering means producing something new, which is required by society.* Nagi's focus was on the transfer of daily life problems into EDP, saying in an interview, "*students never forget when they create their solutions with products*" (Morrison, 2006). All the teachers had a positive attitude about the EDP cycle after producing the bicycle helmet, space shuttle and artificial stomach; thus, it can be seen that EDP motivates not only student learning (Bybee, 2010; Dugger, 2010; Guzey et al., 2014; Mann, et al., 2011; Rogers and Porstmore, 2004) but also in-service elementary school teacher learning. However, the teachers did make mistakes and had difficulties without explaining the content knowledge; for example, (according to the researcher's diary) they chose the wrong materials for the inner structure of the stomach which should not be a thin and rough surface and instead of reading and investigating the structure and functions of the stomach, they preferred to ask the researcher. With the guidance of the researcher asking new questions to encourage them, they read articles and engaged in research on the internet to find solutions to the problems concerning the artificial stomach problem. If they did not know or were not sure about the elements of the stomach, such as acid, epithelial tissue and smooth muscle, they used the time to argue with each other concerning the decision about the correct materials. However, when they redesigned the artificial stomach, they corrected and understood the structure of the stomach, depending on its functions. Thus, the EDP part of STEM improved their reading skills and, thus, their scientific literacy (Brenneman, 2014). **Serra,** who does not like biology concepts, said, *I will never forget the structure of the stomach, and I will change my eating habits*. Thus, STEM does not only provide academic achievement or 21st-century skills; it also affects social behaviors, such as attitudes to health (Dauer and Dauer, 2016). **Jenny** wrote in her diary notes, *I learned the correct meaning of the centrifugal force and if I had experienced EDP, I would be an engineer*. Consequently, even though they were practicing EDP, they were also learning concepts, but elementary school teachers still need the theory of content knowledge (Czajka and McConnell, 2016; Guzey, et al., 2014; NRC, 2013) before STEM implementations. In addition, the teachers put themselves into the students' position and experienced the possible impacts of EDP from the perspective of the students, including creativity, long-term learning, and critical thinking.

When we analyzed the impacts of the use of **technology** in STEM applications for teachers, they were generally surprised about the usage areas of the 'Solidworks program' and they realized that becoming proficient in this application could help them find a job in Turkey. Furthermore, self-belief and self-confidence concerning technology literacy surfaced in their diary notes and interviews. Apart from **Danny and Alice,** who have technical and science education backgrounds, the other teachers had difficulties using Solidworks, but at the end of the technology applications, learning new things enlarged their vision and could possibly affect their teaching and self-confidence. Of the teachers, **Danny** was the most interested in learning how to use the program. This could be due to him having better competency about computer usage than the others. **Danny** commented, *when I saw the Solidworks program, I thought I could use it to teach electricity. I have no ability to think in 3D. Maybe the reason is my brain or the education system; I don't know.* **Serra:** *I am not good at using computers, but it was interesting that without paper and pencil, we could draw objects in 3D.* **Aida:** *If I had learned the Solidworks program before, I could be a designer, but now I will use the program to design toys to avoid paying high prices for imported toys.* **Lisa:** *Technology is difficult for me; for example, I just learned PowerPoint two years ago, so the technology part was not interesting for me and I think I cannot apply this part in my teaching.* **Nagi** also mentioned the lack of computer competency*: this part was difficult for me, but this created awareness about the need to improve my computing skills.* **Aida** developed her self-confidence and explained her feelings: *It was incredible to produce a bicycle helmet from a 3D printer and for the first time, I realized that having good technology literacy would improve the quality of my teaching.* The examples from the teachers reveal that the elementary school teachers' insufficient experience of computer technology prevented them from using technology-based instruction in the classroom (Brush, et al., 2008; Kurz and Middleton, 2006, Watts-Taffe, et.al., 2003) and also affects their self-belief (Appleton, 2002; Mulholland and Wallace, 1996). In this part, the most important results were the teachers' negative beliefs and lack of self-confidence, which were mainly based on the lack of computer technology skills. However, with the evidence from interviews and teachers' diaries, through the practice in the intervention program, their negative beliefs were eliminated, they relaxed, and their confidence developed, allowing them to learn and engage in the new technologies in their classrooms. Pajares (1992) pointed out the effects of a well-designed education program, including the organization and design of tasks on the teacher's beliefs rather than knowledge. Also, there was a positive impact of long-term STEM teaching program on the levels of efficacy, confidence, and attitudes among elementary school teachers (Nadelson et al., 2013). In this research, practicing technology during activities improved teacher's self-beliefs and self-confidence about the usage of technology.

During the coding of the data in the diary notes of the author, in particular, the communication abilities and teamwork of teachers improved day to day through collaboration. Although **Serra** did not listen to any of the opinions of the other teachers during the space shuttle production directing the actions of the group members (researcher's diary), she did mention the importance of brainstorming when creating the bicycle helmet as follows: […] *brainstorming results in better production than self-production and using Aida's knowledge we created a perfect helmet together.* Another data (teacher's diary) is related to Danny**. Serra** indicated that Danny had better scientific knowledge background *when we were making the prototype of the helmet, the group members asked him questions about the materials and he helped us*. **Aida** also supported her group in the technology parts of the implementations. Furthermore (according to the interviews), when the teachers were generating lesson plans together, they realized that *it was better than doing it by oneself.*

### *Instructional Prerequisites for Teachers*

Again, multi-source data and an open axial coding system found teachers need to learn assessment tools, the practice of EDP and contextualization of problems from daily life to apply effective STEM education. When we checked assessment tools in their lesson plans, we found that the teachers tended to prepare rubrics, which generally measured EDP and the whole STEM activity with a 5-point Likert scale. The teachers' lesson plan did not, for example, include rubrics about the evaluation of the product or the use of mathematics and technology, engineering knowledge test, and concept test. Extracts from the teachers show the problems in producing assessment tools. **Aida:** *You did not accept my lesson plan although I corrected it twice, but we have not prepared lesson plans and measurement tools. We obtained the plan from internet sources*.

**Nagi**: *It will take too much time to complete this rubric for each student.* **Serra:** *We need examples of assessment tools*. **Lisa:** *It was difficult in this part to produce the assessment tools; the pictures need to be evaluated.* Danny believed that students should be evaluated during all processes, but he didn't mention portfolios. He prepared the assessment tools to evaluate the EDP scale with a 5-item Likert scale. **Serra** also talked about brainstorming as an assessment tool, but she could not explain how it would be used. The main reasons for this feedback could be related to the insufficient practice and usage of multiple-choice test questions within the general examination system in Turkey and insufficient examples of assessment tools that teachers can obtain as samples. Also, the same problems were mentioned in the research by Harwell Moreno, Phillips, Guzey, Moore and Roehrig (2015) and Lee and Strobel (2010), who found that dealing with an insufficient number of assessment tools and inadequate tools resulted in not being able to measure the deep understanding of students and there was no reference to the STEM application in the answers to the questions on the tools (Stern and Ahlgren, 2002). Smith, Wiser, Anderson and Krajcık (2006) explained the properties of assessment tools as organizing the main concepts and other disciplines at the center of tool production, how they could be improved and contextualized, and how they could be transferred to instructions. Teachers can be supported by the experience of experts in the assessment of STEM, who have produced many kinds of assessment tool samples which measure skills, content knowledge, EDP cycle, products, development of cognitive skills, transfer of information from one discipline to another and take into account student reports (Dorp et al., 2011)

The other prerequisite for teachers was to seek problems from daily life and to engage in the contextualization of concepts with daily life. The examples from their diaries, worksheets and researcher diaries were; *Apart from Danny (graduated from a science teacher education program), none of the others could find examples of an atom, molecule and compound from daily life. None of them could write the problem of noise pollution from daily life.* **Nagi** stated: *My questions changed; for example, before asking questions, I think about how I can improve the student's thinking abilities and now I continue asking more and more difficult questions to improve the students' cognitive thinking levels and also, I learned to wait for their responses. This was a change in my teaching.* **Lisa***: I understood the importance of questions, especially how and why questions.* **Nagi and Lisa** realized the importance of questioning for children, as indicated by Morrison (2006). When their lesson plans were examined, the content had been chosen from the curriculum. **Danny** included a good problem to begin the planned lesson on microorganisms: *When I was leaving my home-city, my mother gave me a bag with many kinds of cookies and muffins for me to eat when I got home. I arrived home, I forgot about the bag and later, I smelt a very bad odor and realized that the cookies and muffins had gone moldy. Why did they decay? How can we protect foods from decaying?* **Jenny's** lesson plan focused on teaching the structure of teeth: *My grandmother likes to eat boiled corn, but when she lost most of her teeth, she couldn't eat corn any more. How can you help my grandmother eat the corn again?* **Aida's** problem was based on the questions: *What is hibernation? Which animals hibernate?* However, even though Aida has sufficient content knowledge and science and technology background. She could not develop her questions. The teachers presented several problems from daily life, such as *what are the living and non-living things in your environment?* **(Lisa). Serra**'s plan to teach the use of a microscope included a video about microorganisms and she asked the question, *how can we see microorganisms*? **Nagi** presented the question, *how can we produce nests for birds to protect them from cold air?* The evaluation of the teachers' problems related to daily life in terms of their lesson plans shows that Aida, Lisa and Nagi could not understand how to improve the structure of their problems in accordance with STEM applications. The problem examples revealed the teachers have the insufficient ability about authentic questioning depending on their background, content knowledge and experiences. Daugherty et al. (2014) recommended that elementary school teacher education providing integrated STEM content and pedagogy include content-rich, standards-driven and engaging problem-based learning. This requires that they improve their scientific knowledge, develop the ability to form authentic questions and tasks and contextualize concepts about real life (Ayar and Yalvac, 2010; Bencze, 2011; Guzey, et al., 2014; Nadelson, et al., 2013).

In addition to generating authentic questions, STEM integration was evaluated in their lesson plans. In their lecture plans, integration of two disciplines was put as a restriction. In his own words, **Danny** integrated technology by *investigating technologies that prevent the production of microscopic organisms*. In the engineering part, he explained: *Students design and produce a dish which prevents the production of microscopic organisms*. In the mathematics part, he integrated the counting of microorganisms in the unit area under the microscope. **Serra** integrated mathematics by discussing the use of geometrical shapes, such as a sphere, cube, and rectangular during EDP. She used technology as homework to investigate different kinds of microscopes. **Nagi** integrated science content concerning the kinds of birds and their characteristics into EDP by undertaking nest examination; however, technology and mathematic integration were absent in her plan. **Lisa's** plan did not include any integration; she just wrote up the activity of living and non-living things**. Aida** presented a video about animals for the integration of technology, and she planned mathematics integration concerning the calculation of the bird nest's surface area, but she did not include any details of calculations. All the teachers integrated science into EDP about the units in the curriculum. However, there was a problem in the integration of mathematics and technology. The teachers believed that the learning of mathematics would be easy when provided by STEM applications. For example, **Serra** explained, *integrating mathematics in a STEM application will provide the easy understanding of mathematical concepts.* Similarly, **Danny** commented that *STEM applications would offer an easy understanding and improve the student's interest in the meaningful understanding of mathematics within daily life problem*s*. However, mathematic teachers and science teachers should plan activities together, and the math teachers should take STEM education*. However, the teachers' lesson plans only included mathematics as summation, extraction, and measurement rather than mathematical thinking processes, such as drawing tables and graphs or the analysis of mathematical results. Pang and Good (2000) indicated that the successful integration of science and mathematics depends largely on teachers' understanding of the subject matter. The results had no connection with the background of teachers; for example, Aida did not reflect her technology and science background, experience and motivations in her lesson plan. The best lesson plan was prepared by Danny, who took many science courses during his bachelor's education.

The other teachers did not plan lessons that involved the four disciplines of STEM (Stohlmann, et al., 2012). This showed that integration of all four disciplines is not easy for teachers and also that integration can be undertaken in many forms (Hurley, 2001; Bybee, 2013) depending on the desired outcomes. In this research, based on the teachers' knowledge and experience, such as their insufficient content knowledge about the brain and stomach and having had no practice in EDP, I carried out activities in separate course hours. Furthermore, the integration of life science units into STEM practices tends to be difficult for teachers (Guzey, Moore and Harwell, 2016). In addition, I inserted a new design program 'Solidworks' in the course to develop their competencies and abilities with technology-based instructions and to teach the importance of new technological tools. Even though the teachers developed their competencies and were motivated to learn new technologies, more and simple activities related to technology should be integrated into STEM practices. Finally, it was concluded that elementary school teachers need more practice (NRC, 2013; Radloff and Guzey, 2017), especially including different forms of integration.

*Conditions in Schools to Apply STEM*

To assess whether the teachers believe that STEM perceptions are appropriate for implementation in elementary schools, during an interview, the teachers were asked a question concerned with STEM applicability in the classroom. Generally, the teachers held positive beliefs and perceptions about STEM. However, they offered suggestions for better practices, which included improving the learning environment, more materials, revised curriculum, need for teacher mentoring, reducing the number of students in the classroom, and increasing the time for practice. Data from the teacher's verbatim comments are as follows: **Serra:** *STEM will be beneficial, but the creativity of teachers and attitude of school administration are important*. **Nagi:** *The professionality of teachers about both constructive approach and content knowledge and practices should be taught over the long term for the effectiveness of STEM*. **Danny:** *Mathematic teachers and science teachers should plan activities together and math teachers should take STEM education* and *insufficient materials may be a problem in my class, but I believe that I can apply with simple materials.* **Serra**: *The curriculum should be regulated to sustain integrated STEM* (she also referred to time constraints). **Lisa**: *I couldn't apply STEM without a mentor and without the support of an advisor.* (She also pointed out the needs for advisors to be present during STEM practice in the class.). **Jenny**: *If teachers are alone in the class with a large number of students, STEM applications will not possible and how could I evaluate so many students with the observation or rubric?* In keeping up with the findings in the literature, the teachers in the current study referred to the following issues concerning the difficulties of implementing STEM in the classroom: time restrictions (Czajka and McConnell, 2016; Guzey, et al., 2014; Lee and Strobel, 2010; NRC, 2013), the number of students in the classroom (Douglas et al., 2004), materials (Eslinger, et al., 2008; Fraser,1998; Krajcik and Delen, 2017; Metz, 2004; Puntambekar and Hubscher, 2005; White and Frederiksen, 1998; Wolf and Fraser, 2008), the need to modify the curriculum taking account of integrated STEM, the professionality of teachers consisting of their content knowledge level (Czajka and McConnell, 2016, Guzey et al., 2014; NRC, 2013), their creativity, and the provision of a mentor or advisor provided with the support of the school administers (Dorp et al., 2011)

### *Benefits of STEM Education for Students*

About the outcomes of STEM, the teachers referred to better job opportunities, increased creativity, long-term learning, and the development of critical thinking. They also emphasized that they may have made different career choices if they had known about STEM during their education period: **Aida:** *If I had learned the solidword program before, I would have been a designer, but now I will use the program to design toys to avoid paying more for imported toys.* **Jenny:** *If I knew that I could do engineering, I would prefer to be a mechanical engineer and my dreams of being a pilot could come true.* **Serra:** *If I learned STEM in secondary or high school years, I would be an engineer.* **Nagi** was surprised about her abilities concerning EDP and the realization of her creativity abilities; thus, she commented, *If I had realized that I was creative and could completely implement EDP, I would have chosen to work in the area of materials science*. **Lisa** gave her opinion of the possible effects of STEM on children in the early grades: *if STEM was practiced in kindergarten, I believe that it would have developed their* [children's] *creativity, thinking skills and attitude towards science and mathematics.* **Nagi** also added that EDP would support the development of creativity and problem-solving abilities of young students. STEM practices improve the creativity of both students (Morrison, 2006) and teachers. One of the outcomes of the implementation of STEM education with children is the development of their problem-solving abilities becoming "problem-solvers—able to frame problems as puzzles and then able to apply to understand and learning to these novel situations (argument and evidence)" (Morrison 2006, p. 2). Nagi also commented on long-term learning: *for example, like me, they* [the students] *will never forget centrifugal force or brain parts or the structure of stomach with STEM activities, which provide long-term learning,* and referring to the students' self-confidence, she commented on her own experience stating, *if I had developed self-confidence, I could have chosen other jobs*. **Serra** mentioned the effects of STEM on the improvement of the critical thinking abilities of a student when she was implementing EDP. As found in the literature, Serra recognized that STEM education affects the students, allows them to realize their abilities, such as creativity and critical thinking (Bybee, 2010; Dugger, 2010; Guzey et al., 2014; Mann et al., 2011; Rogers and Porstmore, 2004) and consider different occupational areas (NGSS, 2013). Their perceptions and awareness of STEM also motivate them to apply practices of STEM (Wang, 2012; Czajka and McConnell, 2016).

## Discussion, Conclusion and Recommendations

This research examined the prerequisites for elementary school teachers before STEM practices with their students within a 13-week education program. Depending on the research questions and multiple data sources, understanding STEM, instructional gains of STEM education for teachers, instructional prerequisites of teachers to apply STEM with students, benefits of STEM for students and conditions of schools to apply STEM were the themes in the research results. According to Stohlman et al. (2012), effective STEM education is vital for the future success of students. The preparation and support of teachers for integrated STEM education are essential (p. 32). Therefore, there is a need for much practice with elementary school teachers to learn integration of STEM practices, improvement of teacher pedagogical competencies consisting of content knowledge, contextualization of problems with real life, improvement of technology usage in their lectures, and producing assessment tools. Although elementary school teachers did not know the meaning of the letters in STEM, after theoretical and practical education, we can say that they learned disciplines in STEM and their integration depending on results. However, similar to many studies, they had difficulties in conceptualization and planning integration of STEM disciplines. We can ask many questions and debate about the integration of STEM disciplines. For example, how integration will be done, which one will be the focus on discipline, how many disciplines should be included at least, should literature and history be added, is the technology discipline or product? The answers to these questions and argumentations about effective integration have been examined (Dugger, 2011; English, 2017; Honey et al., 2014; Sanders 2012; Wang, 2012; Wells, 2013). Bryan et al. (2015) explained that integration is not the teaching of two disciplines or using one of them as a tool to teach another. They pointed out the consideration of content and context. In this case, to produce integrated STEM activities depending on the curriculum, teachers can dominate both content knowledge and contextualization of STEM disciplines. Unfortunately, insufficient content knowledge of elementary school teachers in science was declared many years ago (Chaney, 1995; Darling-Hammond, 2000; Druva and Anderson, 1983), it is again one of the major problems in STEM education (Czajka and McConnell, 2016; Guzey et al., 2014; NRC, 2013) and one of the results of this research is again dealing with the content knowledge of teachers in life-STEM unit examining the contents brain and stomach. The reasons were similar to the results of much research. In Turkey, the reasons could be explained by the teachers' insufficient science background and curriculum of elementary school teacher education programs. Levitt (2002) reported that when provided with useful models, teachers tend to be open to modifications in their teaching. The need for and influence of effective models of STEM teaching provided the motivation for our K–6 teacher STEM professional development (p.3). Therefore, in elementary education, there will be a need for interdisciplinary lectures practicing inquiry-based, problem-based and project-based learning enriched with scientific content. For example, STEM practices could be done in lectures with Science Laboratory Applications or Science Teaching Lecture. Radloff and Guzey (2017) and NRC (2013) was also denoted the need for much practice of integration. Debiase (2016) mentioned the same requirement and also Bencze (2010) explained the relation between content knowledge with self-efficacy to practice STEM. During practicing of two activities, elementary school teachers who were participants in this research indicated that their self-belief and self-confidence levels increased to apply activities dealing with science and they also realized their need to learn science concepts and content knowledge. Similar to Nadelson et al. (2013), it is advised that elementary school teachers need additional theoretical education about STEM disciplines during STEM teaching programs. In the other case, participants in this research know the learning approaches, methods and techniques, but they have limited abilities to transfer their knowledge into STEM implementations. Furthermore, they indicated their need to practice EDP and to have mentors. Therefore, during their undergraduate education or in-service training, they need more practice of learning approaches, methods and techniques to plan and apply STEM education. Also, teachers and teacher candidates need practicing of STEM activities to learn integration in STEM education (Aslan-Tutak, Akaygun and Tezsezen, 2017; Becker and Park, 2011; Cinar, Pirasa, Uzun and Erenler 2016; Corlu and Robert, 2014). When participants are preparing lesson plans, their incompetence about the production of assessment tools was detected. They just produced rubrics similar to samples given during activities. They also need to be presented with many samples of assessment tools, which measure different purposes of STEM education (Dorp et al., 2011; Lee and Strobel, 2010; NRC, 2011; NRC, 2013). The EDP activities motivated the teachers to learn about STEM and improved their communication and collaborative working, which was expressed as teamwork. From this point, we can conclude that elementary school teachers experienced the outcome of STEM education with improved 21st-century skills. The requirements to apply effective STEM activities in schools were also defined by participants. In addition to curriculum revisions, tools in the learning environment, time, need to mentor and the number of students were mentioned as being factors restricting STEM education in schools. This was also indicated in the research of Eroglu and Bektas (2016). Implementing STEM education in the early grades is more effective in developing people who are creative, problem-solvers, and innovative; therefore, elementary school teacher education is key to achieving the expected outcomes of integrated STEM education over the long term.

As a result of the research, we recommend that during the STEM education program of elementary school teachers both theoretical and application should be considered. In the beginning of education, there is a need to determine insufficient knowledge and skills to plan effective STEM education in the other ways, so action research is required. Furthermore, long-term education with many practice sessions, including the production of lecture plans, assessment tools and implementations from professionals in this area to guide them are recommended.

## References

Abd El Khalick, F.,Boujaoude, S., Duschl, R., Lederman, N. G., Mamlok-Naaman, R.,Hofstein, A., & Tuan, H.L. (2004). Inquiry in science education: International perspectives. *Science Education*, 88(3), 9-13. doi:10,1002/sce.10118

Appleton, K. (2002). Science activities that work: Perceptions of primary school teachers. *Research in Science Education,* 32(3), 393-410. https://doi.org/10.1023/A:1020878121184

Aslan-Tutak, F., Akaygun, S., & Tezsezen, S. (2017). Collaboratively Learning to Teach STEM: Change in Participating Pre-service Teachers' Awareness of STEM. *H. U. Journal of Education*, *32*(4), 794-816. doi: 10.16986/HUJE.2017027115

Ayar, M. C., & Yalvac, B. (2010). A sociological standpoint to authentic scientific practices and its role in school science teaching. *Ahi Evran University Journal of Kırşehir Education Faculty (JKEF),* 11(4), 113-127. Retrieved from http://www.acarindex.com/dosyalar/makale/acarindex-1423907673.pdf on May 2016

Bagiati, A. & Evangelou, D. (2015). Engineering curriculum in the preschool classroom: The teacher's experience. *European Early Childhood Education Research Journal*, 23(1), 112-128. doi: 10.1080/1350293X.2014.991099

Becker, K., ve Park, K. (2011). Effects of integrative approaches among science, technology, engineering, and mathematics (STEM) subjects on students' learning: A preliminary meta-analysis. *Journal of STEM Education: Innovations and Research*, 12(5/6), 23.Retrieved from https://www.jstem.org on May 2020

Belden, N., Lien, C., & Nelson-Dusek, S. (2010). *A priority for California's future: Science for students.* Santa Cruz, CA: Center for the Future of Teaching and Learning. Retrieved from http://www.cftl.org/documents/2010/2010SciCFTL4web.pdf

Bencze, J. L. (2010). Promoting student-led science and technology projects in elementary teacher education: Entry into core pedagogical practices through technological design. *International Journal of Technology and Design Education*, *20*(1), 43-62. doi: 10.1007/s10798-008-9063-7

Berlin, D. F., & White, A. L. (2010). Preservice mathematics and science teachers in an integrated teacher preparation program for grades 7-12: A 3-year study of attitudes and perceptions related to integration. *International Journal of Science and Mathematics Education, 8*(1), 97-115. https://doi.org/10.1007/s10763-009-9164-0

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, *3*(2), 77-101. doi: 10.1191/1478088706qp063oa

Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher*, 70(1), 30-35. Retrieved from https://eric.ed.gov/?id=EJ898909

Bybee, R. (2013). *The case of STEM education: Challenges and opportunities*. Arlington, VA: NSTA Press.

Breiner, J. M., Harkness, S. S., Johnson, C. C. & Koehler, C. M. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. *School Science and Mathematics*, 112 (1), 3-11. https://doi.org/10.1111/j.1949-8594.2011.00109.x

Brenneman, K. (2014). *Science in the Early Years*. *The Progress of Education Reform*. Education Commission of the States, 15(2). Retrieved from http://files.eric.ed.gov/fulltext/ED560994.pdf on May 2016

Brown, P. & Borrego, M. (2013). Engineering efforts and opportunities in the National Science Foundation's Math and Science Partnerships (MSP) program. *Journal of Technology Education*, 24(2), 41-54. Retrieved from https://files.eric.ed.gov/fulltext/EJ1005687.pdf on April 2017

Brush, T., Glazewski, K. D., Hew, K. F. (2008). Development of an instrument to measure pre-service teachers' technology skills, technology beliefs, and technology barriers. *Computers in the Schools*, 25 (1-2), 112-125. doi: 10.1080/07380560802157972

Bryan, L. A., Moore, T. J., Johnson, C. C. & Roehrig, G. H. (2015). Integrated STEM education. In C. C.Johnson, E. E. Peters-Burton & T. J. Moore (Eds.), STEM road map: A framework for integrated STEM education (pp. 23–37). New York, NY: Routledge.

Chaney, B. (1995). *Student outcomes and the professional of 8th grades teachers in science and mathematics. NSF/NELS:88 teacher Transcript Analysis*. Rockville, MD: National Science Foundation.

Chute, E. (2009). STEM education is branching out. *Pittsburgh Post-Gazette*.

Cinar, S. , Pirasa, N., Uzun, N. ve Erenler, S. (2016). The effect of STEM education on pre-service science teachers' perception of interdisciplinary education. *Journal of Turkish Science Education*, 13(special issue), 118-142. Retrieved from http://www.tused.org/index.php/tused/article/view/627/541 on May 2020

Creswell, J. W. (2007). *Qualitative inquiry and research design: Choosing among five approaches*. New Delhi, India: Sage.

Creswell, J.W. (2012). *Qualitative inquiry and research design: Choosing among five approaches*. Sage publications.

Cunningham, C. M., & Hester, K. (2007). *Engineering is elementary: An engineering and technology curriculum for children.* American Society for Engineering Education Annual Conference & Exposition. Honolulu, Hawaii.

Corlu, M. S., ve Robert, M. C. (2014). Introducing STEM education: Implications for educating our teachers for the age of innovation, *Eğitim ve Bilim, 39*(171), 74-85.

Czajka, C. D., & McConnell, D. (2016). Situated instructional coaching: a case study of faculty professional development. *International Journal of STEM Education*, *3*(1), 10. doi: 10.1186/s40594-016-0044-1

Darling-Hammond, L. (2000).Teacher quality and student achievement. *Education Policy Analysis Archives,* 8(1). doi: http://dx.doi.org/10.14507/epaa.v8n1.2000

Daugherty, M. K., Carter, V., & Swagerty, L. (2014). Elementary STEM Education: The Future for Technology and Engineering Education?. *Journal of STEM teacher education*, *49*(1), 7. Doi: doi.org/10.30707/JSTE49.1Daugherty

Dauer, J., & Dauer, J. (2016). A framework for understanding the characteristics of complexity in biology. *International Journal of STEM Education*, *3*(1), 13. doi: 10.1186/s40594-016-0047-y

DeBiase, K. (2016). *Teacher preparation in science, technology, engineering, and mathematics instruction*. California State University, Long Beach.

Diefes-Dux, H. A., Hjalmarson, M., Miller, T., & Lesh, R. (2008). Model eliciting activities for engineering education. In J. Zawojewski, H.A. Diefes-Dux and K. Bowman (Eds.) *Models and Modeling in Engineering Education: Designing Experiences for All Students* (pp. 17–35). Rotterdam: Sense Publishers.

Dorph, R., Shields, P., Tiffany-Morales, J., Hartry, A., & McCaffrey, T. (2011). *High Hopes - Few Opportunities: The Status of Elementary Science Education in California. Strengthening Science Education in California.* Sacramento, CA: The Center for the Future of Teaching and Learning at West Ed. Retrieved from http://files.eric.ed.gov/fulltext/ED525732.pdf

Druva, C.A. & Anderson, R.D. (1983). Science teacher characteristics by teacher behavior and by student outcome: A meta-analysis of research. *Journal of Research In Science Teaching.* 20,467-479. doi:10.1002/tea.3660200509

Dugger, W. E. (2010, December). *Evolution of STEM in the United States.* 6th Biennial International Conference on Technology Education Research, Gold Coast, Queensland, Australia. Retrieved from http://www.iteaconnect.org/Resources/PressRoom

Ebert-May, D., Derting, T. L., Hodder, J., Momsen, J. L., Long, T. M., & Jardeleza, S. E. (2011). What we say is not what we do: Effective evaluation of faculty professional development programs. *BioScience*, 61(7), 550-558.

English, L. D., Hudson, P., & Dawes, L. (2013). Engineering-based problem solving in the middle school: Design and construction with simple machines. *Journal of Pre-College Engineering Education*, 3(2), 43-55. doi:10.7771/2157-9288.1081

English, L. D. (2017). Advancing elementary and middle school STEM education. *International Journal of Science and Mathematics Education*, *15*(1), 5-24. doi: 10.1007/s10763-017-9802-x

Eroglu, S., & Bektas, O. (2016). Ideas of Science Teachers took STEM Education about STEM based activities. *Journal of Qualitative Research in Education* – JOQRE, *4*(3), 43-67. doi: 10.14689/issn.2148-2624.1.4c3s3m

Eslinger, E., White, B.Y., Frederiksen, J., & Brobst, J. (2008). Supporting inquiry processes with an interactive learning environment: Inquiry Island. *Journal of Science Education and Technology*, 17(6), 610-617. Doi: 10.1007/s10956-008-9130-6

Fan, S. C. & Yu, K. C. (2015). How an integrative STEM curriculum can benefit students in engineering design practices. *International Journal of Technology and Design Education*, 1-23.doi.10.1007/s10798-015-9328-x.Retrieved from http://download.springer.com/static/pdf on May 2016

Fraser, B. J. (1998). Classroom environment instruments: Development, validity and applications. *Learning Environments Research,* 1(1), 7-34.

Frykholm, J., & Glasson, G. (2005). Connecting science and mathematics instruction: Pedagogical context knowledge for teachers. *School Science and Mathematics*, *105*(3), 127-141. Retrieved from http://www.pucrs.br/ciencias/viali/tic_literatura/artigos/ciencias_matematica/Frykholm%20&%20Glasson_Connecting%20Math%20&%20Science%20Instruction.pdf

Furner, J, & Kumar, D. (2007). The mathematics and science integration argument: a stand for teacher education. Eur*asia Journal of Mathematics, Science & Technology,* 3(3), 185–189. Retrieved from https://pdfs.semanticscholar.org

Furtak, E.M. (2005). The problem with answers: An exploration of guided scientific inquiry teaching. *Science Education*, 90, 453-467. doi:10.1002/sce.20130

Glaser, B.G. & Strauss, A.L. (1967). *The Discovery of Grounded Theory: Strategies for Qualitative Research*. Chicago, IL: Aldine.

Gulhan, F. ve Sahin, F. (2016). The effect of science-technology-engineering-mathematics integration (stem) on 5th grade students' perception, attitude, conceptual understanding and scientific creativity. *International Journal of Human Sciences*, *13*(1), 602-620. doi:10,14687/ijhs.v13i1.3447

Guzey, S. S., Tank, K., Wang, H. H., Roehrig, G., & Moore, T. (2014). A high-quality professional development for teachers of grades 3–6 for implementing engineering into classrooms. *School Science and Mathematics*, 114(3), 139-149. doi: 10.1111/ssm.12061

Guzey, S. S., Moore, T. J. & Harwell, M. (2016). Building up STEM: an analysis of teacher-developed engineering design-based STEM integration curricular materials. *Journal of Pre-College Engineering Education Research (J-PEER)*, *6*(1), 2. doi: 10.7771/2157-9288.1129 .

Harlen, W., & Holroyd, C. (1995). *Primary Teachers' Understanding of Concepts in Science and Technology.Interchange 34.* Edinburgh: Scottish Office Education and Industry Department Research and Intelligence Unit.

Harwell, M., Moreno, M., Phillips, A., Guzey, S. S., Moore, T. J. & Roehrig, G. H. (2015). A Study of STEM Assessments in Engineering, Science, and Mathematics for Elementary and Middle School Students. *School Science and Mathematics*, 115(2), 66-74. https://doi.org/10.1111/ssm.12105

Hsu, M. C., Purzer, S., & Cardella, M. E. (2011). Elementary teachers' views about teaching design, engineering, and technology. *Journal of Pre-College Engineering Education Research* (J-PEER), 1(2), 5. https://doi.org/10.5703/1288284314639

Hurley, M. (2001). Reviewing integrated science and mathematics. The search for evidence and definitions from new perspectives. *School Science and Mathematics*, 101(5), 259–268. https://doi.org/10.1111/j.1949-8594.2001.tb18028.x

Ingersoll, R. M. (2003). *Who controls teachers' work? Power and accountability in America's schools.* Cambridge, MA: Harvard University Press.

Jardine, D. W. (2006). *On the integrity of things: Reflections on the integrated curriculum.* In D. W. Jardine, S. Friesen & P. Clifford (Eds.), Curriculum in abundance (pp. 171-179). Mahwah, NJ: Erlbaum.

Katehi, L., Pearson, G., & Feder, M. (Eds.) (2009). *Engineering in K-12 education: Understanding the status and improving the propects.* Washington, D.C: The National Academies Press.

Kind, V. (2009). Pedagogical content knowledge in science education: perspectives and potential for progress, *Studies in Science Education*, 45(2), 169-204. doi: 10.1080/03057260903142285

Krajcik, J., & Delen, I. (2017). How to support learners in developing usable and lasting knowledge of STEM. *International Journal of Education in Mathematics, Science and Technology*, *5*(1), 21-28. doi:10.18404/ijemst.16863

Kurz, T. L., & Middleton, J. A. (2006). Using a functional approach to change preservice teachers' understanding of mathematics software. *Journal of Research on Technology in Education*, 39(1), 45-65.doi: 10.1080/15391523.2006.10782472

Labov, J. B., Reid, A. H., & Yamamoto, K. R. (2010). Integrated biology and undergraduate science education: a new biology education for the twenty-first century? *CBE-Life Sciences Education*, 9(1), 10-16. https://doi.org/10.1187/cbe.09-12-0092

Lamb, R., Akmal, T. & Petrie, K. (2015). Development of a cognition-priming model describing learning in a STEM classroom. *Journal of Research in Science Teaching*, 52(3), 410-437. doi: 10,1002/tea.21200. Retrieved from http://onlinelibrary.wiley.com/doi/10,1002/tea.21200/epdf

Lee, J., & Strobel, J. (2010). Teachers' concerns on integrating engineering into elementary classrooms. In *Annual Meeting of the American Educational Research Association*. Denver, CO.

Levitt, K. E. (2002). An analysis of elementary teachers' beliefs regarding the teaching and learning of science. *Science education*, *86*(1), 1-22. https://doi.org/10.1002/sce.1042

Mann, E. L., Mann, R. L., Strutz, M. L., Duncan, D., & Yoon, S. Y. (2011). Integrating engineering into K-6 curriculum developing talent in the STEM disciplines. *Journal of Advanced Academics*, 22(4), 639-658. https://doi.org/10.1177%2F1932202X11415007

Masters, G. (2016). Policy insights: Five challenges in Australian school education. Melbourne, Australia: Australian Council for Educational Research Retrieved froöhttps://research.acer.edu.au/cgi/viewcontent.cgi?article=1004&context=policyinsights on October 2017

Maxwell, J. A. (2008). Designing a qualitative study. Bickman, L. & Rog, D. J. (Eds.), *The SAGE Handbook of Applied Social Research Methods (p.*214-253). doi: http://dx.doi.org/10.4135/9781483348858.n7

Mehalik, MM, Doppelt, Y, & Schun, CD. (2008). Middle-school science through design-based learning versus scripted inquiry: better overall science concept learning and equity gap reduction. *Journal of Engineering Education,* 97(1), 71–81. https://doi.org/10.1002/j.2168-9830.2008.tb00955.x

Metz, K. E. (2004). Children's understanding of scientific inquiry: Their conceptualization of uncertainty in investigations of their own design. *Cognition and Instruction*, 22(2), 219-290. https://doi.org/10.1207/s1532690xci2202_3

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis*: *An expanded sourcebook*. Sage Publications.

Ministry of Education [MoNE]) (2018). *Science Education Education Program* Retrieved from http://mufredat.meb.gov.tr/ProgramDetay.aspx?PID=143 on 20 April 2018.

Morrison, J. S. (2006).Attributes of STEM education: The students, the academy, the classroom. TIES STEM Education Monograph Series. Baltimore: Teaching Institute for Excellence in STEM. Retrieved from https://www.partnersforpubliced.org on 23 December 2012

Moore, T. J., Glancy, A.W., Tank, K.M., Kersten, J.A., Smith, K.A., Karl, A., & Stohlmann, M.S. (2014a). A framework for quality K-12 engineering education: research and development. *Journal of Pre-College Engineering Education,* 4(1), 1-13. http://dx.doi.org/10.7771/2157-9288.1069.

Mulholland, J. & Wallace, J. (1996). Breaking the cycle: Preparing elementary teachers to teach science. *Journal of Elementary Science Education*, 8(1), 17-38. Retrieved from https://link.springer.com/content/pdf on 5 July 2016.

Murphy, Ton. (2011). *STEM education – It's elementary*. US News and World Report. https://doi.org/10.1207/s15326985ep4001_1Next Generation Science Standards (USA, 2014). http://www.nextgenscience.org/

National Research Council. [NRC]. (2011). *Successful K-12 STEM education: Identifying effective approaches in science, technology, engineering, and mathematics*. National Academies Press.

National Research Council [NRC]. (2012). *A framework for K-12 science education: practices, crosscutting concepts, and core ideas.* Washington, DC.

Next Generation Science Standards [NGSS]. (2012). *Standards for engineering, technology, and the applications of science.* Washington, DC: National Academy Press, p.14.

Next Generation Science Standards [NGSS]. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: National Academy Press.

National Research Council [NRC]. (2013). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: The National Academies Press. 21-22-23.

Next Generation Science Standards [NGSS]. (2013). Appendix I – *Engineering Design in the NGSS*. Washington, DC: National Academy Press.

Next Generation Science Standards [NGSS]. (2013). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: National Academy Press.

National Research Council. [NRC] (2013). *Monitoring progress toward successful K-12 STEM education: A nation advancing?* National Academies Press. Retrieved from https://www.nap.edu/download/13509

OECD (2012). *PISA in focus 18:* Are students more engaged when schools offer extracurricular activities? Paris: OECD. Retrieved from https://www.oecd.org

Offer, J., & Mireles, S. V. (2009). Mix it up: Teachers' beliefs on mixing mathematics and science. *School Science and Mathematics*, *109*(3), 146-152. doi: 10.1111/j.1949-8594.2009.tb17950.x

Pang, J., & Good, R. (2000). A review of the integration of science and mathematics: Implications for further research. *School Science and Mathematics*, *100*(2), 73-82. doi: 10.1111/j.1949-8594.2000.tb17239.x

Patton, M. Q. (1980). *Qualitative evaluation methods*. Beverly Hills.

Patton, M. Q. (1990). *Qualitative evaluation and research methods*. SAGE Publications.

Pinar, W. F., Reynolds, W. M., Slattery, P., & Taubman, P. M. (2000). *Understanding curriculum: An introduction to the study of historical and contemporary curriculum discourses*. New York, NY: Peter Lang Publishing.

Puntambekar, S. & Hubscher, R. (2005). Tools for scaffolding students in a complex learning environment:What have we gained and what have we missed?. *Educational psychologist*, 40(1), 1-12. https://doi.org/10.1207/s15326985ep4001_1

Purzer, S., Goldstein, M. H., Adams, R. S., Xie, C., & Nourian, S. (2015). An exploratory study of informed engineering design behaviors associated with scientific explanations. *International Journal of STEM Education*, *2*(1), 9. doi:10. 1186/s40594-015-0019-7.

Radloff, J., & Guzey, S. (2017). Investigating changes in preservice teachers' conceptions of STEM education following video analysis and reflection. *School Science and Mathematics*, *117*(3-4), 158-167. https://doi.org/10.1111/ssm.12218

Radloff, J., Capobianco, B., & Dooley, A. (2019). Elementary Teachers' Positive and

Practical Risk-Taking When Teaching Science Through Engineering Design. *Journal of Pre-College Engineering Education Research* (J-PEER), 9(2), 4. https://doi.org/10.7771/2157-9288.1208

Rogers, C. & Portsmore, M. (2004). Bringing engineering to elementary school. Journal of STEM Education, 5(3), 17-28.Retrevied from on 11January 2015.

Roehrig, G. H., Moore, T. J., Wang, H. H., & Park, M. S. (2012). Is adding the E enough? Investigating the impact of K-12 engineering standards on the implementation of STEM integration. *School Science and Mathematics*, 112(1), 31-44. https://doi.org/10.1111/j.1949-8594.2011.00112.x

Sanders, M. (2009). Integrative STEM education: Primer. *The Technology Teacher*, 68(4), 20-26.

Smith, C. L., Wiser, M., Anderson, C. W., & Krajcik, J. (2006). Focus Artıcle: Implications of Research on Children's Learning for Standards and Assessment: A Proposed Learning Progression for Matter and the Atomic-Molecular Theory. *Measurement: Interdisciplinary Research & Perspective*, 4(1-2), 1-98. https://doi.org/10.1080/15366367.2006.9678570

Soy, S. (1997). *The case study as a research method uses & users of information*. p. 2. Retrived from https://www.ischool.utexas.edu/~ssoy/usesusers/l391d1b.htm on 5 July 2015.

Stake, R. E. (1995). *The art of case study research.* Thousand Oaks, CA: Sage Publications.

Stern, L. & Ahlgren, A. (2002). Analysis of students' assessments in middle school curriculum materials: Aiming precisely at benchmarks and standards. *Journal of Research in Science Teaching*, 39, 889–910. https://doi.org/10.1002/tea.10050

Stinson, K., Harkness, S.S., Meyer, H. & Stallworth, J. (2009). Mathematics and science integration: Models and characterizations. *School Science and Mathematics*, 109(3), 153–161.doi. 10.1111/j.1949-8594.

Stohlmann, M., Moore, T. J., Roehrig, G. H. (2012).Considerations for Teaching Integrated STEM Education. *Journal of Pre-College Engineering Education Research* 2:1, 28–34.doi: 10.5703/1288284314653

Ten Have P. *Understanding Qualitative Research and Ethnomethodology* (1st edn). London: Sage Publications, 2004.

Thomas, T. A. (2014). *Elementary teachers' receptivity to integrated science, technology, engineering, and mathematics (STEM) education in the elementary grades* (Doctoral dissertation).

Trends in International Mathematics and Science Study (TIMSS). (2015). International mathematics and science report 8. Grades Retrieved from http://timss2015.org/wp-content/uploads/filebase/science/1.-student-achievement.

Van Aalderen-Smeets, S. I., Walma van der Molen, J. H., & Asma, L. J: F. (2011). Primary teachers' attitudes towards science and technology. *Professional Development for Primary Teachers in Science and Technology*, 89-105. doi: 10.1007/978-94-6091-713-4_8

Wai, J., Lubinski, D., Benbow, C. P., & Steiger, J. H. (2010). Accomplishment in science, technology, engineering, and mathematics (STEM) and its relation to STEM educational dose: A 25-year longitudinal study. *Journal of Educational Psychology*, *102*(4), 860. https://doi.org/10,1037/a0019454

Wang, H-H (2012). *New era of science education: Science teachers'perceptions and classroom practices of science, technology, engineering, and mathematics (STEM) integration*. Retrieved from the University of Minnesota Digital Conservancy, http://hdl.handle.net/11299/120980.

Wang, H. H., Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM integration: Teacher perceptions and practice. *Journal of Pre-College Engineering Education Research* (J-PEER), 1(2), 2. https://doi.org/10.5703/1288284314636.

Watts-Taffe, S., Gwinn, C. B., Johnson, J. R., & Horn, M. L. (2003). Preparing preservice teachers to integrate technology into the elementary literacy program. *The Reading Teacher*, 130-138. http://www.jstor.com/stable/20205332

Wenglinsky, H. (2000). *How teaching matters: Bringing the classroom back into discussions of teacher quality*. Princeton, NJ: Educational Testing Service, Policy Information Center. Retrieved from http://files.eric.ed.gov/fulltext/ED447128.pdf.

White, B. & Frederiksen, J. (1998). Inquiry, modeling, and metacognition: Making science accessible to all students. *Cognition and Instruction*, 16(1), 3-118. https://doi.org/10.1207/s1532690xci1601_2

Wolf, S. J., & Fraser, B. J. (2008). Learning environment, attitudes and achievement among middle-school science students using inquiry-based laboratory activities. *Research in Science Education*, 38(3), 321-341. https://doi.org/10.1007/s11165-007-9052-y.

Wyss, V. L., Heulskamp, D. ve Siebert, C. J. (2012). Increasing middle school student interest in STEM careers with videos of scientists. *International Journal of Environmental Science Education, 7 (4),* 501-522. Erişim adresi: http://files.eric.ed.gov/ fulltext/EJ997137.pdf

Xie, Y., Fang, M., & Shauman, K. (2015). STEM education. *Annual review of sociology*, *41*, 331-357. doi: 10.1146/annurev-soc-071312-145659

Yin, R. K. (2009). *Case study research: Design and methods (4th ed.).* Thousand Oaks, CA: Sage Publications.

# İlkokul Öğretmenlerinin Öğrencilerle Fen, Matematik, Mühendislik, Teknoloji (STEM) Eğitimi Öncesi Gereksinimleri; Durum Çalışması

## Atıf:

Aydin, G. (2020). Prerequisites for elementary school teachers before practicing stem education with students: A case study. *Eurasian Journal of Educational Research 88*, 1-40. DOI: 10.14689/ejer.2020.88.1

## Özet

*Problem Durumu*: İlkokul düzeyindeki STEM öğretiminde en önemli unsur doğal olarak ilkokul öğretmeninin STEM eğitimine ne kadar hazır olduğudur. Başta ABD olmak üzere birçok ülkede bu konuda öğretmen eğitimleri, kısa dönemli sertifika veren kurslara katılım, yüksek lisans programları, ulusal veya uluslararası projeler kapsamında eğitimlerle gerçekleştirilmektedir. Öğretmenlerle yapılan eğitimlerde genel olarak yaşanan sorunlar, geliştirilmesi gereken yeterlilikler ve eğitimlerle ilgili öneriler şu şekilde sıralanmaktadır: Öğretmenlere uzun süreli içeriğinde bol pratik uygulamaların olduğu eğitimler verilmesi, STEM entegrasyonunu anlama ve uygulamada sorunlar yaşadıkları, mühendisliği ayrı bir konu olarak algıladıkları, Mühendislik tasarım süreçleriyle ilgili uygulamalara ihtiyaçları olduğu, STEM alanları konu içerik bilgilerinde eksiklikleri olduğu, teknoloji yeterliliklerinin zayıf olduğu, zamanın yetersizliği ve müfredatın STEM entegrasyonunu içerecek şekilde düzenlenmesi gerektiği, öğretmenlerin öz inanç kendine güvenlerinin yetersizliğinin öğrenmelerini ve isteklerini etkilediği okullarda uygulamalar için gerekli malzemelerin olmayışı ve ölçme değerlendirme araçlarına ihtiyaçları olduğudur.

Bu araştırmada ise ilkokul öğretmenlerine STEM eğitim süreci içinde ortaya çıkan ihtiyaçları doğrultusunda planlanan 13 haftalık teorik ve uygulamalı eğitimlerle öğretmenlerin STEM eğitimini anlama ve STEM öğretimi için ihtiyaçlarını belirlemek amaçlanmıştır. Araştırmanın problemleri ise;

a- İlkokul öğretmenlerinin STEM eğitimini anlamadaki değişimleri nelerdir?
b- STEM eğitimin öğretimsel süreçte hangi boyutlarda katkısı olmuştur?
c- STEM öğretini gerçekleştirmek için gereksinimleri nelerdir?
d- STEM eğitimin faydalarıyla ilgili görüşleri nelerdir?

*Araştırmanın amacı:* MEB (2018) yılından itibaren yürürlüğe giren Fen Bilimleri programın kazanımlarında yer alan mühendislik ve tasarım becerileri uygulamaları ilkokul 3. sınıftan itibaren programda yer almıştır. Bu nedenle bu araştırmada teorik ve pratik uygulamalarla gerçekleştirilen STEM eğitiminin ilkokul öğretmenlerinin STEM eğitimini öğrencilerle uygulamadan önce gereksinimleri belirlenmeye çalışılmıştır.

*Araştırmanın Yöntemi:* Araştırma örnek olay yöntemiyle bir öğretmen hariç 6 ilkokul öğretmenliği yapmakta olan katılımcılar 13 haftalık yüksek lisans dersinde uygulamalı eğitimle gerçekleştirilmiştir. Dersin başlangıçtaki planında öğretmenlerin açık uçlu

ön-test sorularına verdikleri yanıtlar ve süreç içindeki ihtiyaçları göz önüne alınarak değişikliklere gidilmiştir. Buna göre; STEM nedir? STEM entegrasyonu nedir?, PISA, TIMSS nedir, örnek sorular ve ülkelerin son durumu açıklanmıştır. STEM uygulamalarında kullanılan öğrenme yaklaşımları, modelleri uygulamalarla gerçekleştirilmiştir. Daha sonra Mühendislik nedir ve Mühendislik Tasarım Süreci (MTS) basamakları nelerdir, uzay mekiği örnek uygulaması gerçekleştirilmiştir. Daha sonra eklerde ( EK-2) Türkçe ve İngilizcesi yer alan Beyin ve Kask, Yapay Mide etkinlikleri gerçekleştirilmiş ve öğretmenlere yazılım mühendisi tarafından çizim programı olan Solidword programı kullanım eğitimi verilmiştir. Öğretmenler kask veya yapay mide tasarımlarını bu programda çizmiş daha sonra prototipleri 3 D yazıcı aracılığıyla üretilmiştir. Daha sonra Fen Bilimleri öğretim programında yer alan bir konuyu seçerek ders planı hazırlamaları istenmiş ve tüm öğretmenlerin ders planları incelenerek düzeltme ve önerilerde bulunulmuştur. Yine ders planlarına göre değerlendirme ölçeklerini nasıl hazırlayacakları, değerlendirme de nelere dikkat etmeleri gerektiği, rubrikler, açık uçlu sorular, test soruları gibi birçok örnekle açıklanmış ve ders planları için ölçme değerlendirme araçları hazırlamaları istenmiştir. Son olarak hazırladıkları tüm ölçme değerlendirme araçları öneriler verilerek değerlendirilmiştir. Veri kaynakları ön-son test olarak kullanılan açık uçlu sorular, tüm süreç boyunca elde edilen araştırmacı ve öğrenci günlükleri, ders planları, çalışma kâğıtları görüşme formları ve ölçme değerlendirme örnekleri çoklu veri olarak kullanılmıştır. Veriler araştırmacı ve alanda iki uzman yardımıyla açık ve çapraz kodlama ile kodların oluşturulması çoklu kontroller sonunda temaların oluşturulmasıyla tematik analizle değerlendirilmiştir.

*Araştırmanın Bulguları:* Çoklu veri analizleri sonucu STEM nedir anlama, öğretimsel olarak kazanımlar, öğretmenlerin STEM öğretimi için gereksinimleri, okulların STEM öğretimi için gereksinimleri ve STEM eğitiminin öğrenciler üzerinde faydaları başlıklarında temalar elde edilmiştir. STEM nedir temasında, başlangıçta dört öğretmenin STEM kelimesindeki harflerin açılımını bilmemelerine rağmen eğitimler sürecinde öğrendikleri, ancak STEM entegrasyonu olarak çizdikleri şekiller sonucu tam olarak anlayamadıkları tespit edilmiştir. Yine Teorik STEM eğitimi sırasında STEM eğitiminde kullanılan öğrenme yaklaşım ve modelleriyle ilgili öğretmenlerin ön testte probleme dayalı öğrenme, araştırma sorgulamaya dayalı öğrenme, proje tabanlı öğrenme, beyin fırtınası, soru sorma, yaparak öğrenme yanıtlarını verirken uygulamalar sırasında öğrenme yaklaşımları, öğrenme modelleri, yöntem ve teknikleri karıştırdıkları, aralarındaki farkları açıklayamadıkları ve öğrenme yaklaşımlarını pratiğe aktaramadıkları tespit edilmiştir. Öğretmenlik eğitim programlarının tümünde yer alan öğrenme kuramları, modeli öğretim strateji, yöntem ve teknikleri konusunda lisans mezuniyetini yeni tamamlamış iki öğretmen ezbere doğru yanıt vermiş olmasına rağmen pratik uygulamaları öğretmenlerin tümü gerçekleştirmede zorlanmışlardır. Ayrıca problem cümlesi oluştururken soru sorarken günlük hayattan örneklendirme konusunda zorlanmışlardır. Bunların dışında öğretmenlerin Mühendislik tasarım süreçlerini bilmemelerine rağmen bu çalışma ile deneyimledikleri ancak daha çok pratiğe ihtiyaç duydukları eğitimin sonunda yapılan görüşmelerde belirtilmiştir. Öğretmenlerde öğretimsel olarak gelişen kazanımlar ise, iletişim, takım çalışması ve teknoloji kullanım becerilerinin yanında, mide ve beyin konu içerik bilgisi, MTS ve beyin fırtınasının uygulamalardaki etkilerini görerek problem çözmede ve tasarım kararını vermede önemini anlamaları ve yine teknolojileri öğrenme ve derslerini teknolojiyi kullanma konusunda sahip oldukları özgüven ve negatif inançlarının etkinliklerde olumlu yönde geliştiği söylenebilir. Araştırmanın problem cümlesinden biri olan İlkokul öğretmenlerinin STEM öğretimi için gereksinimleri nelerdir sorusuna verilen yanıtlar öğretmenlerin ihtiyaçları ve uygulama için okullardaki gereksinimler olarak temalara ayrılmıştır. Burada öğretmenler STEM entegrasyon pratikleri, ölçme değerlendirme araçları ve mühendislikte problem oluşturmada günlük hayatla bağlam kuramama ve daha çok pratiğe ve örnek uygulama içeren kaynaklara ihtiyaç duyarken okullardaki uygulamalarda, öğrenci sayısı, araç gereç, zaman, öğretim programının sınırları ve danışman ihtiyacı öne çıkmıştır. Ancak ilkokul öğretmenlerinden STEM eğitimin öğrenciler üzerinde faydalarıyla ilgili veriler analiz edildiğinde kendi deneyimlerinden yola çıkarak uzun süreli öğrenme, eleştirel düşünme, problem çözme, soru sorma, yaratıcılık, meslek seçimi kodlarının oluşumunu sağlayan veriler elde edilmiştir.

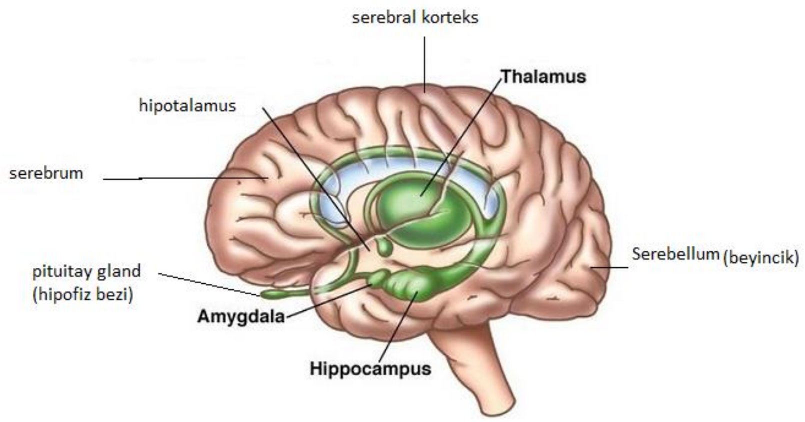
*Araştırmanın Sonuçları ve Önerileri:* İlkokul öğretmenlerine 36 saatlik teorik ve uygulamalı gerçekleşen STEM eğitimini içeren bu araştırmayla, öğretmenlerin etkili STEM öğretimi için öğretmenlerin STEM entegrasyonu, MTS, STEM öğretimi uygulamaları için gereken öğrenme kuramları ve modellerini daha uzun süre ve çok sayıda uygulama içeren eğitimlere ihtiyaç duydukları, konu alan bilgilerinin STEM etkinlikleriyle geliştirilmesine, teknoloji kullanımını pratik uygulamalarla gerçekleştirdiklerinde öz yeterliliklerinde gelişimler olduğu, STEM eğitiminin ilkokul öğretmenlerinde takım çalışması, beyin fırtınası, eleştirel düşünme, problem çözme becerileri gibi diğer derslerde de kullanabilecekleri yeterliliklerinde olumlu yönde katkı sağladığı ve STEM eğitiminin öğrencilerin eleştirel düşünme, meslek tercihi, uzun süreli öğrenme, problem çözme, soru sorma ve yaratıcılıklarına katkı sağlayacağını kendi deneyimleri üzerinden belirtmişlerdir. En çok zorlandıkları kısım ise STEM entegrasyonu, öğretim programındaki konuyu günlük hayatla bağlamlaştırarak soru sorma, mühendislik problemi oluşturma, ölçme değerlendirme araçları üretme olmuştur. STEM eğitiminin okullarda uygulanması için öğretim programı, materyal ihtiyacı, danışman desteği ve öğrenci sayısı engeli ortaya konulmuştur. İlkokul öğretmenleriyle yapılacak STEM eğitim programlarının eylem araştırması modelinde uzun süreli, teorik ve farklı STEM entegrasyonlarını içeren çok sayıda uygulamayı içeren ve Fen, matematik, mühendislik ve teknoloji alanında teorik eğitimi kapsayan bir içerikte verilmesi önerilir.

*Anahtar Sözcükler: STEM* eğitimi, İlkokul öğretmen eğitimi, Biyoloji-STEM, Mühendislik tasarım süreci, tematik analiz

## APPENDIX

## BRAIN AND HELMET

Henry Gustav Molaison, or H.M., known for his pioneering work based on modern neuropsychology. The story of the case. Henry Gustav Molaison was born on 26 February 1926 in Hartford, USA. After an accident with the bicycle, his epilepsy becomes life-threatening; his family applies to the city hospital. Unexpected and sudden electrical discharges of the central nervous system cells result in a seizure. Generally, it takes a few minutes and then passes. If this condition repeats more than once, it is called seizure disorder or epilepsy. There are approximately 40 million epileptic patients in the world. This number is around 700 thousand in our country. William Beecher Scoville, who was examined H.M being a neurosurgeon, was taken a radical decision to perform an experimental surgery to end epilepsy seizures. At the end, this surgery saved H.M.'s life but left behind an unexpected permanent illness. H.M. could not success to form any memory after the day of surgery. He could not keep new data in his mind for more than a few minutes. Although he read any magazine, he kept reading again and again without any cognition even he initially read it. In the case mentioned above, use the following picture below to investigate which part of the brain may have been removed or damaged during H.M. surgery.




Try to find the damaged part of HM surgery on the sheep brain in your dissection cups and mark the parts you find out?

Each group should answer the question, depending on the marked part in your brain sample.

Which kinds of symptoms will be seen in a person if the **marked part** (A, B, C, D) of your brain sample is damaged?

*(Depending on the cognitive level of students, you can add or simplify questions. For example, you can add the following questions)*

Why can babies not walk before one year old?

Does the adolescence's brain parts change physically? Which part does it change? What is the name of this change in scientifically?

Write the names of structures in your skull to protect the brain parts?

**Note:** If you are examining this activity with prospective teachers, you can ask them to find the steps of 5 E-learning model in the activity plan.

## BIO-MEDICAL ENGINEERING

People who create tools, devices, systems or processes to find solutions or compensate a requirement to a specific problem are called engineers. The main tasks of an engineer are to design, operate, examine, improve and develop the product under different conditions. The new branches of engineering have emerged and diversified with the increasing and complexity of the problems to be solved in daily life. One of these engineering disciplines is bio-medical engineering, which has grown rapidly in the last fifty years. The main focus of biomedical engineering is to understand the systems of the human body, which is a complex system, and to develop the necessary tools, devices, and systems for the solution by identifying the functional disorders. Therefore, individuals who will become bio-medical engineers they attend to science, human anatomy, physiology, basic and applied mathematics, system modeling and analysis methods, basic knowledge about materials, electronics, control and computer, theoretical and practical knowledge about design and production of medical products and devices. Electronic devices such as ECG and MRI used for diagnosis, cautery, catheters, dialysis machines, robotic surgical systems, hearing aids, bone and vascular prostheses, heart valves, etc. and their developments are produced by biomedical engineers. In conclusion, bio-medical engineering works closely with the discipline of biology, a branch of science. This integration is formed by combining different disciplinary knowledge of engineers and doctors and aids to solve real problems in the human body.

### The reasons for Epilepsy in TURKEY

In a nationwide survey conducted in Turkey, epilepsy in children between 0-16 years old was found in a ratio of 0.8%. The overall prevalence of epilepsy in Turkey is approximately between 7-12.2 / 1000. Almost 134,000 men in military age are suffering from epilepsy. In general, the reasons for epilepsy cannot be found, but it is known that some factors which often occur in childhood bring to disorder. The reasons may be brain deprivation or injury during labor, chromosome mutations, enzyme deficiency which results from labor or inflammation of the brain membranes (meninges) as a result of meningitis, or tumors in the brain. In addition to these, diseases during pregnancy or alcohol, cigarette, or drug usage of the expectant mother may lead to epilepsy. However, the effects of the head on hard ground (traffic accidents, skiing, falling on concrete floors, violent trams) and feverish referrals are among the leading causes of epilepsy in children aged 0-16 years.

## IDENTIFY- INVESTIGATE

Imagine yourself as a biomedical engineer, and what kind of helmet would you produce to protect the children wouldn't have epilepsy if they fell while cycling? In daily life, the helmet is used to minimize injuries to the athlete, especially during sporting events. The first helmets were made by leather in 1970. The use of helmets in transport and traffic aims to minimize the potential risk of life at the time of an accident in many countries, where helmets are easily available. Motorcycle riders are required to wear helmets. Bike riders also commonly use helmets. Since the 1990s, helmets are made of fiber- reinforced and lightweight resin and plastic. Helmets used in bicycle today are shown below. Foam has been used frequently in helmet production from past and today.

## IMAGINE- PLAN

Write your problem statement?

In the last lesson, we examined the structure, functions, and parts of the brain that could be damaged in case of an accident. Now imagine that you are a biomedical engineer, and how would you design a helmet to solve the problem given to you? Why is that? Draw the parts of the helmet you will create and write the necessary materials by reading the limitations.

***(Draw your helmet by using solid word)***

## CREATE

Now create the helmet you designed. At this stage, make sure that the helmet that you design in accordance with your imagination is thick, durable, safe, cost effective and ergonomic.

***(Produce your prototype by using 3 D printer)***

**Limitations:**

You can use up to 5 kinds of materials (except glue, scissors)

Thickness of your helmet is less than 10 cm

Maximum weight of your helmet is between 500gr and 1 kg

When your helmet hits the ground hard, the paintball inside will not break.

The cost of your helmet does not exceed 20 TL.

Your helmet can be used in accordance with human anatomy without disturbing the ears, neck and neck.

# TEST

## Thickness Score

Calculate the material thickness of the helmet you designed with a caliper.

If the thickness is less than 10 cm, you can proceed to the testing phase.

| Score | | Our score |
|---|---|---|
| 3 | Helmet thickness less than 3 cm | |
| 2 | Helmet thickness is between 3 and 6 cm | |
| 1 | Helmet thickness greater than 6 cm | |

## Weight Score

Calculate the weight of your helmet

…………………………………………………………….

| Score | | Our score |
|---|---|---|
| 3 | If the helmet weight is less than 50 gr | |
| 2 | Helmet weight is between 50 g-100 g | |
| 1 | Helmet weight heavier than 100 g | |


## Safety Score

Secure a small plastic bag containing one paint ball to the top of the model head. Place your helmet onto the model head, drop the head to the floor, and inspect the paint ball.

| Score | | Our score |
|---|---|---|
| 3 | The paint ball is not damaged at all. | |
| 2 | The paint ball has cracked or leaked | |
| 1 | The paint ball is smashed | |

**Cost**

Add up the total cost of materials you used.

…………………………………………………..

| Score | | Our score |
|---|---|---|
| 3 | Cost is less than 10 pounds | |
| 2 | Cost is in the range of 10-20 pounds | |
| 1 | Cost is over 20 pounds | |

**ERGONOMICS…………………………………………..**

| Score | | Our score |
|---|---|---|
| 3 | The head can be turned right and left. | |
| 2 | When using a helmet the ears do not feel discomfort. | |
| 1 | The head does not remain in the cavity or does not feel compressed. | |

## IMPROVE

Redesign the helmet with aspects that can address the challenges you face during helmet making, or can be improved to get a better result.

## RETEST

Thickness score:

Weight score:

Our security Score:

Our ergonomics score:

Our cost score:

Your total score

## COMMUNICATE

During the showcase, you'll get to share information about your engineering challenge with other teams. What are some things you might want to tell them about engineering helmets, and your design in particular?

| Score | | Our score |
|---|---|---|
| 3 | The head can be turned right and left. | |
| 2 | When using a helmet the ears do not feel discomfort. | |
| 1 | The head does not remain in the cavity or does not feel compressed. | |