AN INVESTIGATION OF PRESERVICE TEACHERS' STEM AWARENESS THROUGH DEFINITIONS AND RELATIONSHIPS OF STEM AREAS

by

Seçil Tezsezen

Integrated B.S. and M.S. Program in Teaching Mathematics, Boğaziçi University, 2011

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APPROVED BY:

Assist. Prof. Fatma Aslan-Tutak .....
(Thesis Supervisor)

Assoc. Prof. Sencer Çorlu .....

Assist. Prof. Sevil Akaygün .....

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Dedicated to my nuclear family which has begun with our son,
with deepest love…

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ABSTRACT

AN INVESTIGATION OF PRESERVICE TEACHERS' STEM AWARENESS THROUGH DEFINITIONS AND RELATIONSHIPS OF STEM AREAS

The purpose of the study is to investigate STEM (Science, Technology, Engineering, Mathematics) awareness of preservice freshman and senior teachers who study in STEM related teaching programs through definitions and relationships of STEM areas. In this sense, participants' definitions and descriptions of STEM areas through STEM related daily topics were examined. The study investigated whether there was a significant difference between freshman and senior preservice teachers in terms of using relationship between STEM areas while defining and describing STEM areas. In addition, the study aimed to describe how participants who see the relationship between STEM areas express the relationships between STEM areas. In this study, mixed-method approach was used. The research had two phases. In the first phase, STEM awareness (STEM-A) Open-Ended Questionnaire was administered to 204 participants. The results of this instrument were quantitatively analyzed. According to analysis of STEM-A Open-Ended Questionnaire, there was no significant difference between freshman and senior participants in terms of using relationship between STEM areas while defining and describing STEM areas. For the second phase, participants who defined and described at least one STEM area in terms of relationships between STEM areas were chosen and 9 participants were interviewed to investigate their understanding of relationship. Four different STEM related daily topics were used to collect data (2 in STEM-A and 2 in interviews). The research showed that participants used more statements related to relationships between STEM areas while defining STEM areas. In this sense, it can be stated that they had difficulty in expressing the relationship between STEM areas in daily life STEM related cases.

ÖZET

ÖĞRETMEN ADAYLARININ FeTeMM FARKINDALIKLARININ FeTeMM ALANLARI TANIMLARI VE İLİŞKİLERİ ÜZERİNDEN İNCELENMESİ

Araştırmanın amacı FeTeMM (Fen, Teknoloji, Mühendislik, Matematik) ile ilgili öğretmenlik programlarında okuyan birinci sınıf ve son sınıf öğretmen adaylarının FeTeMM farkındalıklarını FeTeMM tanımları ve alan ilişkileri üzerinden tanımlamaktır. Bu bağlamda, katılımcıların FeTeMM alanları tanımları ve FeTeMM ile ilgili günlük hayat konuları üzerinden FeTeMM alanlarını betimlemeleri incelenmiştir. Araştırma birinci sınıf ve son sınıf öğretmen adaylarının FeTeMM alanlarını tanımlarken FeTeMM alanları arasındaki ilişkileri ifade etmeleri bakımından anlamlı bir fark olup olmadığını incelemiştir. Ek olarak, çalışmada FeTeMM alanları arasındaki ilişkileri gören katılımcıların FeTeMM alanları arasındaki ilişkileri nasıl ifade ettiklerini tanımlamak amaçlanmıştır. Bu çalışmada karma metot araştırma yöntemleri uygulanmıştır. Araştırma iki aşamalıdır. Birinci aşamada, FeTeMM Farkındalığı Açık Uçlu Anketi (FeTeMM-F) 204 katlımcıya uygulanmıştır. Bu ölçeğin sonuçları nicel olarak analiz edilmiştir. FeTeMM farkındalığı açık uçlu anketinin sonuçlarına göre, birinci sınıf ve son sınıf öğretmen adayları arasında FeTeMM alanlarını tanımlarken FeTeMM alanları arasındaki ilişkileri ifade etmeleri bakımından anlamlı bir fark olmadığı ortaya konmuştur. Çalışmanın ikinci aşaması için, en az bir FeTeMM alanını FeTeMM alanları arasındaki ilişkiler üzerinden tanımlayan ve betimleyen katılımcılar seçilmiştir ve 9 katılımcıyla görüşmeler yapılmıştır. Dört farklı FeTeMM ile ilgili günlük hayat konuları (İkisi FeTeMM farkındalığı anketinde ikisi görüşmelerde) veri toplamak için kullanılmıştır. Araştırma sonuçları katılımcıların FeTeMM alanlarını tanımlarken FeTeMM alanları arasındaki ilişkelere ilişkin ifadelere daha fazla yer verdiğini göstermiştir. Bu anlamda, katılımcıların günlük hayat örneklerinde FeTeMM alanları arasındaki ilişkileri ifade etmekte zorlandıkları söylenebilir.

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LIST OF ACYRONYMS / ABBREVIATIONS

AAAS	American Association for the Advancement of Science
ABET	Accreditation Board for Engineering and Technology
CET	Computer Education and Educational Technologies
GAO	U.S. Government Accountability Office
GPA	General Point Average
MoNE	Ministry of National Education
NSF	National Science Foundation
OECD	Organization for Economic Co-operation and Development
PISA	Programme for International Student Assessment
SCED	Secondary School Science and Mathematics Education
SCHEM	Secondary Chemistry Education
SMATH	Secondary Mathematics Education
SPHYS	Secondary Physics Education
STEM	Science, Technology, Engineering, Mathematics
STEM-CR	STEM Cases Relationship
STEM-DCR	STEM Definitions and Cases Relationship
STEM-DR	STEM Definitions Relationship
STEM-A	STEM Awareness
PMATH	Primary Mathematics Education
PRED	Primary School Education
PSCIENCE	Primary Science Education

1. INTRODUCTION

The scientific advancements and technological improvements, which occurred in last century, have affected the structures we have interaction with in our daily lives. Being only literate is not enough to understand the elements of our world and to spend our life. There are hundreds of new products that are encountered in daily lives. Technology has been continuing to develop new products with the collaboration of science, engineering and mathematics. To communicate through these products, to evaluate them scientifically, to decide about the advantages and disadvantages of them, to make changes on these products that is to say to innovate and, to develop new ones does not only depend on technological literacy and skills. The ability to make all of them needs science, technology, engineering and mathematics knowledge and skills that integrate these areas.

It is predicted by U.S. Government Accountability Office (GAO, 2000) that one of every three jobs will be science, technology, engineering, and mathematics (STEM) related by 2015 (as cited in Breiner *et al*., 2012) and therefore require STEM knowledge. Furthermore, multidisciplinary natures of problems of today need integration of STEM areas for their solutions (Roehrig *et al*. (2012). Hence, STEM is important for the nations to compete in the global world and for the individuals to take a meaningful place in 21st century. In addition to this, rapid globalization of the world resulted in the boundaries of nations become blurred. The more important thing than to become a citizen of any nation is to be a 21st century person.

The changing structure of the world has given birth to needs for some skills. It can be said that in the past the principle of division of labor was important for employers to increase the productivity, in today's world the collaborative work environments have gained importance. One of the main reasons of this is in today's world there is more extensive knowledge in every area compared to past. It is hard for a person to have all kind of knowledge in certain area(s) so the areas have become

more specialized and each have their specialists. In such a situation, the communication and collaboration skills stand out. In this sense, those skills have also great importance in STEM that integrates four deep areas.

On the other hand, it is important for todays' people to be aware of STEM and the relationships between STEM areas because literacy in any area needs awareness of that area. Being aware of something can be enabled through knowing and experiencing it. Similarly, STEM awareness needs knowing the knowledge of STEM areas and experiencing them in real life situations. The knowledge and experience of STEM areas can be enabled in schools by giving place to applications of STEM in education. In this sense, STEM education refers to the knowledge, skills and beliefs that are collaboratively constructed at the intersection of more than one STEM subject area (Corlu *et al*., 2014). The aim of STEM education is to raise the individual as a real life engineer or scientist by integrating the STEM areas (Breiner *et al*., 2012). The way of raising the individual as a real life engineer or a scientist passes through learning by doing which has generally been considered the most effective way of learning and students show more motivation to learning experiences that come from learning by doing (Lombardi, 2007). The STEM literacy of the societies can be increased firstly making them aware of STEM by giving students opportunities to deal with daily life problems, to produce creative solutions, to work in collaborative environments, to use technology effectively, to make genuine designs, to form mathematical models of the situations in their educational life.

So, it is very important for educational systems to raise individuals who can keep pace with this century and have the knowledge and skills that are needed in today. Therefore, the importance of STEM in education was rapidly conceptualized and the attempts were done and are being continued to done. It became so popular in education and also in research. However, there is a great need on the effects of empirical research in STEM education (Becker & Park, 2011). Under these circumstances, STEM education was also negatively affected by its popularity. There existed many approaches and applications on STEM education. However, the trouble with some of the approaches is their limited view of STEM education as

collaboration, integration and daily life relationship. To achieve STEM education, understanding of its nature and nature of its elements (science, technology, engineering, mathematics), having the knowledge in these areas and the skills important in doing STEM should be provided. Therefore, STEM Awareness should be gained by students, teachers and other stakeholders of STEM so that there exist true applications and approaches in STEM education.

Teachers are the backbones of STEM education. They will learn and develop their own understanding about STEM education. The readiness of implementers of STEM education should be investigated so that new action plans can be done in teacher education. Therefore, this study focused on how implementers of STEM education are aware of STEM. Participants of the study were from STEM related teaching departments. Participants' definitions of STEM areas, STEM education, and descriptions of STEM areas and the relationships between STEM areas were examined through STEM related daily topics.

2. REVIEW OF THE LITERATURE

2.1. STEM (Science, Technology, Engineering, Mathematics)

STEM is the acronym for science, technology, engineering and mathematics. The acronym SMET was firstly used to refer science, mathematics, engineering and technology in 1990s by National Science Foundation (NSF) but it was changed to STEM by NSF again (Sanders, 2009). The important thing in understanding and defining STEM is not bringing the definitions of STEM areas together. The issues, which should take more attention and should be focused, are the things that hold these areas together. However, not only common characteristics they have but also different properties of these areas keep them together as STEM. These four areas complete each other and support the improvements of each other. STEM provides learners with dealing with these areas in an integrated way rather than dealing with separated pieces of knowledge of science, technology, engineering, and mathematics (Dugger, 2010).

STEM areas have naturally interaction in our daily lives. While maintaining our daily needs, STEM areas are not being separated. All of STEM areas professionals need to have the knowledge of other areas of STEM besides their own profession specific knowledge. A scientist needs to have understanding of all areas of STEM to better carry out the experiments or an engineer cannot make improvements in designs and applications without integrating the knowledge and skills of science, technology, engineering and mathematics (Breiner *et al*., 2012). Thus, it is impossible to individually perform science, technology, engineering and mathematics without benefiting the concepts and products of each STEM areas. To better understand the meaning of STEM, the relations between STEM areas will be discussed by providing the definitions of each area with examples.

First of all, mathematics has always been considered to be the language of science. It has an important role in explaining and sharing of scientific knowledge.

Instead of saying density is the mass per unit volume; a universal language is used to state this scientific knowledge as $d=\frac{m}{v}$. Scientific knowledge is communicated through mathematics. Indeed, science produces interesting problems for mathematics to investigate and mathematics presents science significant tools to make the scientific data meaningful (American Association for the Advancement of Science, 1990). Mathematics is a "diverse discipline that deals with data, measurements, and observations from science; with inference, deduction, and proof; and with mathematical models of natural phenomena, of human behavior, and of social sciences" and "a science of pattern and order" (National Research Council of (U.S.), 1989, p.31). Mathematics is also a tool in science, technology, engineering that helps them to solve problems by using logical thinking and models. Comprehension of the nature of mathematical thinking and being familiar with the key mathematical ideas and skills are requisite for scientific literacy (Science for All Americans Online, 1989).

According to Science Council of UK (2009), "Science is the pursuit and application of knowledge and understanding of the natural and social world following a systematic methodology based on evidence" (para. 1). Another definition of science emphasizes that science is not the collection of the truths about the world; it is a way of thinking and research, which are grounded on the logical thinking and continuous inquiry (Ministry of National Education, 2005). Both definitions of science explain the importance of some skills while doing science. These skills that are much related to nature of mathematics are understanding and logical thinking because in simplest way of expression, mathematics is the science of patterns and relationships and it relies on logic (AAAS, 1990). Therefore, a great role of mathematics takes place in understanding the science behind a natural event by exploring the patterns and relationships.

However, neither science nor mathematics can be isolated from technology. "Technology is comprised of the products and processes created by engineers to meet our needs and wants" (Project Lead the Way, 2011). In Turkish Science and

Technology Curriculum (MoNE, 2005), technology is defined as both a type of knowledge that uses concepts and skills which are obtained from other disciplines (physical sciences, mathematics and culture etc.) and is a presentation of that knowledge to the service of human with the aim of satisfying a certain need and solving a certain problem by using materials, energy, and tools. Science and technology are complementary parts of each other in terms of their field of occupation. Science deals with understanding about the natural world and technology concerns human built world (Project Lead the Way, 2011). In this sense, many technologies can be said that they are inspired by the processes of natural world that are observed and explained by science. For example, robotic hands are designed by investigating the human hand. Besides, a robot that has the ability to walk on the ceiling has been made by modeling the insects' legs.

Nevertheless, there is an important part that should not be forgotten; engineering. "Engineering is the application of science to the optimum conversion of the resources of nature to the uses of humankind" (Encyclopedia Britannica, 2014, para.1). This area of STEM applies science by using the tools of mathematics and technology for the benefit of humankind and the nature. According to Accreditation Board for Engineering and Technology (ABET, 2015), "Engineering is the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize economically the materials and forces of nature for the benefit of mankind". While science is being modeled in engineering process, mathematics finds an application area in there. Technology takes place in almost every step of engineering design process. As a result of such relationships between science, technology, engineering, and mathematics, for example, there exists *Institute for Biologically Inspired Engineering*, which uses nature's design principles to develop bioinspired materials and devices (Wyss Institute, 2012). The advancements in every area of life in 21st century have accelerated the visibility of the effect of the natural interaction between STEM areas.

The areas of STEM have always been in an interaction and the functions of life have always been actualized by the integration of these areas. For example, for centuries perfume production takes into consideration many aspects of odorous matters while making perfumes. There are decisions to be made based on scientific knowledge. If the perfume will be made of rose, roses should be collected before 10 am due to the fact that the smelly particles in the rose vaporize as the sun warms the earth. On the other hand, the ratio of the odorous matters, which will be used as ingredient in a perfume, constitutes the key factor of creating different perfumes (Kokuriku Açık Parfüm, 2015). Until this process, it seems that there should be a person who is knowledgeable with the chemistry of odorous matters and a person who is able to calculate the relationships and ratios between the odorous matters and is able to adjust the ratios to different amounts of the product. However, there can be one person who can perform all procedures. Perfume production process needs more to perform its best. There should inevitably be used technologies which some of them are special to perfume production and some of them are the general technologies such as computer software that are used in many areas of life. Additionally, there will be a need for creating better products or getting better results after the production.

In this sense, there is a certain need for the collaboration of science, technology, engineering, and mathematics. As seen in the example, the real life applications of STEM are naturally integrated, however it is not experienced in this way in the schools (Breiner *et al*., 2012). The students generally deal with knowledge and applications of science, technology, engineering, and mathematics areas in different courses with the help of teachers who are specialized in one of the areas of STEM. For example, a mathematics teacher is generally responsible for gaining students advanced calculations or problem solving skills by only using paper based problems or a science teacher may try to explain a phenomenon without revealing and practicing the mathematical skills behind it. Because of the classification of the topics as science and mathematics, teachers begin to see particular topics as their responsibility and other topics as the responsibility of other subjects' teachers (Byrne and Brodie, 2011). Engineering and technology are not even considered. So,

separating the STEM areas as science, technology, engineering, and mathematics lessons blurs the integrative parts of STEM areas.

Science, technology, engineering and mathematics professionals may also integrally do STEM without separating them as in the schools like physics, chemistry, and mathematics subjects. For example, engineers seek the optimum situation for the end product and need to compose and try a prototype or a computer based model before constructing the end product. They add variables and factors that should be taken into consideration. These variables and factors are obtained by searching the science under the phenomena they interested in. Then they work on their design by changing these variables. So, in the real life applications, science, technology, engineering, and mathematics cannot be separated from each other.

As seen in the examples and definitions of STEM areas, all areas are fed by the use of reason and inquiry for problem solving and require great effort for the work (Read, 2013) and also all of them are open to innovation. To innovate, there is a need for collaboration and integration in STEM areas. “Innovation is also rarely occurs in isolation; it is a highly interactive and multidisciplinary process and increasingly involves collaboration by a growing and diverse network of stakeholders, institutions and users” (OECD, 2010, p.10). Therefore, it is important to be gained collaboration and integration skills in school years by the teachers who understand and value STEM (Brown, Brown, Reardon, and Merrill, 2011). The parallel natures of the science, technology, engineering and mathematics promotes the necessity of a learning environment that provides us with teaching and learning these areas holistically as STEM in real life (Rockland *et al*., 2010).

2.2. STEM Education

Roehrig and her colleagues (2012), state that the current problems in the rapidly globalizing and changing world are multidisciplinary and most of them need the integration of science, technology, engineering, and mathematics concepts to be solved (Wang *et al*., 2011). Besides, it can be said that today’s world has quite more

interactive relation with technology. Bybee (2000) remarks that there is little known about technology and engineering as a society. He argues that rather than being just a good computer user, to overcome this limited understanding of the technology and engineering, students should be provided with opportunities to learn about the processes of design, fundamental concepts of technology and engineering, and the limits and possibilities of technology in the society. While doing STEM, technology stands as dynamic study area that always takes effective part in other STEM areas and life. STEM education is considered to be one of the important solutions in satisfying the economic and social needs of 21st century workplace (Asunda, 2011). While the importance of integrated STEM education and the need for that are being emphasized, the compartmentalized system of STEM areas in schools has drawn the attention. The areas of STEM are intrinsically combined and they should be presented in this way in the schools (Byrne and Brodie, 2011; Breiner *et al*., 2012). It is a fact that the dynamics between education and social, cultural and economical factors are in circularity (Singh, 1991). For today's world, the interrelations between education and the needs of world emphasize the importance of STEM in education.

One of the main goals of education has always been to raise the individual as compatible with a vocation or a profession (Findley, 1956). On the other hand, Astrachan (1996) argues that theory and practice should be integrated throughout the curricula so that students learn the effects of real data and situations in daily life by working on them. In this sense, it is crucial to have the relations between different concepts and the counterparts of these concepts in daily life in the system of education. The situation of handling STEM integrally in schools may probably contribute the real life applications to be used in schools. Because, the aim of STEM in education is to educate the individual in educational system as a real life engineer or scientist by integrating STEM areas (Breiner *et al*., 2012). The days of memorizing the formulas and putting the numbers in them will no longer exist in this century (Read, 2013).

To begin with the events occurred in 20th century may be helpful in understanding the change in needs of this century. 20th century was indeed the century

of many technological developments and beginning of the information age. In this sense, 20th century is a transitional stage from industrial age to information age (Huitt, 2007). When the potentials and opportunities of the 20th century were considered, especially at the beginning of the 20th century, any information and knowledge is not as accessible as today. The computers that look most similar to today's computers had arisen at the third quarter of the 20th century and the Internet was limited to few computers. The widespread usage of the Internet began at the last quarter of the twentieth century. As a consequence of this and other increasing number of technological improvements in this area caused the time, which begins with 1990 and continues today to be named as information age. Information age has created a world that has different and unique needs than the needs of industrial age resulting from the advances in science and improvements in technology. In accordance with these needs, different occupations have emerged and the existing occupations' areas have become specialized or enlarged. For example, nanomechanics which represents pure combination of science, technology, engineering and mathematics investigates "mechanical properties of engineered and biological materials at the nano to macro-scale using experimental, analytical, computational techniques" (Massachusetts Institute of Technology, 2015, para. 1). There are many research areas like nanomechanics that need cooperation and integration of different fields of study. Accordingly, to be able make research and innovations in these areas there is a certain need for human resources that will serve this purpose.

Consequently, information age gave birth to the concept of 21st century skills. According to Partnership for 21st Century Skills (2015), these skills are defined in four categories: Content Knowledge and 21st Century Themes, Learning and Innovation Skills, Information, Media and Technology Skills, and Life and Career Skills. Some expected outcomes for students of 21st century are to be collaborative, to understand global issues which need literacy in different areas, to effectively participate in civic issues, to think and work creatively, to innovate, to access and evaluate information, to analyze media, and to apply technology effectively (Partnership for 21st Century Learning, 2015). In this sense, STEM education has became important in addressing the needs of 21st century learners. Knowing the question of what the formula about a

specific subject is not enough anymore. Students need to know why they use that specific formula, the relationships between the numbers and/or algebraic expressions in the formula and why this formula works. The more important skills which will survive in this century are: To be able to structure hypotheses; design and conduct an experiment; collect, analyze, and interpret the data; draw conclusions and justify them (Read, 2013). While performing these skills, communication and sharing with others are also crucial.

As a result of increasing information and knowledge in the 21st century, people have become in need of human collaboration more than in the past to compete both in small districts and in the global economy. According to Corlu *et al*. (2014), the knowledge, skills, and beliefs that are constructed by the collaborative work of at least two STEM areas are the products of STEM education. On the other hand, the employers' expectancies from STEM education are to raise students who are not only full of facts and basic skills; students who have ability to use their basic skills in work life (Casner-Lotto *et al*., 2006). Natural interaction between STEM areas and the importance of having 21st century skills led people to think about teaching the subjects of science, technology, engineering, and mathematics in an integrated manner. It is certainly getting more and more importance to be able to make science, technology, engineering, and mathematics than learning the facts of STEM areas for today's people and next generations. Therefore, STEM education has been taking an important role in the educational systems of nations.

However, STEM is not a simple acronym that every reader understands the same thing. STEM is a concept that interacts with people from different groups. Government officials who make investment for this enterprise, teachers who are the implementers of STEM education, parents who seek best education for their children, business people who spend money for their future benefits about STEM areas and students who are at the center of STEM education (Breiner *et al*., 2012). Therefore STEM education has different meanings for different groups of people. The definition of STEM and STEM education changes according to where you seek the answer (Breiner *et al*., 2012). Dugger (2010) defines STEM education as the integration of

science, technology, engineering, and mathematics into a new cross-disciplinary subject in schools. According to interview results done with experts in STEM education and teacher preparation, STEM education is often defined as "a new way to deliver content knowledge, an interdisciplinary approach that dissolves the boundaries between the four STEM disciplines and that relies on real-world, project based learning." (Read, 2013, p.7) In this sense, Sanders (2009) argues that STEM is not new topic while STEM education has caught great attention lately. STEM education is the integration of science, technology, engineering, and mathematics curricula to raise the individual in the educational system as close as the real life engineer or scientist (Breiner *et al*., 2012) However, Merrill (2009) defined STEM education as "a standards-based, meta-discipline residing at the school level where all teachers, especially science, technology, engineering, and mathematics (STEM) teachers, teach an integrated approach to teaching and learning, where discipline-specific content is not divided, but addressed and treated as one dynamic, fluid study." (As cited in Brown, 2011, p.6). It is seen that there are some emergent common issues in the definitions of STEM education from the educational perspective: integration of the areas of STEM, collaboration in STEM areas, and the importance of real life applications of STEM.

So, students are expected to have a chance to understand the integrated world we live in with the gains of STEM education rather than learning about the parts and pieces of it as a collection of knowledge and practices (Dugger, 2010). The first aim should be to create awareness of STEM to make students willing to learn about the STEM disciplines rather than having to learn about these subjects (Read, 2013). It is believed that STEM education can contribute a person more than the ability to relate the curricula and real life. Also, STEM education is considered to gain students increased problem solving skills, critical thinking, and analytical thinking (Brown *et al*., 2011). On the way of gaining those skills, STEM educators emphasize the needs for the replacement of lecture based teaching methods with more inquiry and project-based approaches (Breiner *et al*., 2012).

2.3. STEM Education Practices

The importance of STEM education has increased in recent years. Basically, it has been a fundamental agenda topic because of the economical and political needs. Hence, the policy of education has been affected by these needs. STEM education is firstly appeared in the United States by highlighting some issues. For example, the Committee on Prospering in the Global Economy of the 21st Century of America (2007, p.254) published Rising above the Gathering Storm, which is an indicator of the importance of the STEM skills. In here, American national objectives were stated as:

(i) Lay a foundation for a workforce that is capable in science, technology, engineering, and mathematics (STEM)—including those who can create, support, and sustain innovation.
(ii) Develop a society that embraces STEM literacy.
(iii) Develop and sustain K–12 teacher corps capable of and motivated to teach science and mathematics.
(iv) Establish meaningful measures.

The national goals explained above refer to the importance of STEM education in four aspects; economical, societal, educational, and political. This point of view emphasizes the significance of STEM education in the global world. Because it is not only related with education but also directly connected with the issues that are important for the nations that aim to fulfill the needs of 21st century and compete in the global market.

In parallel with this issue, the usage of the term STEM and the number of research in the area of STEM education have accelerated since 2001 (Breiner *et al*., 2012). Many research studies have been conducted related to STEM education involving both teacher education and K-12 education and there is indisputably more need for research in STEM education (Brown, 2012). Brown investigated the diversity of the recent STEM based research and concluded that the focus of the research is

intensively about the integrative STEM education by describing and analyzing the integrative activities and studies. According to this analysis of STEM research, most of the research comes from practitioners and clearly missing part of the STEM research was stated as large studies that aim to assess the effectiveness of integrative instructional methods on K12 students' performances.

As discussed in previous section, one of the main aims of STEM education is to increase the students' interest in STEM areas and to provide students with pursuing the STEM related careers in the long term. Another important issue is that STEM education is considered to be rich in gaining students valuable skills and knowledge. To pursue true careers in life heavily depends on the true interactions with the elements of these careers in young ages (Magnuson and Starr, 2000). Therefore STEM education is also important in addressing the students who have interest and ability in science, technology, engineering, and mathematics. On the other hand, to be competitive in the 21st century, nations need an innovative STEM workforce (Corlu *et al*., 2014). Innovative STEM workforce may be better when it is constituted by the people who are educated in the way of STEM thinking and learning in young ages. Every student has their own way of thinking so it is important to give them the chance to find out themselves through STEM activities. A case study is conducted to see learning outcomes of STEM integration curricular module in a fifth grade science class. The researchers aimed to see the elements of engineering learning outcomes. Evidence of student learning outcomes for the key engineering components was found throughout student work and student interactions and varying levels of learning were exhibited by each group (Moore *et al*., 2014). On the other hand, Yamak *et al*. (2014), conducted an experimental research about the effects of STEM activities on scientific process skills and attitudes towards science. The results showed that the usage of STEM activities in 5th grade science class positively affected students' scientific process skills and attitudes towards science.

However, the issue of implementation of STEM education is vital to consider. In this sense, based on the all possible outcomes of integrated STEM education, it is crucial for teachers to learn how to effectively implement integrated STEM education

(Stohlmann *et al*., 2012). On the other hand, most K-12 teachers are not prepared to teach STEM areas integrally in their classes and therefore they are lack of experience to use their curriculum and materials for the actualization of STEM education (Rockland *et al*., 2010). To achieve the willingness and preparedness of teachers for teaching integrated STEM, their engagement with STEM areas and having experience in teaching and learning STEM activities are very important. There are initiatives for teachers to integrally experience STEM. For example, Southern Illinois University Edwardsville prepared 3 weeks informal summer program with the aim of addressing the need of STEM teaching experience of K-8 teachers. The program was realized in collaboration with STEM center of the university and attendant teacher candidates experienced inquiry based STEM activities with STEM professionals. According to the preliminary analysis of the research, science teaching efficacy of the candidate teachers and their interest in science increased (Bracey *et al*., 2013). Another research was done with 83 preservice science teachers Yıldırım and Altun (2015). They investigated the effects of STEM education and engineering applications on science laboratory course. In this experimental study, a statistically significant result was found between experimental and control groups. Experimental groups were better at improving their success as a result of STEM education and engineering applications.

To provide teachers or teacher candidates with experiencing STEM activities may be helpful for their awareness about STEM and STEM areas. According to Reeve (2015), to achieve the goals of STEM education, teachers should be STEM *thinkers* who are able to show their students the applications of STEM in their daily lives. In this sense, STEM thinking is defined as "purposely thinking about how STEM concepts, principles, and practices are connected to most of the products and systems we use in our daily lives" (Reeve, 2015, p.8). When teachers become STEM thinkers, they can promote their students' considering about benefits and integrity of STEM subjects in daily life so that students' interests in STEM areas increase.

Teachers are the bridges between curriculum planners and students. Their way of implementing curricula or any educational approach differ by their knowledge, beliefs, goals, experiences, perception of curriculum and students, and identity

(Remillard, 2005). Due to different characteristics and perceptions of teachers, there may be differences in implementation of STEM education. Stohlmann *et al*. (2012) carried a research on considerations for teaching integrated STEM education and concluded that teachers' content knowledge in integrated STEM education, the support of schools for the collaboration of teachers of STEM areas, and the materials that promote STEM education are crucial for effective STEM education. As seen in the research results, one of the important issues in STEM education is collaborative work of STEM teachers. However, to be able to aware of the collaboration between the STEM areas is a must for being a collaborator in STEM education. The study done with more than 200 teachers of STEM areas and administrators showed that 90% of the participants are not in collaboration with their colleagues from other STEM areas (Brown *et al*., 2011). Collaboration has a place in the nature of STEM hence the collaborative working environments and conditions should be provided with teachers of STEM areas. In this sense, to begin with the contents that have multidisciplinary natures can be more helpful to create participatory working environments for teachers and teachers, teachers and students, and students and students. To exemplify, Rockland *et al.* (2010), advise the usage of robotics in STEM education because of their relationship with areas of technology, computer science, engineering, mathematics and other sciences. In this sense, Şahin *et al*. (2015) conducted a research on the effects of after school STEM activities on students. One of the STEM activities was robotic science in this research. In this activity, students were expected to prepare their robot models and design and these models in collaboration with their friends. The results showed that students who were in collaboration with their friends stated that they complete each other, they learn from each other and so they improve together. Therefore it can be said that STEM activities provide students with learning from their peers and new skills. For example, they learn communication skills in collaborative environments.

Although the collaborative work of STEM has an important role in every part of our life, this collaboration may not be seen easily. It is because of the way of thinking of the people get accustomed to. A science teacher may be more prone to see the role of science in the perfume production process which was mentioned earlier in

literature review than the role of mathematics. And it is likely harder for both science teacher and mathematics teacher to express the role of engineering than the role of technology. However, among the areas of science, technology, engineering and mathematics, engineering is the least known about its nature and functionality by teachers. One of the reasons of this issue is the situation that most of teacher education programs don't offer engineering education classes. Similarly, students do not have chance to deal with engineering topics and processes in K-12 education (Rockland *et al*., 2010) and therefore teachers have not met with engineering concepts and practices both in their K-12 education and teacher education program. In this sense, engineering stands as a distant relative. A research conducted by Leonard Gelfand Center for Service Learning and Outreach at Carnegie Mellon University (2008) concluded that many K-12 teachers stated the "E" in the acronym STEM stands for education. To see the relationships between engineering and the other areas of STEM, the first thing to be done can be to begin with discovering the engineering design process. Rockland *et al*. (2010) express that engineering design process support teachers in teaching scientific inquiry because of the similarity of the natures and problem solving characteristics of these two areas. However, to be able to give place to engineering concepts by integrating with other three STEM areas needs teacher education in this area. It is important for teachers to know the alternatives that they can use in the way of bringing the STEM education in their classes and creating an integrated environment for science, technology, engineering and mathematics concepts. In Turkey, STEM project was applied in 2015 with the aim of introducing science teachers STEM activities so that they integrate these activities in their classes. Participants of the project attended 8 days program designed and presented by academicians who study STEM education. Before the program, participant teachers were mainly stating the relationships between STEM education and academic success but after the program they also expressed the relationship between STEM activities and creativity, problem solving, inquiry, technology usage skills, and positive attitudes towards science (Bütünleşik Öğretmenlik Projesi Öğretmen Bülteni, 2016).

Furthermore, to be able to implement STEM education, firstly the awareness and literacy of teachers should be considered as an important issue. Because without

awareness about STEM education and its benefits, teachers may not be eager to learn deeply about STEM and use it or do STEM in their classes. Also, STEM awareness of students may depend on their teachers' awareness and way of doing STEM. In a project which aims to increase awareness in STEM careers, at the beginning, most students remarked that they thought of scientists primarily as white males working alone in a lab, whose jobs are less creative and people-oriented than other careers (Kier *et al*., 2014). As time passed and their teacher provided them interaction with STEM, their misconceptions about STEM and STEM professionals decreased. So, it is probable that the increase in their awareness about STEM let them to learn more about areas of STEM. When the knowledge and skills to integrate STEM areas and make STEM is enabled, it can be said that STEM literacy can be achieved (Washington STEM Study Group, 2011). Therefore, students need true connections with STEM in the way of being STEM literate people and STEM awareness is an important catalyst for STEM literacy.

2.3.1. STEM Awareness and STEM Literacy

Literacy has always been an important subject for both society and individual. The importance of literacy has been emphasized as the wealth of information and the variety of information are increasing all over the world. The improvements, developments, and innovations in every area of life in the 21st century have encouraged or obliged people to have new literacy skills. For a 21st century individual, it is important to have literacy in different areas of life to understand the world he or she lives in.

Zollman (2012) states that being literate and literacy is two different things. For example, for this statement: "If the precautions and warnings about global warming are not taken into consideration, the Earth will be the second Venus." The question of what the earth will look like can be answered quickly however the question of why the Earth is looked like Venus needs literacy to be answered (Zollman, 2012). Actually, to answer the first question, being literate is enough however to answer the second one needs having literacy. Literacy is generally defined

as the ability to read and write. Nonetheless, literacy puts forward more skills and abilities than reading and writing (Zollman, 2012). OECD (2000) defines literacy as "the ability to understand and employ printed information in daily activities, at home, at work and in the community – to achieve one's goals, and to develop one's knowledge and potential" (p.10). In this sense OECD widens the meaning of literacy and also rather than saying that an individual has literacy or not, it categorizes literacy of people in different levels. According to National Council of Teachers of English (2008, para. 2), the 21st century readers and writers need to:

(i) Develop proficiency with the tools of technology,
(ii) Build relationships with others to pose and solve problems collaboratively and cross-culturally,
(iii) Design and share information for global communities to meet a variety of purposes,
(iv) Manage, analyze and synthesize multiple streams of simultaneous information,
(v) Create, critique, analyze, and evaluate multi-media texts,
(vi) Attend to the ethical responsibilities required by these complex environments.

These can be said as literacy skills that are aimed for 21st century individuals. When the meaning of skill is considered, it is seen that to have literacy in any areas of life needs education, training, and action besides the knowledge of these areas. Having literacy in one area is also beyond the having knowledge about this area. The combination of this knowledge and 21st century learners' skills affect the level of literacy a person possesses.

In similar way, as a consequence of developing society and changing world, STEM literacy have been an important issue as well as science literacy, technology literacy, mathematics literacy, and engineering literacy. STEM literacy has deeper context than the combination of separately defined literacy areas of science, technology, engineering, and mathematics just as in the STEM (Zollman, 2012). However, it is not possible to describe STEM literacy without giving precise literacy definitions related to the areas of STEM.

First of all, the 2015 Definition of Scientific Literacy for Programme for International Student Assessment (PISA) is

"Scientific Literacy is the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen. A scientifically literate person, therefore, is willing to engage in reasoned discourse about science and technology which requires the competencies to:

1. Explain phenomena scientifically:

• Recognize, offer and evaluate explanations for a range of natural and technological phenomena.

2. Evaluate and design scientific enquiry:

• Describe and appraise scientific investigations and propose ways of addressing questions scientifically.

3. Interpret data and evidence scientifically:

• Analyze and evaluate data, claims and arguments in a variety of representations and draw appropriate scientific conclusions." (p. 7).

So, as described above, having scientific literacy is similarly not only related with having the scientific knowledge. The ability to communicate through this knowledge is a requirement for to be scientifically literate person. The third competency which is about quantitative literacy needs basic mathematical skills. Secondly, International Technology and Engineering Educators Association (2007) defines technological literacy as the ability to use, manage, understand, and assess technology (As cited in Sneider, 2011, p. 31). Therefore, being a good technology user does not mean that technologically literacy is achieved. Besides using technology, to understand the technological principles, the science which underlies a specific technology is important.

Thirdly, the OECD (2003) describes engineering literacy "the ability to systematically and creatively apply scientific and mathematical principles to practical ends such as the design, manufacture, and operation of efficient and economical structures, machines, processes, and systems as the understanding of how technologies are developed via engineering design process" (As cited in Zollman, 2012, p. 14). However, because of the strong and inseparable relationships and connections

between technology and engineering, development committee of The National Assessment of Educational Progress of U.S. (NAEP, 2013) made a change in their technology literacy framework and brought technology and engineering literacy subjects together to understand the usage, effects and designing of technologies. So, according to NAEP, "Technology and engineering literacy is the capacity to use, understand, and evaluate technology as well as to understand technological principles and strategies needed to develop solutions and achieve goals" (p.1). Finally, mathematical literacy is an individual's capacity to identify, and understand, the role that mathematics plays in the world, to make well-founded judgments and to use and engage with mathematics in ways that meet the needs of that individual's life as a constructive, concerned, and reflective citizen (OECD, 2013).

The four literacy definitions have similarities and differences in general. Scientific literacy and mathematical literacy deal with creating reflective citizens. Technology and engineering literacy definitions are one within the other and both are nourished by science and mathematical literacies. These similarities and differences integrate and give STEM literacy more meaning than the sum of four. All of these literacy definitions have one goal in common: to understand the world and its elements by using the knowledge and skills of these areas. When today's world is considered, it is seen that today's people are facing with increasing number of advancements and innovations in every area particularly in STEM. So, to be able to understand today's world and its elements, literacy of four STEM areas and the integration of them are crucial.

The similarities and differences of the literacy concepts of STEM areas, STEM literacy definition has broader meaning. Zollman (2012) asserts that STEM literacy is the synergy of the four STEM areas. Nobel Laureate Physicist (1998) Leon Lederman defines "STEM literacy" as the ability to adapt to and accept changes driven by new technology work with others (often across borders), to anticipate the multilevel impacts of their actions, communicate complex ideas effectively to a variety of audiences, and perhaps most importantly, find measured yet creative solutions to problems which are today unimaginable (As cited in National Governors Association,

2007, p.3). Reeve (2015) states that STEM literacy is "being able to know, understand, use, and evaluate the STEM concepts, principles, practices, artifacts, and phenomena being studied" (p.10). STEM literacy also necessitates some basic skills which is intrinsic to STEM's nature. Because of the collaborative work between the STEM areas, STEM literacy needs collaboration skills. Just as the STEM areas' constitution of STEM by being integrated, STEM literacy is formed by the integration of the literacies in each areas of STEM.

All in all, to achieve STEM literacy there are some considerations. Zollman (2012) states that four main aspects should be taken into account by curriculum planners and implementers in creating STEM literate society: (i) STEM areas should not be separated from each other, there should be integrative curriculum for STEM areas; (ii) Content and pedagogy should be interlaced so that students deal with scientific questions rather than proving the scientific content; (iii) Students should be educated as value giving to STEM by considering their attitudes, beliefs, self-esteem, self-confidence, and motivation; (iv) there is a need for students to use STEM technologies efficiently.

Based on the literature, integration of STEM areas in educational context and creating STEM literate society is very important in this century. Creating STEM literate society begins with creating STEM literate teachers and educating students in this way in the schools. Especially STEM areas teachers' STEM awareness, STEM literacy, perceptions of STEM teaching STEM are of great value in taking true steps in implementation of STEM education. STEM is not a new concept but the importance of STEM education has accelerated in recent years (Sanders, 2009). Therefore, there are few instruments to measure the concepts, skills, and ideas which are related to STEM education. Above all, the components of perceptions, awareness, and literacy of STEM should be determined. Besides the translation of the Design/Engineering/Technology (DET) Instrument to Turkish, this study will mainly contribute to determine the components of STEM awareness and STEM literacy with the aim of contributing to the development of new strategies and tools for STEM Education.

3. SIGNIFICANCE OF THE STUDY

The world has rapidly changed as a result of the advancements in science and improvements in technology that occurred in recent years. To be able to succeed in the 21st century world, people need to have some skills. These skills that were developed by the insights and input of the teachers, experts in education and business people are information literacy, collaboration, communication, creativity and innovation, problem solving, and responsible citizenship (Partnership for 21st Century, 2015; Skills 21 at Education connection, 2015). The future prosperity of both nations and institutions depends on the innovations they achieve. According to National Academy of Sciences, National Academy of Engineering, and Institute of Medicine (2005), the driver of the future economy will be the innovation and the jobs in the 21st century will be derived from the advances in science and engineering. Building connections between people and the organization, integration of new, different perspectives and other social interactions are important in fostering innovation (Knoll Workplace Research, 2013). Therefore, one of the goals of educational systems has become to raise innovative individuals. The way of achieving this goal needs educating people according to the needs of digital age. The age we are in is driven by science, technology, engineering, and mathematics. When the 21st century skills and the knowledge of science, technology, engineering, and mathematics were intertwined, STEM education exists. So, for today's people it has become very important to take the knowledge of science, technology, engineering, and mathematics integrated so that the skills of collaboration, communication, integration of different perspectives and awareness and literacy in every area can be achieved. Therefore, each STEM area should have equal importance because only at that time an exact integral STEM education can be achieved.

However, among the areas of STEM, engineering is the least known by the teachers. It is because of the curricular programs of teacher educations and K-12 education. Most of the teacher education programs do not provide engineering

education in their curriculum and they wouldn't have chance to deal with engineering topics and processes in their K-12 education (Rockland *et al*., 2010). A research conducted by Leonard Gelfand Center for Service Learning and Outreach at Carnegie Mellon University (2008) revealed the deficiency of understanding of the acronym STEM. Many K-12 teachers stated the "E" in the acronym stands for education. In Turkey's educational context, engineering education does take place neither in K-12 education nor in teacher education programs of STEM related areas. So, the concepts related to engineering are hard to be described or integrated by teachers who want to do STEM in their classes. Therefore, the current research is important in presenting the preservice teachers perceptions on each STEM area both individually and integrally through STEM related daily topics.

Students' having deep knowledge in the areas of STEM, their ability and motivation to use them in their daily life requires STEM education. However, it can be truly achieved when it is truly understood by the people who deal with STEM and teachers who are implementers of STEM education. Firstly, to understand what STEM is very important. Understanding STEM depends heavily on understanding each area of STEM. The way of understanding the areas of STEM needs inquiring about the similarities, differences and common parts of science, technology, engineering, and mathematics. To be aware of what STEM means is to be aware of the relationships between STEM areas. This awareness should show itself both in theory and in practice. Namely, it is important for implementers of STEM education to have both knowledge of STEM areas and the applications of STEM in daily life. In this sense, the study focused on how participants defined each STEM area to examine the "knowledge component" of STEM awareness and also it was investigated that how participants describe each STEM area through STEM related daily topics for examining "experience component" of STEM awareness.

4. STATEMENT OF THE PROBLEM

This study aims to describe preservice freshman and senior mathematics, chemistry, physics, science and technology, and computer education and educational technology teachers' STEM awareness, their definitions of individual STEM areas, and perceptions of relationships between STEM areas through STEM related cases. Therefore this study aims to investigate the following questions:

4.1. Variables

There are four variables of this study that are relationships in STEM definitions, relationships in STEM cases, relationships in both STEM definitions and cases, and status. The definitions of these variables are as follows:

(i) Relationships in STEM definitions (STEM-DR): This variable addresses participants' statements about relationships between STEM areas while defining individual STEM areas. It was measured by the first section of STEM Awareness Open-Ended Questionnaire.

(ii) Relationships in STEM cases (STEM-CR): This variable addresses participants' statements about relationships between STEM areas while describing individual STEM areas in STEM related cases. It was measured by the second section of STEM Awareness Open-Ended Questionnaire.

(iii) Relationships in both STEM definitions and cases (STEM-DCR): This variable addresses participants' statements about relationships between STEM areas while defining and describing individual STEM areas. It was measured by STEM Awareness Open-Ended Questionnaire.

(iv) Status: This variable indicates the participants' year of study at university. There are two different categories for this variable; freshman who is in the first year of department and senior who is in the last year of department.

4.2. Research Questions

(i) What are the *definitions* given by freshman and senior students of primary school science and mathematics teaching, secondary school chemistry, physics and mathematics teaching, and educational technology department on the individual STEM areas as measured by STEM-A Open-Ended Questionnaire?

(ii) What are the *perceptions* of freshman and senior students of primary school science and mathematics teaching, secondary school chemistry, physics and mathematics teaching, and educational technology department on the individual STEM areas in given STEM related cases areas as measured by STEM-A Open-Ended Questionnaire?

(iii) Is there any significant difference between STEM-DR of freshman and senior students of primary school science and mathematics teaching, secondary school chemistry, physics and mathematics teaching, and educational technology department?

(iv) Is there any significant difference between STEM-CR of freshman and senior students of primary school science and mathematics teaching, secondary school chemistry, physics and mathematics teaching, and educational technology department?

(v) Is there any significant difference between STEM-DCR of freshman and senior students of primary school science and mathematics teaching, secondary school chemistry, physics and mathematics teaching, and educational technology department?

(vi) How do participants who defined and described at least one individual STEM area in terms of relationships between STEM areas through all sections of STEM-A open-ended questionnaire describe the relationships between STEM areas as investigated by STEM-A semi-structured interviews?

5. METHODS

This section describes the design, participants of the study, selection of the sample, data collection instruments, and data collection and analysis procedures.

5.1. Research Design

The aim of this study is twofold; to describe STEM awareness of participants (preservice teachers of STEM related teaching programs) through examining how participants of the study perceive STEM areas, and to investigate how selected participants (high score on relationship between areas) perceive the relationships between STEM areas.

In this study, both quantitative and qualitative methods were used. Therefore, mixed methods research design procedures were followed in the research. The aim of using both quantitative and qualitative methods is to obtain deeeper understanding of the research questions from different ways. According to Cresswell (2011), mixed methods research design uses both quantitative and qualitative forms of data to understand research problem in detail. Mixed methods research provides opportunity to investigate the research problems by integrating characteristics of qualitative and quantitative research methods. Quantitative research methods are used to describe a trend or to discover the differences or relationships among variables while qualitative research methods aim to give in depth information about the phenomena under study (Cresswell, 2011).

There are different types of mixed methods research design. In this study, convergent parallel design was used. In convergent parallel design, the researcher separately collects quantitative and qualitative data and then makes separate analysis of these data with the aim of merging the results of quantitative and qualitative data analysis (Cresswell, 2015).

5.2. Sampling and Participants

The target population of this study is all senior and freshman preservice teachers who are studying in Secondary School Science and Mathematics Education Department, Primary Education Department, and Computer Education and Educational Technology Department in Turkey. In here, preservice teachers who are studying in STEM related teacher education programs (Teaching biology, teaching chemistry, teaching physics, teaching science, teaching mathematics, teaching technology, and teaching engineering) were aimed to be the participants of the study. However, convenient sampling technique was used to select one university. So, the participants of this study were the senior and freshman preservice teachers who were studying in faculty of education of a mid-size public university in Istanbul. In faculty of education of this university, there are three programs in Secondary School Science and Mathematics Department: Physics Education (SPHYS), Chemistry Education (SCHEM), and Secondary Mathematics Education (SMATH). There are two programs in Primary School Department: Science Education (PSCIENCE) and Primary Mathematics Education (PMATH). There is one program in Computer Education and Educational Technology Department: Computer Education and Educational Technology (CET). Since Biology Education and Engineering Education programs weren't taught in this university, preservice teachers who study in these departments couldn't take part in this study.

The aim of choosing only freshman and senior preservice teachers was to investigate the possible difference of paticipants' perceptions about relationships between STEM areas both in definitions and in cases. Because, freshman students were in first term of their university education and they haven't completed any departmental course yet during this study. On the other hand, senior students completed most of their departmental courses related to their teaching programs. They were in their last year of university education and they will be teachers in a very short term.

In this university, the language of education is English. All students of the university study one year preparation program. Then, students take area courses from area specialists. All three departments take their common area courses like mathematics, physics, chemistry, and biology together with other departments of other faculties. For example, they took a mathematics course with students study in engineering, management, economy programs and so on. Besides, students of secondary school science and mathematics department take more area courses compared to students of primary school department. Lastly, computer education and educational technology department students take many courses from computer engineering department.

The data were collected in Fall 2015. The number of participants in the study was 204 preservice teachers. The numbers of participants for each program can be seen in Table 5.1.

Table 5.1. Number of participants.

Department	**SCED**			**PRED**		**CET**	**Total**
Program	SPHYS	SCHEM	SMATH	PSCIENCE	PMATH	CET	
Freshman	4	1	7	27	26	31	96
Senior	12	15	25	12	18	26	108

Even if the data were collected in all participants' required courses, the number of participants for SCED freshman is low, as seen in Table 5.1. There are two reasons for this situation: Firstly, the quotas of these departments (SPHYS, SCHEM, SMATH) are 21 for 2014-2015 academic years. Almost all students register to preparatory class. At the end of the year, language proficiency exam is taken. Students who couldn't pass the exam can't begin the first year of the program. So, this affects the freshman participant number. Secondly, Council of Higher Education in Turkey (Yüksek Öğretim Kurulu) didn't take new students to these departments in 2013-2014

academic years. Therefore, there were no freshman students who pass the proficiency exam and registered to first year of the program from 2013-2014 academic years.

According to the answers given to demographic information form, the gender distribution of participants is presented in below.

Table 5.2. Gender distributions according to department and status.

		CET	PMATH	PSCIENCE	SCHEM	SMATH	SPHYS	Total	
Female	Fr	14	19	21	1	7	4	66	139
	Sn	10	16	11	10	18	8	73	
Male	Fr	17	7	6	0	0	0	30	65
	Sn	16	2	1	5	7	4	35	
Total		57	44	39	16	32	16	204	

It is seen that the number of female participants was two times more than the number of male participants. The highest number of participants belonged to computer education and educational technology department. The lowest number of participants belonged to secondary school physics and chemistry education departments.

Participants were contacted through the required freshman and senior courses. Participants who registered to required courses of freshman year are freshman students and participants who registered to required courses of senior year are senior students. In this study, numbers of freshman and senior participants were close to each other. Figure 5.1 shows GPA (General Point Avarage) distributions of participants. The number of the participants in the research was 204 however there were 117 participants who stated their GPA. There were two reasons of not stating GPA; (i) Participants who registered to first semester didn’t have a GPA yet. (ii) There were participants who intentionally left blanked the GPA information. Among participants

who stated their GPA, there were 6 people (3%) who have GPA lower than 2,00. There was no participant who has GPA higher than 3,50.

All of these participants completed STEM Awareness Open Ended Questionnaire (STEM-A) and demographic information form. Some of the participants were interviewed for in-depth understanding of the research questions. The participants who will be interviewed were selected according to findings from the analysis of the STEM-A open-ended questionnaire.

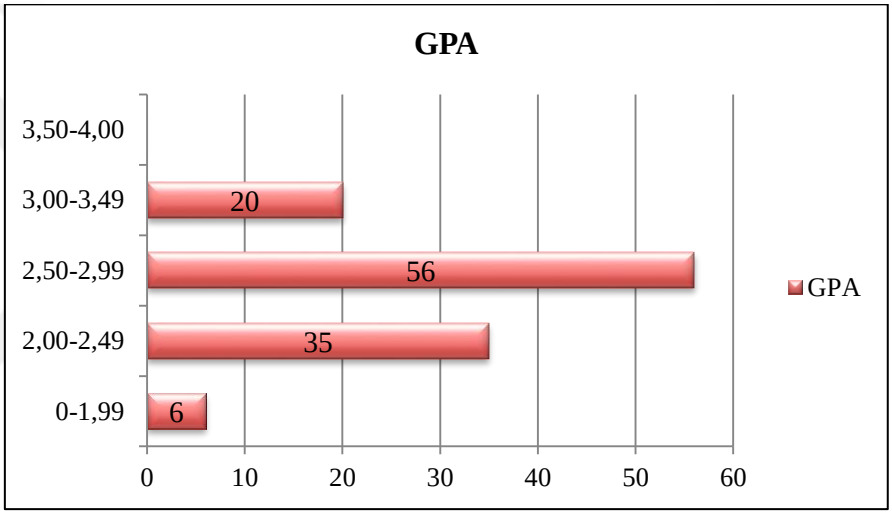

Figure 5.1. Number of participants in specific GPA ranges.

STEM-A open-ended questionnaire has two sections. In the first section of it, participants were asked to define science, technology, engineering, mathematics, and STEM education. In the second section, they were expected to read two different STEM related cases and answer the questions by defining how science, technology, engineering, and mathematics take place in the given cases. Also, there were questions about the relationships with any area other than STEM and teaching roles of participants. Therefore, the participants were selected to interviews according to analysis results of these questions. There were two steps in selecting participants. Firstly, the participants who answered the questions in STEM-A open-ended questionnaire by defining the relationships between the STEM areas were selected. In

here, it can be stated that 148 participants made their descriptions by using the relationships between the STEM areas while answering the STEM-A open ended questionnaire in at least one question of survey. There were 56 participants who didn't define any area in terms of relationships. However, the aim of the current research was to investigate perceptions of participants who describe at least one of the questions of each section and each STEM related case in terms of relationships between STEM areas. So, there was second step of selection of the participants for the interviews. The participants who had descriptions in terms of relationships between STEM areas in at least one question of each section and each STEM related case were determined as participants who will be interviewed. Table 5.3 describes the selection of the participants to the interviews. There were 16 participants who were suitable. One of them was male and 15 of them were female students. Seven interview participants were freshman and 9 interview participants were senior students and 4 of them SCED departments, 7 of them PRED departments, and 5 of them from CET departments.

Table 5.3. Selection of the participants to the interviews.

STEM-A Open-Ended Questionnaire	Section 1: Definition of STEM areas				Section 2a: Description of STEM areas in Case 1 (Microbiological Corrosion)				Section 2b: Description of STEM areas in Case 2 (Radioactive Verbs)			
Areas	S	T	E	M	S	T	E	M	S	T	E	M
Selection Criteria for Interviews	At least one STEM area should be defined by the participant in terms of relationship with other areas.				At least one STEM area should be described by the participant in terms of relationship with other areas.				At least one STEM area should be described by the participant in terms of relationship with other areas.			

5.3. Instruments

This study has two data collection instruments: I) STEM Awareness (STEM-A) Open-Ended Questionnaire including demographic information form II) STEM

Awareness Semi-Structured Interview Questions. In this research, STEM Awareness is defined as: *To know the integrative and collaborative natures of STEM areas, to perceive a situation or an experience that is related to STEM and encountered in present based on knowledge or experience*. In this sense, instruments included questions that aimed to examine participants' STEM awareness through two components (i) participants' knowledge of STEM areas and integrative and collaborative nature of STEM and (ii) their perceptions about STEM in a situation or an experience by using daily life STEM examples.

Both instruments include STEM related cases, which are based on daily topics. Firstly 7 STEM related daily topics were chosen and prepared by the researcher. Then, based on expert evaluation 4 of them were found appropriate for the instruments of the research. Among these four STEM related daily topics, 2 of them were selected for STEM-A Open-Ended Questionnaire and other 2 were selected for STEM-A semi-structured interviews. The details were presented below.

5.3.1. STEM Awareness (STEM-A) Open Ended Questionnaire

The aim of this instrument is to investigate the awareness of STEM and perceptions of science, technology, engineering and mathematics of all preservice teachers who participated in the study. It is an open-ended questionnaire. The language of the instrument is Turkish. STEM-A instrument has two sections; (i) Section 1 and (ii) Section 2. In the first section of the questionnaire, participants are asked to define STEM areas individually and their perceptions of STEM education. Second section of the instrument has two subsections; (i) Section 2a and (ii) Section 2b. In Section 2a, there is one STEM related case (Case 1: Microbiological Corrosion) and in Section 2b, there is another STEM related case (Case 2: Radioactive Verbs). The participants are expected to read the cases and answer the questions of how science, technology, engineering, and mathematics take place in these cases. Besides this, participants are asked to define whether there is any other area (different from STEM areas) that is related to given cases. Another question was about participants'

teacher roles. It was also aimed to be used for the selection of the participants to the interviews as mentioned in section 5.2.

STEM education has some characteristics in its nature. Even though different definitions of STEM education have taken place in the literature, two common points are observed in these definitions; having relationship with daily life and being interdisciplinary (Dugger, 2010; Breiner *et al*., 2012). So, in order to investigate participants' descriptions of STEM areas through the STEM related cases, these two issues were considered while choosing the topics of the cases. The topic should be addressed the participants and be made them speak about the issue without hesitation. Both cases were prepared based on the procedure, which is explained in detail below for Microbiology case. As a researcher, after making research on scientific journals and reading different topics related to STEM, 7 topics were determined to be possible topics for the instruments. These 7 STEM related topics were evaluated by area expert and researcher. 4 cases were determined by considering the issues of daily life relationship and the relationship between STEM areas. So, Microbiological Corrosion topic, which integrates all STEM areas, and Radioactive Verbs topic, which uses every STEM area for one goal, was chosen as the cases of STEM-A open-ended questionnaire. The sources of topics are scientific journal called Science and Technic (Bilim ve Teknik). The reading texts were made suitable for the research after some changes because the length of the reading text is important for making the readers' interest alive. So, for microbiological corrosion topic the adaptation was made from Science and Technic journal however for radioactive verbs topic the original source was found and it was used for adaptation. In adaptation, journals were examined again and again and very technical and detailed knowledge were excluded so as to create the content of the reading text concise.

An evaluation form that asks for whether the text and questions are appropriate for the aim of the questionnaire or not was prepared. The final version of STEM-A Open-Ended Questionnaire and the evaluation form were sent to experts in related areas via e-mail. In this sense, one academician from biology department whose interest area was microbiology, two academicians from teaching mathematics

department, one academician from teaching chemistry department, and one academician from teaching primary mathematics department were contacted and their opinions were taken into consideration. 4 of them have been studying STEM education in their research. Experts stated their opinions on STEM-A Open-Ended Questionnaire and some changes (Ex: A graphic was added to radioactive verb case) were made in STEM-A Open-Ended Questionnaire based on their evaluations and suggestions.

5.3.2. STEM Awareness Semi-Structured Interview Questions

The aim of this instrument is to investigate how preservice teachers conceptualize the areas of STEM and perceive the relationships between the STEM areas through cases written about STEM related daily topics. In other words, it is designed for gathering further data to answer the questions of how participants describe individual STEM areas and how STEM areas are integrated or differentiated by the participants through the cases. The focus of this instrument is to reveal how participants who already see the relationships between STEM areas described relationships between these areas. The language of the instrument is Turkish.

The cases, which were used for interview data, were chosen by considering the same criteria in forming the cases of STEM-A Open-Ended Questionnaire. The topics were determined according to having relationship with daily life and being interdisciplinary. After making research and reading different topics related to STEM, 3D Printers (Case 3) and Global Warming (Case 4) topics were chosen for interview data of the research. 3D printers are considered to be popular because of having different daily news about them in different times. Also, 3D printers have begun to take place in our education system or working area. In this sense, it was thought that the participants of the study might have been in interaction with 3D printers in their life. On the other hand, the issue of global warming is another popular and important topic of today's world. It was thought that every participant would feel comfortable about expressing his or her opinion in interview questions.

While forming the reading text about 3D printers, scientific journals were searched. The original article is a technical essay which was published by Turkish Engineer and Architecture Union Metallurgy Engineers (Türk Mimarlar ve Mühendisler Odası Birliği Metalurji Mühendisleri Odası). It is titled as "Producing Last Product and Prototype Quickly by 3D print (3D Baskı ile Hızlı Prototip ve Son Ürün Üretimi)" and 6 pages long. This article is reorganized by the researcher by cutting the technical information off and making it more daily life news. After reorganizing the 3D Printers essay, interview questions had been formed. The same procedures were followed for the second STEM related case in the interview.

The interview questions were prepared by considering the aim of interview (APPENDIX C). So, differently from STEM-A Open-Ended Questionnaire, STEM-A interview questions included questions, which intend to obtain answers related to relationship between STEM areas. There are 11 interview questions. The first question is for gathering demographic information about the participant, the second question is about their description and previous interaction with STEM and the third question asks about definitions of STEM areas. The rest 8 questions are specific to STEM related cases. After completing the final version of STEM-A interview protocol and its evaluation form, they were sent to experts to examine the content validity. Opinions and evaluations of six experts were taken into consideration. These experts are one teaching chemistry academician, one teaching science academician, two teaching mathematics academician, one teaching primary mathematics academician, and one physics academician whose interest area is climate change. 5 of experts are studying on STEM education in their research.

The pilot study was done for STEM-A Open-Ended Questionnaire in spring 2015. For the pilot study, purposeful qualitative sampling strategy was used to select participants. In consultation with the advisors of participants, 1 mathematics, 1 physics, and 1 chemistry preservice teachers were determined as the participants of the research. All three participants were in their last year of teacher education programs. In this pilot study, all four STEM related cases (Microbiological Corrosion, Radioactive Verbs, 3D Printers, and Night Flies) were used in interviews. It was

experienced that when all the cases were used in interviews, the time for the completion of the interviews was approximately 60-70 minutes. This time was considered to be long because the interviewee could be distracted or may not want to speak nearly one hour. So, it was decided to use two of the cases in STEM-A Open-Ended Questionnaire. Also, STEM-A semi-structured interview questions were revised after the pilot study.

5.4. Data Collection

The data were collected in two phases. In the first phase, all participants were given STEM-A Open-Ended Questionnaire and demographic information form. In the second phase, 9 participants were chosen according to analysis results of STEM-A instrument by considering the criteria that was defined in section 5.2 for the individual interviews. Then, they were interviewed.

5.4.1. STEM Awareness (STEM-A) Open Ended Questionnaire and Demographic Information Form

The instruments were given to preservice teachers who are in STEM related teaching programs (5 programs) and enrolled their last year's and first year's obligatory courses. All participants were asked for their voluntary participation in the study before data collection. The STEM-A instrument and demographic form were given to participants described above in their first semester courses in 2015 – 2016 academic year. The researcher got in contact with instructors of these courses to take permission for the implementation of the data collection instruments.

The STEM-A Open-Ended Questionnaire and demographic information form were administered to participants in their obligatory courses of their programs. Firstly, demographic information form was given to participants, and soon after STEM Awareness Open Ended Questionnaire (STEM-A) was administered. The time for the completion of these data collection instruments was approximately 30 minutes. There were 240 preservice teachers who completed STEM-A instrument. The data that had

missing parts (Ex: no answer throughout a section), missing ID number or irrelevant answers (Ex: I couldn't write more because I have an exam.) were removed. After removing such data, there were 204 preservice teachers' STEM-A data to be analyzed.

5.4.2. STEM Awareness Semi-Structured Interviews

After analyzing the results of STEM-A instrument, participants who answered the questions of STEM-A by describing the relationships between the STEM areas were chosen for the individual interviews. There were 16 participants chosen for individual interviews. All of them were informed about the second phase of the data collection and STEM-A instrument via e-mail. They were also asked for their voluntary participation. In this process, 13 participants were contacted and 9 of them expressed their voluntary participation. Even though second e-mail was sent to other 3 participants, the contact couldn't be provided with them. The interviews with 9 participants were completed within one week. The average completion time for the interviews was 35 minutes.

5.5. Data Analysis

In this section, data analysis procedures of both STEM-A Open-Ended Questionnaire and STEM-A semi-structured interviews were presented.

5.5.1. STEM Awareness Open Ended Questionnaire (STEM-A) Analysis and Demographic Information Form

204 participants filled STEM Awareness Open Ended Questionnaire (STEM-A) and Demographic Information Form. The analysis of STEM-A Open-Ended Questionnaire was made section by section. Firstly, the first sections of 204 data were open coded, and then the second sections and its parts. In a certain section, firstly all participants' papers' first questions were open coded and it was completed in this way. So, in the analysis of STEM-A, thematic analysis was used to quantify student answers. Primarily, the data were coded and then similar codes were gathered together

and themes were appeared. For only the first section of STEM-A instrument which participants were asked to define science, technology, engineering, mathematics, the themes were obtained from the definitions of these concepts in the literature (American Association for the Advancement of Science (AAAS), 1990; National Research Council of (U.S.), 1989, p.31; Science Council of UK, 2009, para. 1; Ministry of National Education (MoNE), 2005; AAAS, 1990; Project Lead the Way, 2011; Encyclopedia Britannica, 2014, para.1; ABET, 2015). However, in case of not being able to code student answers according to themes came from the definitions in the literature, those answers were coded as a new code. The themes appeared from the literature for the area of science are "function", "nature", and "method". "Relationship" and "PCB (Physics, chemistry, biology)" themes came from research data. All themes of technology came from literature. They are "process", "who make technology", "function", "relationship". Engineering has 3 themes from literature and 1 theme from research data. 3 themes that came from literature are "process", "function", and "relationship". 1 theme that came from research data is "product". For the area of mathematics, all 4 themes came from the literature; "nature", "method", "skills", and "relationship". Also, there is one theme that existed in the literature but didn't emerge in research data. The theme "who makes technology" for the area of technology is like that. To inform the reader more about the analysis, the themes, their explanations, and examples of participants' answers for science, technology, engineering, and mathematics areas were given in following tables.

The second section of STEM-A open-ended questionnaire includes two different STEM related cases. Case 1 is microbiological corrosion and case 2 is radioactive verbs. Participants were expected to read the case and answer two questions. The first question asks about how science, technology, engineering, and mathematics take place in this case and the second question asks for whether there is any other area different from STEM areas which is related to the given case or not. For the first question, the analyses were individually made for each STEM areas. Table 5.8 shows the themes existed in the analysis of the first question of Case 1: Microbiological Corrosion.

Table 5.4. Themes for area of science and participant examples.

STEM Areas	Themes	Definitions of Themes	Examples from Participants' Answers
Science	Nature	Properties related to nature of science.	Freshman SMAT03: "*Experiment.*" Senior SPHYS05 "*Basic, observable, objective science.*"
	Function	Function or goal of science.	Senior CET03: "*The branch of science that helps us to explain incidents and facts happen in nature.*" Freshman PSCIENCE20: "*Understanding and facilitating life.*"
	Method	Scientific methodology	Senior CET10: "*Investigation of findings that are obtained from the results of observations.*" Freshman PMATH17: "*Profession that tries to explain natural events in a logical framework.*"
	Relationship	Relationship between science and other STEM areas.	Freshman CET21: "*A branch of science that enables us to step into new age and is friend with mathematics.*" Senior SCHEM02: "*Development of technology, discovery of the new things.*"
	PCB (Physics-Chemistry-Biology.)	Defines science as Physics-Chemistry-Biology.	Freshman PMATH06: "*Science is collected under the three branches of science; chemistry, physics, and biology.*" Senior SMATH14: "*Chemistry, physics, and biology areas.*"

In the second part of last section of the STEM-A open-ended questionnaire, second STEM related case was presented to participants. It was titled as "Radioactive

Verbs". It was analyzed like Case 3. Table 5.9 shows the themes existed in the analysis of this case.

Table 5.5. Themes for area of technology and participant examples.

STEM Areas	Themes	Definitions of Themes	Examples from Participants' Answers
Technology	Process	Defines process and what technology contains.	Freshman CET29: "*It states development and innovation.*" Freshman CET15: "*Computer, and information technologies.*"
	Function	Function or goal of technology.	Senior PSCIENCE10: "*Making human's life easier and more practical.*" Freshman PSCIENCE12: "*Effort that is made for more useful life.*"
	Who makes Technology	Defines who makes technology.	* Participant answers didn't refer to this theme.
	Relationship	Relationship between technology and other STEM areas.	Senior SPHYS12: "*It is both a product of science, and a contributor to development of science.*" Senior SMATH23: "*It is a working area that integrates scientific findings to daily life and uncovers applications of science.*"

For the themes for perception about STEM education, the answers were open coded, and themes were appeared from data. Firstly, participants were asked about whether they knew about STEM education or not. They were asked to state yes or no. Secondly, if they knew they were asked about what STEM education is, and if they didn't not know, they were asked about what STEM education could be. There were 50 participants who said yes and there were 130 participants who stated she or he didn't know STEM education. In here, five themes were emerged. These are relationship between areas, integrity of areas, collaboration of areas, real life

relationship, disjunction of areas. Table 5.10 shows participant examples for these themes.

Table 5.6. Themes for area of engineering and participant examples.

STEM Areas	Themes	Definitions of Themes	Examples from Participants' Answers
Engineering	Function	Function or goal of engineering.	Freshman PSCIENCE20: "*A branch of science that applies science and technology and makes tools that ease our life.*" Senior PMATH02: "*Building some things*"
	Process	Defines how engineering is made.	Freshman PSCIENCE18: "*Skills that include planning, designing, making technological tools.*" Senior SPHYS02: "*Engineering is doing research and development by using science and technology.*"
	Relationship	Relationship between engineering and other STEM areas.	Senior PSCIENCE06: "*To develop, produce, or fix some things by synthesizing science, technology and mathematics.*" Freshman CET14: "*An occupation that creates a work by using the knowledge gained by mathematics, technology and other branches of science."*
	Product	Engineering is only defined by its products.	Senior PMATH01: "*Machine. Production.*" Freshman PMATH07: "*Electric, electronic. Computer*."

5.5.2. STEM Awareness Interview Analysis

STEM-A open-ended interview consists of two sections as STEM-A open-ended questionnaire. In the first section of the interview, participants are asked about their basic demographic information like name-surname, department name, years studied in the university. Even though these data were got in STEM-A questionnaire, they were asked again to make the participant comfortable about the interview. The second section of the STEM-A interview includes two STEM related cases. Case 3 is 3D printers and case 4 is global warming. 9 participants were interviewed. The average time for the completion of the interviews was 35 minutes.

Table 5.7. Themes for area of mathematics and participant examples.

STEM Areas	Themes	Definitions of Themes	Examples from Participants' Answers
Mathematics	Nature	Properties related to nature of mathematics	Senior CET02: "*Mathematics is always in everywhere. It is the meaning of science, technology, engineering, and life.*" Senior SCHEM12: "*Calculations.*"
	Skill	Mathematical skills.	Senior PMATH17: "*Mathematics is the art of thinking logically for me.*" Senior SMATH04: "*Mathematics is for improving logic and thinking level*."
	Method	Mathematical methods.	Freshman SMATH04: "*Proving.*" Senior CET11: "*Mathematics is like evidentiary explanation of existence and different situations of very interesting things in space for me.*"
	Relationship	Relationship between mathematics and other STEM areas.	Senior PSCIENCE05: "*Engineers make their designs by using mathematics. Science people make observations by using mathematics.*" Freshman SPHYS01: "*It is the language of science. It is important to use mathematics in proving chemistry, physics and everything. We couldn't prove physics laws without mathematics.*"

After all interviews were completed, they were transcribed by using Transcription Software. All of the participants were assigned a pseudo name because of the ethical considerations. When all of the transcriptions were finalized, they were read several times. Thematic analysis, a way of pattern recognition within the data, which allows for existing themes to reveal the categories for analysis was used (Fereday and Muir-Cochrane, 2006). As a result of thematic analysis themes were existed in two categories for each case. The first category is about individual STEM areas and the second is about relationship between these areas.

Table 5.8. Themes existed in STEM case 1: Microbiological corrosion.

	Themes	Definition of Themes	Examples from Participants' Answers
Science	Content	Scientific terms that are mentioned in reading text are emphasized.	Freshman PMATH22: "*Chemical and electrochemical reactions mentioned in the definition of corrosion.*"
	Explanation	It is stated that science has a role in explaining the case scientifically or making it clearer to readers.	Senior CET03: "*The definition of corrosion was made and the things that corrosion caused were revealed by science. The difference of microbiological corrosion is understood by science*."
	Investigation	It is stated that science has the role of investigating such a subject.	Senior SCHEM02: "*Understanding that corrosion is a world wide problem and making research to prevent it.*"
Technology	General technology	Technology is discussed superficial or exemplified by a product.	Senior CET20: "*Technology is used in calculating statistical information given in the text.*"
	Technology for research	Technology that is considered to be used in searching the issues related to case	Freshman PMATH11: "*It* helped to reveal realistic results in shorter time while doing research."
	Relationship	Technology is explained by using the relationship between other STEM areas or products.	Senior CET23: "*It can be stated that technology is merged with science to give ideas to people in solving problems in life.*"
Engineering	Engineering --Products	It is stated by man-made structures-products or specific engineering area such as chemical engineering.	Senior PMATH04: "*Natural gas pipelines, bridges, constructions, and automobiles are the products of engineering*."
	Function	The function of engineering is stated.	Senior SCHEM07: "*To provide durability*."
	Process	How engineering is done is stated.	Senior SCHEM07: "*Preparing projects by considering the effects of corrosion*."
	Relationship	Engineering is explained by using the relationship between other STEM areas or products.	Senior CET19: "*According to me, the relationships and inferences that are expressed by using science and technology in the reading text should be under the engineering*."
Mathematics	Nature	Mathematics is stated as concepts related to its nature such as calculations, numbers, and statistical data.	Senior SPHYS08: "*Values, percentages, and calculations*."
	Skill	The mathematical skills like data analysis, interpretation, and synthesis are expressed in defining mathematics in the case.	Senior PSCIENCE02: "*Data analysis*."
	Relationship	Mathematics is explained by using the relationship between other STEM areas or products.	Senior SPHYS01: "*Measuring the loss of microbiological corrosion, planning the necessary technology, and obtaining the statistical results*."

Table 5.9. Themes existed in STEM case 2: Radioactive verbs.

	Themes	Definitions of Themes	Examples from Participants' Answers
Science	Content	Science concepts and terms, which are a part of science curriculum, are stated.	Freshman SMATH02: "*Particle physics, half life*."
	Explanation	It is stated as science has a role in understanding the case.	Senior CET19: "*Actually, a chemistry subject is given as an example to better explain the issue that is related to our daily life language. If particles were not explained, I couldn't make of the half life of words*."
	Association	The association of science and linguistics were stated.	Senior PSCIENCE04: "*Verbs were associated with a physics subject that is named as particle physics*."
Technology	General Technology	Things related to technology but superficial and general are stated.	Freshman PMATH17: "*TV era.*"
	Process	Technology that is used in research in the case.	Freshman CET29: "*Technology is used to get some statistical information*."
	Relationship	Technology is explained by describing the relationship between other STEM areas.	Senior CET11: "*Technology can be said as all of this research. Finding solution to the given problem and using the scientific knowledge are technology*."
Engineering	Superficial Engineering	It is stated as engineering names or very superficial explanations related to engineering in the case.	Freshman CET24: "*Physics engineering that investigates subatomic particles.*"
	Skills	Engineering skills like modeling, predicting, problem solving and etc. are stated.	Senior SCHEM09: "*Interpretation of data needs engineering skills*."
	Relationship	Engineering is explained by describing the relationship between other STEM areas.	Senior CET13: "*Integrating physics and linguistics is the engineering that mathematician achieve.* "
Mathematics	Nature	Mathematics is stated as concepts related to its nature such as calculations, numbers, and statistical data.	Freshman CET30: " *Calculating the half life time*."
	Skills	The mathematical skills like data analysis, interpretation, and synthesis are expressed in defining mathematics in the case.	Senior CET21: " *Calculating the time of transforming verbs into regular form by developing formulas*."
	Relationship	Mathematics is explained by using the relationship between other STEM areas or products.	Senior SPHYS01: " *Mathematical association of half life time and language use*."

Table 5.10. Themes and participant examples related to STEM education.

Themes	Examples from Participants' Answers
Relationship Between Areas	Senior SPHYS4: "Presenting these four areas with their relationships rather than explaining them separately."
Integrity of Areas	Senior SMATH15: "Integrating science technology engineering and mathematics areas while teaching them in schools."
Collaboration of Areas	Senior SPHYS01: "It is an area that science, technology, engineering, and mathematics collaborate."
Real Life Relationship	Senior SPHYS09: "It seems to me that it is like a Project that tries to produce solutions to problems we encounter in our daily lives."
Disjunction of Areas	Freshman PMATH03: "Educational system that includes only natural sciences."

5.5.2.1. Analysis for Individual STEM Areas. Case 3 (3D Printers) and Case 4 (Night Flies) were analyzed integrally and themes were existed for individual STEM areas from data came from two cases. There were four themes for each STEM area; (i) Content, (ii) Skills/Expectations, (iii) Direction, and (iv) Nature. Content theme describes the terms that participants used to explain science, technology, engineering, and mathematics areas. These terms were specific to areas. The second theme is skills/expectations. It states expectations from the area or skills of the specialists who work in the STEM areas. Direction theme refers to explanations that specific STEM area or areas were considered to be a base for another area(s). The last theme for individual areas is nature and it means that there are statements about the nature of the areas. Table 5.11 includes participant examples related to these four themes.

5.5.2.2. Analysis for Relationships between the STEM Areas. There existed four themes in the analysis for the relationship between STEM areas. These are definition of relationship, direction, skills, and nature. To begin with definition of relationship, it can be stated that participants directly referred to the relationship between STEM areas. They stated how this relationship was and there existed four types of relationship. In plain relationship, participants only stated there was a double, trio, or quart relationship. Working together means that participants emphasized STEM areas' collaboration with each other. Dependence describes how STEM areas were dependent to each other. In this sense, participant answers emerged three types of dependence; (i) Cyclic, (ii) Chain, and (iii) Mutual. Finally, position theme refers to how STEM areas were positioning to each other. It included three types of position; (i) Inclusion, (ii) Intertwined, and (iii) Identity. Table 5.12 presents participant examples for these themes.

Table 5.11. Participant examples of themes of individual STEM areas.

	Themes			
	Content	**Skills / Expectations**	**Direction**	**Nature**
Science	Freshman PSCIENCE 09/Case 3: "*Science is defining matters.*" Senior CET16/Case 4: "*Global warming*."	Freshman PSCIENCE 09/Case 3: "*Scientist knows the properties of materials.*" Senior SPHYS04/Case 4: "*To see the effects by scientific research*."	Senior SPHYS04/Case 3: "The thing that consists of the models created by science is technology." Senior CET16/Case4: "*Engineers benefit from the feedbacks of scientists' research*."	Senior SPHYS04/Case 3: "Science is the modeling of the real world." Senior SPHYS04/Case 4: "*Scientific research.*"
Technology	Senior CET19/Case 3: "*CAD program.*" Senior SPHYS04/Case 4: "*Plain.*"	Freshman PMATH05/Case 3: "*Developing the printer*." Freshman PSCIENCE/Case 4: "*Modeling the world during the technology production.*"	Senior SCHEM05/Case 3: "Technology is created by engineers." Senior SMATH18/Case 4: "*The negative effect of technology to the atmosphere.*"	Freshman PMATH05/Case 3: "*Facilitating the life.*" Freshman PMATH05/Case 4: "*Increasing the number of night flies makes people's life easier and they look technology positively*."
Engineering	Freshman PSCIENCE03/Case 3: "*Software*" Freshman PSCIENCE 09/Case 4: "*Plain*."	Senior CET16/Case 3: "*Using prototypes*." Senior CET19/Case 4: "*Making Calculations*."	Senior SPHYS04/Case 3: "*Engineering is the way of arriving technology*." Senior SCHEM05/Case 4: "*Engineering is producing technology.*"	Freshman PSCIENCE05/Case 3: "*Product wouldn't exist if it was not engineers.*" Senior CET19/Case 4:: "*Engineering is in everywhere from research to producing technology.*"
Mathematics	Senior CET16/Case 3: "*Numbers*." Freshman PSCIENCE09/Case 4: "*The heating and cooling degrees of air*."	Senior CET19/Case 3: "*To develop algorithms*." Senior SCHEM05/Case 4: "*Interpreting the findings*."	Freshman PSCIENCE18/Case 3: "*A mathematician helps engineers in complex computations.*" Senior CET19/Case 4: "*Mathematics is the mother of engineering*."	Senior SMATH18/Case 3: "*Mathematics is the language of other sciences*." Senior SMATH18/Case 4: "*Mathematics naturally exists*."

Table 5.12. Participant examples of themes of relationship between STEM areas.

Themes		**Examples from Participants' Answers**
Definition of Relationship	Plain Relationship	Freshman PSCIENCE18: "There are duo-trio relationships between STEM areas."
	Working Together	Freshman PSCIENCE18: "Engineering and mathematics are in an organization for technology."
	Dependence	Senior CET19: "STEM areas are dependent to each other."
	Position	Senior CET16: "Engineering contains all other STEM areas."
Direction		Freshman PMATH05: "Engineer presents different ideas by using the ideas or materials that scientist develop."
Skills		Senior CET16: Physicians develop mathematical models."
Nature		Senior SMATH18: "Mathematics is a language that is used to explain other STEM areas."

6. RESULTS AND FINDINGS

In this section, results related to STEM-A Open-Ended Questionnaire and findings related to STEM-A semi-structured interviews were presented. STEM-A Open-Ended Questionnaire was applied to all participants (n=204) of the study. The data that came from STEM-A Open-Ended Questionnaire were open coded and then themes emerged. The themes were quantitatively presented. The numbers and percentages of themes related to STEM-A Open-Ended Questionnaire were explained. STEM-A semi-structured interviews were done with participants who explained relationship between STEM areas in all sections of STEM-A Open-Ended Questionnaire. There were 9 participants who were interviewed. STEM-A semi-structured interview data were also open coded and themes emerged. Finding related to these themes were qualitatively presented in the following sections.

6.1. Results Related to STEM-A Open-Ended Questionnaire

STEM-A open-ended questionnaire was applied to 204 participants. In the first section of it, participants were asked about their familiarity with engineers and engineering, their project experiences, their after school activities, and also they were asked to define science, technology, engineering, mathematics, and STEM education. In the second section of it, two different STEM related cases (Case 1: Microbiological Corrosion & Case 2: Radioactive Verbs) were given to participants and they were asked about how STEM areas took place in these cases, whether there was any other area different from STEM areas related to these cases, and the way how they would use these cases in their teaching. The results related to these questions will be discussed respectively in this section.

6.1.1. Results Related to Section 1 of the STEM-A Open-Ended Questionnaire

Firstly, the participants were asked about their familiarity with engineers. It was a question that they could mark more than one statement. Results showed that 56

(27%) of 204 participants have little or no idea about what an engineer does. Also, the most marked familiarity type was having a friend who is an engineer (n=165, 81%). Table 6.1 presents numbers of all given answers and their percentages.

Table 6.1. Participants' familiarity with engineers.

Familiarity with Engineers	**Number of participants**	**Percentage**
I am an engineer.	0	0%
My boy/girl friend is an engineer.	24	12%
I took some engineering courses.	36	18%
I have a friend who is an engineer.	165	81%
There is an engineer in my family.	79	39%
I had contact with engineers.	119	58%
I have little or no idea about what an engineer does.	56	27%
Other.	8	4%
None.	0	0%

The participants were asked about their experiences related to projects in STEM areas, STEM, and STEM education. In this question, it was expected to write their experiences in detail. To enable this, some guiding questions were also given place at the end of the question in a parenthesis. The aim of getting in detail answer was to understand whether the project was actually related to type of the project that participant reported. For example, 20 participants stated that their projects were about one of the STEM areas, however when their explanations were examined, it was seen that these projects included all parts of STEM and integration of these areas. So, these projects were evaluated according to explanations of the participants. The numbers and percentages of the participants who carried out a project or had a role in a project related to science, technology, engineering, mathematics, STEM, and STEM

education is in table 6.2. It should be stated that participants could state that they had more than one type of project.

Table 6.2. Numbers of the participants who participated in projects in STEM areas, STEM, or STEM education.

Project/working area	The number of the participants	Percentage
Science	8	4%
Technology	2	1%
Engineering	3	1,5%
Mathematics	7	3,5%
STEM	20	10%
STEM Education	16	9%
Other	1	0,5%
None	149	73%

In this table, when the profiles of the participants were considered, there is an outstanding result. 73% percent of the participants stated that they had no experience in projects related to science, technology, engineering, STEM, or STEM Education.

Also participants were asked about their after school activities. There existed 3 categories according to their answers in demographic form. Answers of the participants may include more than one category. For example, one of the participants may have teaching experience and have been attended trainings or seminars or another one could state that she or he preferred to do all type of after school activities. In this sense, the percentages of each category were calculated singularly. Among these categories, the percentage of having "Teaching Experience" is the least. Only 9% of all participants stated that they had taught before. The most experienced after school activity by these participants was "Voluntary Studies & Club Activities" (n=88, 43%).

Finally, participants were asked to define science, technology, engineering, mathematics, and STEM education in the first section of STEM-A open-ended questionnaire. For the definitions of STEM areas, definitions of science, technology, engineering, and mathematics, which is in the literature, were open coded and themes

Table 6.3. Numbers and percentages of participants according to types of after school activities.

Categories of After School Activities	The Numbers of Participants	Percentage
Teaching Experience	18	9%
Volunteer Studies & Club Activities	88	43%
Training & Seminar	42	21%
None	86	42%

were emerged for each STEM area. After this, answers of the participants were open coded and themes emerged. As well as themes of literature definitions and participants'answers were parallel to each other; there existed more or less themes for any STEM area. For example, for the area of technology, the definition of technology in the literature explains who makes technology. However, there is no participant who stated that. Besides this, it should be noted that, an answer of a participant could be coded with more than one theme. Because of that, the total number of codes for all the themes is more than the total number of participants. Table 6.4 shows the numbers of each theme.

On the other hand, some participants gave no answer or irrelevant answers to the questions in this part. The numbers and percentages of participants who gave no answer to definitions of STEM areas were 2% (n=5) for science, 4% (n=9) for technology, 5% (n=10) for engineering, and 5% (n=11) for the mathematics area. The numbers and percentages of participants who gave an irrelevant answer to definitions

of STEM areas were 9% (n=19) for science, 9% (n=19) for technology, 11% (n=23) for engineering, and 10% (n=21) for mathematics area.

Total number of codes emerged for each STEM area respectively are 203, 230, 250, and 206. As seen, the most number of codes existed in "Engineering" themes (n=250) and the least number of codes existed in "Science" theme (n=203). As seen in the table, area of science had 5 themes and other technology, engineering, and mathematics had four themes.

Table 6.4. Numbers and percentages of each theme for definition of STEM areas.

Area	Themes	Number of Participants	Percentage of Participants
Science	Function	102	50%
	Nature	46	23%
	Physics/Chemistry/Biology	40	20%
	Method	9	4%
	Relationship	6	3%
Technology	Function	102	50%
	Process	82	40%
	Who makes technology	0	0%
	Relationship	46	23%
Engineering	Function	83	41%
	Process	71	35%
	Product	9	4%
	Relationship	87	43%
Mathematics	Nature	130	64%
	Skill	14	7%
	Method	8	4%
	Relationship	54	26%

The common theme for each STEM area is “Relationship” theme. The remarkable result in here is that science has the least number of answers for relationship theme. Only answers of 9 participants refer to relationship with science and other STEM areas while defining science. On the other hand, Engineering has the most number of answers of the participants for the theme of relationship. 87 participants described engineering area by addressing the relationship with other STEM areas.

As seen in the table 6.4, 50% of the participants described science in terms of its function. Function is the most appeared theme in participants’ answers. However, only 3% of them explained about the relationship of science and other STEM areas. Relationship theme is the least appeared theme in definition of science.

On the other hand, 50% of participants described technology by giving place to functions of it. It is the most used theme in answers of participants. An interesting result in here is that even though definitions of technology in the literature state who makes technology, any participant didn’t explained about this in STEM-A open-ended questionnaire.

Engineering was described mostly by its relationship with other STEM areas. 43% of participants stated area of engineering by communicating through relations between engineering and other STEM areas. Therefore, when all STEM areas were considered, it was seen that science was the least described in terms of relationship and engineering was the most described in terms of relationship by research participants. Also, while defining engineering, it was seen that participants used products of engineering least for describing engineering.

Mathematics was mostly explained by elements related to its nature. It was seen that 64% of participants used concepts of nature of mathematics while describing it. On the other hand, the least emerged theme for mathematics was method. Only 4% of participants explained about the methods of mathematics.

At the end of first section, participants were asked about whether they heard STEM education before or not. 50 of them stated that they heard STEM education before and 130 of them stated that they didn't. Others didn't state anything. The analysis of this question posed five themes; (i) Relationship between Areas, (ii) Integrity of Areas, (iii) Collaboration of Areas, (iv) Real Life Relationship, and (v) Disjunction of Areas. The highest percentage is of Integrity of Areas theme (26%). Collaboration of areas has the lowest percentage (1%). Figure 6.5 shows all percentages related to STEM Education themes.

Table 6.5. Numbers and percentages of STEM education themes.

Themes	Number of Participants	Percentage of Participants
Relationship Between Areas	49	24%
Integrity of Areas	53	26%
Collaboration of Areas	1	0,5%
Real Life Relationship	7	3%
Disjunction of Areas	31	15%

6.1.2. Results Related to Section 2 of STEM-A Open-Ended Questionnaire

In the second section of STEM-A open-ended questionnaire, two different STEM related cases (Case 1: Microbiological Corrosion & Case 2: Radioactive Verbs) were presented to participants. They read the texts and answer the questions of how science, technology, engineering, and mathematics take place in the given cases, whether there was any other area different from STEM areas related to these cases, and the way how they would use these cases in their teaching. The results of each case will be shared separately in this section.

6.1.2.1. Results Related to Case 1: Microbiological Corrosion. In this part, each STEM area has its own themes, which emerged from data. Science has 3 themes (Content, Explanation, Investigation), Technology has 3 themes (General Technology, Technology for Research, Relationship), Engineering has 4 themes (Engineering/Products, Function, Process, Relationship), and Mathematics has 3 themes (Nature, Skills, Relationship). Table below shows the numbers and percentages of the themes for each STEM area.

According to results presented in Table 6.6, science was mostly discussed by participants by using the content of science. 50% of participants explained technology as technology used in research. 43% of them dealt with engineering processes in Microbiological Corrosion case while answering the question of how engineering takes place in this case. Finally, it can be said that most of the participants (89%), discussed mathematics in the case by using the elements of nature of mathematics.

Even though all of the cases emphasized the integration of STEM areas, there were some participants who stated that science, technology, engineering, or mathematics didn't take place in this case. Such a situation didn't occur for the area of science, that is to say, each participant somehow stated the role of science in Microbiological Corrosion case. 2% (n=4) of participants stated that there was no technology in the case, 1,5% (n=3) of participants stated the same thing for engineering, and 0,5% (n=1) of participant said that the case doesn't include mathematics. However, there were participants who stated no answer or an irrelevant answer for description of STEM areas in case 1. The numbers and percentages of participants who gave no answer to descriptions of STEM areas in microbiological corrosion case were 1% (n=2) for science, 14% (n=29) for technology, 16% (n=32) for engineering, and 5% (n=10) for mathematics area. The numbers and percentages of participants who gave an irrelevant answer to descriptions of STEM areas were 1% (n=2) for science, 3% (n=7) for technology, 2% (n=4) for engineering, and 0,5% (n=1) for mathematics area.

The participants were also asked whether Microbiological Corrosion Case has a relation with any other areas different from STEM areas. At the end of the analysis, their answers were categorized into two sections; (i) Areas related to social sciences and (ii) Areas related to STEM. Table 6.7 presents these areas and number of participant answers of them.

It is seen that 16 participants stated a relationship with STEM areas. However, they gave detailed answer. For example, instead of saying it is related with science, technology, engineering, or mathematics, they mentioned about branches of these areas. 30% of participant saw a relationship with social sciences. However, almost half of participants (45%) didn't answer this question and the percentage of participants who stated an irrelevant answer is 5%. There were 32 participants who thought that there was no relationship with any other areas different from STEM areas.

The last question of Microbiological Corrosion case was about teacher roles of the participants. In this question, they were asked about how they act as science/mathematics/technology teacher who wants to make a project about preventing microbiological corrosion's effects on daily life and also they were asked about what kind of support they need for this issue. In here 40 participants didn't give an answer for this question and 2 participants gave irrelevant answers. 34% of the participants said that they take actions in their lessons. However, among these actions, only 4% was including collaborative actions. On the other hand, the type of support, which was mentioned most by participants, was manpower resources support. Namely, they stated that they need an engineer, a technician, another teacher and etc. to make the project. In Table 6.8 the themes for these questions and their numbers of participant answers were presented.

Table 6.6. Numbers and percentages of themes for STEM case 1: Microbiological corrosion.

Area	Themes	Number of Participants	Percentage of Participants
Science	Content	122	60%
	Explanation	73	36%
	Investigation	13	6%
Technology	Technology for Research	102	50%
	General Technology	43	21%
	Relationship	24	12%
Engineering	Process	88	43%
	Engineering/Products	58	28%
	Function	32	17%
	Relationship	11	5%
Mathematics	Nature	181	89%
	Skills	17	8%
	Relationship	10	5%

Table 6.7. Areas thought to be related to microbiological corrosion case.

Categories	Areas	Number of Participants	Percentage of Participants
STEM Areas	Biology, Physics, Chemistry, Genetics, Environmental Sciences, Statistics, Metallurgy, Geology, Industry.	16	8%
Social Sciences	Sociology, History, Psychology, Economy, Politics, Geography, Education.	61	30%

Table 6.8. Using microbiological corrosion case for teaching: Numbers and percentages.

Categories	Themes	Number	Percentage
Action	Action in Lesson	68	34%
	Action in School	9	4%
	Wide Range Action	63	31%
	Collaborative Action	9	4%
Support	Financial Support	30	15%
	Technical Support	6	3%
	Government Support	6	3%
	Manpower Resources Support	46	23%

6.1.2.2. Results Related to Case 2: Radioactive Verbs. In here, each STEM area has its own themes like in Microbiological Corrosion case. Science has 3 themes (Content, Explanation, Association), Technology has 3 themes (General Technology, Process, Relationship), Engineering has 3 themes (Engineering Names, Skills, Relationship), and Mathematics has 3 themes (Nature, Skills, Relationship). Table below shows the numbers and percentages of the themes for each STEM area.

According to results presented in Table 6.9, participants mostly discussed science by using the content of science. Anyone didn't state that there was no science in Radioactive Verbs case. 37% of participants explained technology in terms of general technology like TV, web site link and so on and 4 participants stated that there was no technology. 32% of them described engineering by using skills related to engineering while answering the question of how engineering takes place in this case. Similarly, 9% (n=19) of the participants thought that there was no engineering in Radioactive Verbs case. Finally, it can be said that most of the participants (74%), discussed mathematics in the case by using the elements of nature of mathematics. There were only 5 participants who defined mathematics in terms of relationship with

other STEM areas. Only 1 participant stated that there was no mathematics in this case.

On the other hand, some participants gave no answer or irrelevant answers to the questions in this part. The numbers and percentages of participants who gave no answer to descriptions of STEM areas in radioactive verbs case were 8% (n=16) for science, 24% (n=49) for technology, 40% (n=82) for engineering, and 7% (n=15) for the mathematics area. As seen in the results, engineering became the most undetectable STEM area for this case. The numbers and percentages of participants who gave an irrelevant answer to descriptions of STEM areas in radioactive verbs case were 4% (n=9) for science, 4% (n=9) for technology, 7% (n=15) for engineering, and 3% (n=6) for mathematics area.

The participants were also asked whether Radioactive Verbs case has a relation with any other areas different from STEM areas as in the first case. Their answers were categorized into two categories; (i) Areas related to STEM and (ii) Areas related to social sciences. For this question, 88 participants didn't give an answer and 3 participants gave an irrelevant answer. On the other hand, 11% (n=23) of the participants stated that there was no relationship with areas other than STEM. Table 6.10 presents these areas and numbers and percentages of participant answers of them.

The last question of the Radioactive Verbs case has parallel aim with Microbiological corrosion case's last question. In this question, participants were asked to think that they read this scientific news and pay attention to it. They were asked that in such a case how they would use this scientific news in their teaching. 49 (24%) participants didn't give an answer to this question and 28 participants' answers were irrelevant. Themes that emerged from other 127 answers were presented below.

Table 6.9. Numbers and percentages of themes for STEM case 2: Radioactive verbs.

Area	Themes	Number of Participants	Percentage of Participants
Science	Content	108	53%
	Association	41	20%
	Explanation	32	16%
Technology	General Technology	76	37%
	Process	67	33%
	Relationship	13	6%
Engineering	Skills	66	32%
	Relationship	13	6%
	Engineering Names	11	5%
Mathematics	Nature	150	74%
	Skills	46	23%
	Relationship	5	2%

Table 6.10. Areas thought to be related to radioactive verbs case.

Categories	Areas	Number	Percentage
STEM Areas	Physics, Statistics	2	1%
Social Sciences	Philology, Sociology, History, Literature, Geography	88	43%

Most of the participants explained that they can use the case to inform their students about such a case (n=65, 32%). Almost same number of participants expressed they can explain related concepts like half-life by using this case. The remarkable result is that only 8 participants stated that they could collaborate with other STEM teachers to use Radioactive Verbs case in their lessons.

Table 6.11. Using radioactive verbs case for teaching: Numbers and percentages.

Themes	Numbers of Participants	Percentage of Participants
Using for Informing Students	65	32%
Using for Explaining a Concept	61	30%
Using for a Homework	19	9%
Collaborating with STEM Teachers	8	4%

6.1.3. Results Related to Comparison of Defining and Describing Relationship between STEM Areas according to Status

After participants' answers were coded and themes were created, participants' answers related to relationship between STEM areas were used to investigate whether there was a difference between freshman and senior preservice teachers in terms of seeing the relationship between STEM areas through two sections of STEM-A Open-Ended Questionnaire. In this sense, participants' answers that included relationship between STEM areas while defining STEM areas in the first section of STEM-A Open-Ended Questionnaire were coded as 1 and participants' answers that didn't refer to relationship between STEM areas while defining STEM areas were coded as 0. This was done for each STEM area and their STEM Definitions Relationship (STEM-DR) scores were calculated. For example, if a participant defined all STEM areas by using relationship between them, she or he got 4 STEM-DR scores. So, STEM-DR scores can be maximum 4 and minimum 0. The same approach was followed to compute participants' STEM Cases Relationship (STEM-CR) scores. However there were two cases in the second section so there were 8 answers for one participant to be coded as 1 or 0. The maximum score for STEM-CR was 8, and minimum was 0. Finally, their total STEM relationship (STEM-DCR) scores were calculated by adding STEM-DR and STEM-CR scores of each participant. For STEM-DCR scores, the maximum score was 12 and minimum was 0. Then, their scores were compared by using appropriate statistical testing methods. The assumptions of parametric tests were

checked and because of violation of the required assumptions, non- parametric tests were used. Since the distributions of STEM-DR scores were significantly deviated from normal distribution; nonparametric Mann-Whitney U test was conducted to compare mean ranks of STEM-DR, STEM-CR, and STEM-DCR scores of participants.

The data were gathered from 204 preservice teachers who were studying STEM related teaching departments. Among participants, there were 96 freshman preservice teachers and 108 senior preservice teachers. Mann Whitney U Test revealed no statistical significant difference in STEM-DR scores of freshman (Md=1, n=96) and senior (Md=1, n=108), U=4968, z=-.548, and p=.584. Also, there were no statistical significant difference in STEM-CR scores of freshman (Md=0, n=96) and senior (Md=0, n=108), U=5166, z=-.050, and p=.960. Finally, there were no statistically significant difference in STEM-DCR scores of freshman (Md=1, n=96) and senior (Md=1, n=108), U=5052, z=-.325, and p=.745.

6.2. Findings related to STEM-A Semi-Structured Interviews

In this part, findings related to STEM awareness semi-structured interviews will be presented. The themes that emerged from data analysis will be explained. Both cases (3D Printers and Night Flies) were separately examined. However, the themes will be came up together because of two reasons; firstly, the themes for each STEM related cases were parallel to each other and secondly, to answer the research question of the study holistically.

STEM-A semi-structured interview consists of two parts. In the first part of the interview, participants were asked about their basic demographic information like name-surname, department name, semester registered during research. Even though these data were got in STEM-A open-ended questionnaire, they were asked again to make the participant comfortable about the interview. The second part of the STEM-A semi-structured interview includes Case 3 (3D Printers) and Case 4 (Night Flies).

The interviews were done with 9 participants. These participants were chosen according to analysis results of STEM-A open-ended questionnaire. Each participant expressed the relationship between STEM areas in their answers to the Section 1, Section 2a, and Section 2b of STEM-A open-ended questionnaire. 1 of them was male and 8 of them were female participants. 4 of them were in freshman status and 5 of them were in senior status. The distribution of the participants to the departments were like that; 2 participants from CET (Computer Education and Educational Technologies) 4 participants from PRED (Primary Education), and 3 participants from SCED (Secondary Education).

6.2.1. Findings Related to STEM Related Cases (Case 3 and Case 4) in the Second Section of STEM-A Semi-Structured Interviews

Qualitative analysis procedures (Thematic Analysis) were followed and themes were emerged into two categories. The first one is STEM Areas category and this category has four themes; (i) Content, (ii) Skills/Expectations, (iii) Direction, and (iv) Nature. The second category is Relationship between STEM Areas. Themes of this category are (i) Definition of Relationship, (ii) Direction, (iii) Roles, and (iv) Nature. These themes will be discussed in detail in the following sections.

6.2.1.1 Findings Related to Individual STEM Areas. Content: This theme brings together the participant answers related to terms specific to science, technology, engineering, and mathematics. In another way, participants were expressed their perceptions on each STEM area by using terminology of these areas while examining the STEM related cases. To give examples for participants' answers for each STEM area, one of the participants explained science as "defining matters" (Case 3), the other defined as "global warming" (Case 4). Technology was detected as "CAD program" (Case 3) or "plane" (Case 4). On the other hand, engineering area was also stated as "plane" (Case 4). Mathematics was defined as "numbers" (Case 3) or "the heating and cooling degrees of air" (Case 4). In here, numbers and degrees were remarkable. Table 6.12 includes all of the terms that came from the STEM related cases and had a place under the content theme.

Table 6.12 Emerging terms under the content theme for each STEM area.

Theme	Science	Technology	Engineering	Mathematics
CONTENT	-Matter -Material -Physics -Chemistry -Biology -Design -Model -Global warming -Nature -Environment -Condensation -Temperature -Reflection -Moisture -Cooling effect	-Machine -Printer -Program -Artificial intelligence -Electronic data -Prototype -Software -Tool -Plain -Electric circuit	-Plain -Software -Prototyping -Design -Computer programming -Printer -Electronic	-Software -Comparing -Geometry -Numbers -Thickness- depth -Derivative -Integral -Dimension -Coding -3D -Operations -Calculations -Economy -Ratio -Measuring -Data -Difference -Degree -Prediction -Formulas -Theorems -Proportional relationship

Nature: It describes statements related to key principles, ideas, and characteristics of the areas. For example, a participant defined science, as “Science is the modeling of the real world” and another participant mentioned about “Scientific research”. In here, real life relationship of science is a characteristic of science. Technology was explained by most of the interviewees as a thing that facilitating the life. Engineering was stated that it is in everywhere. One interviewee told, “Mathematics naturally exists”. In addition to these participant examples, codes related to the nature theme were shared in Table 6.13.

Skills/Expectations: Expectations from each STEM area or skills of the specialists who work in the STEM areas were stated. Participants were asked about how people who work in science, technology, engineering and mathematics contribute to the situation in the given cases. It was seen that participants expressed specialists’ works as “Scientists do this …” or “An engineer helps this …”. In addition to this,

they stated their expectations from each STEM area or area specialists when they were asked that which knowledge or skills do they need if they work on the subject mentioned in the case. They generally stated it by referring to area specialists. For example; participants stated “Scientists knows the properties of materials” (Case 3) or “To see the effects by scientific research” (Case 4) so “I need to know properties of materials”. For the area of technology, their expectations from a technologist were “Developing the printer” (Case 3) or “Modeling the world for the production” (Case 4). Skills or expectations from engineering were “Using prototypes” (Case 3) or “Making Calculations” (Case 4). Mathematics was stated, “To develop algorithms” (Case 3) or “Interpreting the findings” (Case 4). Table 6.14 represents all of the codes related to the skills/expectations stated by participants in the interviews.

Table 6.13. Codes related to nature theme.

Theme	Science	Technology	Engineering	Mathematics
NATURE	-Scientific processes -Being flawless -Modeling real life -Being a base	-Technology for production -Adapting to real life -Tool -Development -Being ergonomic -Facilitating life -Need	-Being for humanity -Adapting to real life -Use of mathematics -Use of technology -Using science -Being in everywhere -Designing	-Being in everything -As a language -As a tool -Naturally existing -Meaning the same thing for everyone -Uniform Symbolic language

Direction: Even if participants weren’t asked about the relationship between STEM areas, they couldn’t define areas without thinking/talking about interaction between them. This theme expresses not the relationship between the areas but the effect of areas on each other. In this sense, a specific STEM area or areas were considered to be affecting concept for another one/s. This effect can be a source that was benefited from, a support that came from an area to other area, or it can be directly an effect.

Table 6.14. Skills/expectations stated by participants for each STEM area.

Themes	Science	Technology	Engineering	Mathematics
Skills / Expectations	-Researching -Mathematical modeling -Application -Prototyping -Production -Using scientific methods -Informing -Making observations -Investigation -Formulization -Collecting data	-Development -Designing -Adaptation -Comparison -Production -Application -Taking inspiration from nature -Integrating parts of a machine -To know efficiency -To know about energy -Determining the usage area -Producing software -Measuring -Using plain -Producing new production ideas	-Using prototypes -Applying the theory to the real life -Obtaining efficiency -Choosing materials -Designing -Mechanization -Making predictions -Producing technology -Development -Making graphics on computer -Plotting -Making calculations -Optimization -Producing software -Researching -Measuring -Interpreting data -Finding solutions -Making observations -Collecting data -Experimentation -Coding -Communicating with science and technology people -Producing ideas	-Stating by numbers -Making analysis -Measuring -Calculating -Reflecting the data -Using software -Making predictions -Making comparison -Making graphs -Sharing forecasting -Interpreting findings -Using quantitative data -Deducing -Searching for practicality -Using mathematical models -Programming -Using logarithms, integrals -Using differentials -Producing algorithms

In here, each STEM area was seen as an affecting area. To exemplify, science were considered to be “The thing that consists of the models created by science is technology”. In this answer, when the participants talked about an individual area, s/he is also referring a direction that science affects technology (S➔T). In this example,science can be said that it is a source for technology. On the other hand,

technology was stated as "The negative effect of technology to the atmosphere", so this statement indicates a direction from technology towards science (T➔S). It can be said that there is a direct effect of technology. Engineering was described, as "Engineering is the way of arriving technology". It is seen that engineering affects the technology so the direction was generated from engineering towards technology (E➔T). In here engineering stands as support to technology. Lastly, a participant stated mathematician as "A mathematician helps engineers in complex computations". In here, the support comes from mathematician (M➔E). Therefore, the direction is from mathematics towards engineering. Table 6.15 shows all directions related to STEM areas.

Table 6.15. Directions related to each STEM area.

Theme	**Science (S)**	**Technology (T)**	**Engineering (E)**	**Mathematics (M)**
Direction	S➔T S➔E S➔T, E, M T, E, M➔S E➔S M➔S	T➔S E➔T T➔E S➔T S➔T, E, M T, E, M➔S	E➔T S➔E T➔E E➔S M➔E S➔T, E, M T, E, M➔S	M➔E M➔S S➔T, E, M T, E, M➔S

6.2.1.2 Findings Related to Relationship Between STEM Areas: Definition of Relationship: The interviewees were asked to define the relationship between science, technology, engineering, and mathematics by considering the given STEM related cases. So, this theme explains the type of the relationship between STEM areas described by the interviewees. There existed 4 sub-themes under this theme; (i) Plain Relationship, (ii) Working Together, (iii) Dependence, and (iv) Position.

(i) Plain Relationship: This sub-theme consisted of participant answers that only stated that there was a relationship between one or more than one STEM areas. There was no detail about the relationship explained. For example: One of the

interviewee states “There are duo-trio relationships between STEM areas”. It couldn’t possible to understand how these relationships occur.

(ii) Working Together: In here, two or more STEM areas were stated that they were working together or supporting each other in a concept. Answers related to coexistence of the areas were detected and took place under this theme. For example: A participant said, “Engineering and mathematics are in an organization for technology.”

(iii) Dependence: Two or more STEM areas were defined as they were dependent to each other or they were inseparable. Findings showed that this dependence occurred in three ways; (i) Cyclic Relationship, (ii) Chain Relationship and (iii) Mutual Relationship. In cyclic relationship of dependence, STEM areas were dependent to each other in cyclic way. For example; a participant stated that areas were dependent to each other like a cycle not like a chain.” There was no beginning and end for this type of relationship. However, in chain relationship, STEM areas were dependent to each other like a chain. For example; it begins with mathematics and goes on engineering, technology, and science in respectively. Mutual relationship was stated as STEM areas were mutually dependent to each other. For example: “STEM areas are dependent to each other” was one of the answers of the interviewees. It can be said that STEM areas are mutually dependent to each other.

(iv) Position: This theme explains how each STEM area took positions according to each other. It defines the place of a STEM area in relation to other STEM areas. It emerged in three ways; (i) Inclusion, (ii) Intertwined (iii) Identity. In inclusion, it was seen that participants explained that one area includes other area(s). For example: “Engineering contains all other STEM areas.” In this participant answer, engineering was in inclusive position. It includes all STEM areas. In intertwined relationship, participants stated that STEM areas intertwined. In identity, some areas were stated as identical. In here, engineering and technology was seen as identical.

Direction: The purpose of conducting the interviews was to see how participants conceptualize the relationship between STEM areas. This theme, indeed,

emerged from participants' answers on how areas affect each other. So, a specific STEM area or areas were considered to be affecting or affected concept for another one/s. In here, each STEM area was seen as both an affecting area and affected area. So, this effect can be a source, a support or a direct effect. To exemplify, science was described as an affected area in the following answer: "A reason originated from science is expressed by mathematics." On the other hand science was stated as affecting area in this sentence: "Science makes research and reflects it to technology." Table 6.16 shows all type of directions related to relationship between STEM areas.

Table 6.16. Directions existed in relationship of STEM areas.

Theme	**Science (S)**	**Technology (T)**	**Engineering (E)**	**Mathematics (M)**
Direction	S, E, M→T S→E S→T, E, M S→T S, M→E, T S, T, M→E S→M S, M→E S, M→E→T S, T, E, M→S, T, E, M T→S M→S, T, E T, E, M→S	T, E, M→S T→S S, E, M→T E→T S→T, E, M S→T S, M→E, T S, M→E→T S, T, E, M→S, T, E, M M→S, T, E S, T, M→E	E→T S, E, M→T T, E, M→S S, M→E→T M→E S→E S→T, E, M S, M→E, T S, M→E S, T, E, M→S, T, E, M M→S, T, E S, T, M→E	M→E M→S, T, E S, M→E, T S, M→E S, M→E→T T, E, M→S S, T, M→E S, E, M→T S→M S→T, E, M S, T, E, M→S, T, E, M

Roles: When participants were asked how the relationship between four STEM areas was, they defined relationship by appointing some roles to STEM areas in this relationship. Science had "explanatory", "informative", and "researcher" roles in the relationship. Technology was considered to be "a concept that each STEM area used". Engineering was thought as "connective" area that brings all STEM areas together. Mathematics had roles of "being the language" and "being a tool" in this relationship. For example, it was explained as "Mathematics is a language that is used to explain other STEM areas." Table 6.17 shows all roles for each STEM area.

Table 6.17. Roles of each STEM area in relationship between STEM areas.

	Science	**Technology**	**Engineering**	**Mathematics**
Roles	Explanatory Informative Researcher	A concept that each STEM area used	Connective	Being the language Being a tool

Nature: Besides STEM areas' have their own natures, when STEM was considered integrally; there also existed information about nature of this relationship. Participants stated that each STEM area generates each other and while doing STEM, four areas use each other. It is like two-sided arrow S, T, E, M←→S, T, E, M. However, it was stated that this usage had not to be equal always; sometimes one or more STEM areas can take more place than others.

7. DISCUSSION

The aim of the research was to investigate STEM awareness of preservice teachers who study in STEM related teaching departments. In this sense, participants' definitions of STEM areas and STEM education, descriptions of STEM areas in STEM related daily cases, and perceptions of relationships between STEM areas were examined through STEM-A Open-Ended Questionnaire and STEM-A semi-structured interviews. To achieve this, STEM awareness Open-Ended Questionnaire was applied to a large number of participants (n=204). Later on, 9 participants who described STEM areas in terms of relationship between STEM areas in this questionnaire were interviewed. The purpose in this section was to present firstly participants' descriptions of individual STEM areas both in STEM-A and interviews, secondly to present their perceptions on relationships between STEM areas in interviews and finally to discuss about the data on STEM education.

7.1. Descriptions of Individual STEM Areas

7.1.1. Identification of Individual STEM areas in STEM related Cases

In STEM-A open-ended questionnaire, participants of the study identified STEM areas with their content, function, process, nature, area skills or relationships with other areas in STEM related cases. Also, there were answers that participants wrote nothing (empty answers) and answers that participants said that there were no science, technology, engineering, or mathematics in the given case (nonexistence). Similar approach in identifying the areas resulted in the interviews. Interviewees described STEM areas by pointing their content, area skills, nature and effect. However, there were differences in identification of each STEM area in STEM related cases, and some areas were not even addressed by the participants. In here, participants' identification of the area means that participants gave a relevant answer to the questions related to individual STEM areas in STEM related cases. Empty and irrelevant answers tell that there was no identification of the area by the participant.

Among STEM areas, science was the only one that was identified by all of the participants both in Case 1 (Microbiological Corrosion) and Case 2 (Radioactive Verbs). For the areas of technology, engineering and mathematics, in addition to empty answers, there were answers describing *nonexistence* of the area in given STEM related cases. In this sense, science can be said that it is easy to be posed by participants in STEM related cases. It can be related to their view of science. Participants defined science by separating it from other STEM areas. There was no relationship theme for the identification of science. Cevizci (2016) states this type of definition of science, as "science is the collection of theoretical knowledge that allows human to understand and explain the world." So, this definition emphasizes the relationship between science and daily life. STEM related cases were intentionally designed as related with daily life to serve the nature of STEM and it can be said that all participants noticed science and daily life relationship in these STEM related cases. STEM-A Open-Ended Questionnaire showed us that more than half of the participants identified science by using the terms of science that was included by the cases. In other words, most of the participants' answers related to science can be found in the texts. The situation is the same for two cases. This may be explained by participants' being familiar to science terminology. Because in most schools, students learn scientific terms and ideas from course books. They couldn't find chance to develop or experience these terms and ideas in laboratories or projects. So, their description of science in STEM related daily cases revealed that they put their ideas with scientific terms in restricted words not by elaborative sentences with daily life examples.

In Turkey, many schools do not have laboratories or materials to learn the things by doing but even if schools have laboratories or opportunities for doing projects, teachers may not prefer to use these in their science classes. One of the reasons of this situation is the curriculum density in for one academic year. However, another important reason for this situation is teachers' competence about laboratory usage and materials or projects. In this sense, Böyük and his friends (2010) conducted a research on the proficiency views of science and technology teachers on laboratory studies. The research revealed that using the laboratories in science and technology classes by the teachers was considered to be important factor to attract the attention of

the students and provide effective learning. However, it has been found out that the teachers did not know and use all the equipment very well in the laboratory, and do not know how to repair and maintenance them, so they did not prefer to use the techniques and methods of laboratory in their classes.

Preservice teachers who study in STEM related teaching areas described technology by using its function, processes and relationship with other STEM areas. However, even though definitions of technology in the literature include the knowledge of who makes technology (Project Lead the Way, 2011), no participant stated this in their answers while explaining technology in STEM-A Open-Ended Questionnaire. It can be said that participants considered technology as a tool used by other area specialists, and it functions or takes roles in processes rather than thinking who makes technology. However, even though STEM areas were asked individually in interviews, interviewees explained two-sided effect of technology and engineering to each other related to this theme. They stated both that engineers makes technology and technology is a product of engineering.

Engineering became the STEM area that has least number of answers related to identification of it in STEM related cases. Approximately 20% of the participants gave an empty answer, an irrelevant answer, or an answer stating that there is no engineering in STEM related cases. Demographic data showed that 80% of the participants' familiarities with engineering were restricted to their family members or friends. Engineering education is not a subject of science, technology, and mathematics teaching departments, where participants were studying. So, participants may have limited experience with engineering and engineers. This can be interpreted as the reason of their difficulty in describing engineering in STEM related cases (Rockland *et al*., 2012).

Participants identified mathematics in terms of its nature, skills, and relationship with other STEM areas. Among these, 89% of participants used properties related to nature of mathematics while describing mathematics in STEM related cases. Although mathematical and quantitative skills are very important for a

student and also in adult life (Wismath and Worrall, 2015), it was seen in the research that very few participant uncovered mathematics in terms of mathematical skills used in the given cases and relationship with other STEM areas in STEM-A Open-Ended Questionnaire. For example, participants mostly described mathematics by exemplifying its symbolic language; numbers, diagrams, or marks and etc. In this sense, Augustin *et al*. (2012) states that taking one or more traditional mathematics courses were not sufficient to develop quantitative reasoning. So, it would be better to provide preservice teachers in STEM related areas with mathematics courses that aim to develop students understanding of mathematics and their quantitative reasoning skills. However, interview results showed that those participants' description of mathematics included mathematical skills, its content, its nature, and relationship with other STEM areas uniformly. So, it may be interpreted as people who already see and describe the relationship between STEM areas discuss STEM areas thoroughly.

7.1.2. Descriptions of STEM Areas with Relationships Between STEM Areas

Participants used relationship between STEM areas to describe science, technology, engineering, and mathematics in STEM-A open-ended questionnaire. However, in their description of STEM areas, how much they used relationship between STEM areas changed. Science was least described STEM area in terms of relationship with other STEM areas while defining STEM areas. Similarly, they didn't use relationship between science and other areas while defining science both in Case 1 (Microbiological Corrosion) and Case 2 (Radioactive Verbs.) Remembering the result on science being identified by all participants, they didn't identify the relationship with science and other STEM areas. It can be said that science was seen isolated even in STEM related daily life examples. However, other three STEM areas were both in definition (in the first section of STEM-A open-ended questionnaire) and in case (in the second section of STEM-A open-ended questionnaire) described (identification) in terms of relationship with other STEM areas. Cevizci (2016), states that there are two approaches in defining science; (i) defining science by associating it with technique or technology, (ii) defining science by separating science from technique. It can be said that participants of the research stated science separately as in the second approach.

This may because of their prior learning of science (Fuentes, Bloom, & Peace, 2014). In Turkey's educational system, primary school science course was named "Knowledge of Science" till 2005-2006 academic years. Then, it was changed to "Science and Technology" by 2005 (MEB, 2005). At least half of the participants took their primary science course as "Science and Technology" course. The aim of this change was to emphasize the science-technology-society relationship (Yangın ve Dindar, 2007). However, the study showed us that participants couldn't define science by relating it with other STEM areas even technology. Accordingly, the interview results showed that participants who defined any one of STEM areas in terms of relationship in STEM-A open-ended questionnaire, she or he also defined science by using relationship with other STEM areas during interviews.

Technology was described in terms of relationship both in STEM areas' definitions and in STEM related cases. When the type of relationship with technology and other areas were investigated, it was seen that participants emphasized the relationship between science and technology. For example, one of the participants defined technology as a product of science, and also a contributor to development of science while defining STEM areas. Another participant described technology in Case 1 (Microbiological Corrosion) like that technology was merged with science to give ideas to people in solving problems in life. It may be said that the relationship between science and technology was more visible than the relationship between technology and other areas. Also, the relationship between science and technology is visible when technology was considered because the participants didn't describe science-technology relationship when they were making the description of science. One explanation of this association of technology with science may probably come from their K12 education. As mentioned above, in Turkey, science education starts in primary school under the name of Science and Technology Education since 2005 (MoNE, 2005). When the backgrounds of participants were considered, their description of this relationship may be expected. This shows us that to emphasize all relationships between STEM areas is important in education. Because, even in interview results one way or two-way effect didn't emerge between technology and mathematics when participants were asked to explain STEM areas individually. Only

if they were asked directly about the relationship between STEM areas, they focused on other type of relationships and told all relationships between STEM areas.

Among the STEM areas, engineering was defined in terms of relationship with other STEM areas most in section 1 of STEM-A Open-Ended Questionnaire that asks the definitions of individual STEM areas. 43% of the participants stated engineering and other STEM areas' relationship. However, their description of engineering in cases didn't include that much relationship with other areas. Only 5% of participants in Case 1 and only 6% of participants in Case 2 described engineering by using the relationship with other STEM areas. It may be cause of the difference between. Almost half of the participants stated the relationships between engineering and other STEM areas while defining engineering but most of them had difficulty in setting these relationships in daily life examples. When the relationships in STEM-A were considered it is seen that in general, descriptions of participants included interaction of more than two STEM areas. To exemplify, one of the participants explained that integrating physics and linguistics is the engineering that mathematician achieve. As seen in this example, there is interaction of science, engineering, and mathematics. The findings of STEM-A semi-structured interviews had parallel result with this. Participants saw engineering as connector of STEM areas in interviews. So, it seems that they set double, trio, or quart relationships between engineering and other STEM areas. Cavanagh (2009) states that engineering is like a catalyst for achieving more interconnected K12 STEM education. Therefore, while integrating science, technology, engineering, and mathematics, engineering plays a crucial role (Mativo and Park, 2012). It seems that engineering is the must of integrated STEM education.

Finally, mathematics was also described in terms of relationships both in definition and in cases. Research participants mostly stated trio and quart relationships between mathematics and other STEM areas like in engineering. For example, one of them stated mathematics in Case 1 (Microbiological Corrosion) as measuring the loss of microbiological corrosion, planning the necessary technology, and obtaining the statistical results. The description of this participant included science, technology, and mathematics relationship. In STEM-A semi-structured interviews, which included

Case 3 (3D Printers) and Case 4 (Night Flies), it was expressed that mathematics was an area that has the property of being in everywhere or in everything. On the other hand, interview results showed that participants saw mathematics as the language used by all STEM areas and a tool needed by all STEM areas. Their view of nature of mathematics may have effect on their perception of relationships between mathematics and other STEM areas.

STEM Awareness open-ended questionnaire was applied to all participants. The participants were chosen from freshman and senior preservice teacher who were studying STEM related teaching departments. When they were asked to describe science, technology, engineering and mathematics, most of them gave separate descriptions of the areas. It means that participants didn't emphasize the relationship between STEM areas in their answers. Even if the number of participants who used relationship between STEM areas by defining and describing STEM areas were low, any statistical significant difference were examined for freshman and senior preservice teachers in terms of stating relationship between STEM areas. However, there was no statistically significant difference between freshman and senior students through all STEM-A Open-Ended Questionnaire in terms of using relationship statements while defining and describing STEM areas. There could be a difference on behalf of senior preservice teachers because universities can be said to have more opportunities to reflect and empower the understanding of STEM and experience in STEM education. There should be a paradigm shift in universities but when the courses and curriculums in the universities were considered, it was seen that they didn't reflect integration property of STEM. In almost all universities in Turkey, preservice teachers who study in STEM related teaching departments do not have chances to collaborate other preservice teachers in STEM related teaching departments. They don't have the opportunity to experience keystones of STEM education; communication, collaboration, integration. They have the knowledge of STEM areas one by one, but for STEM, the integration of this knowledge is needed. Participants of the study were asked to define and describe STEM areas in STEM-A Open-Ended Questionnaire, which was paper-based, and it was seen that they had difficulty in focusing and stating the relationships between STEM areas. However,

interview results showed that even though STEM areas were asked separately, interview participants described STEM areas by referring to the relationships between STEM areas more than they did in STEM-A Open-Ended Questionnaire. These relationships will be discussed in the following section.

7.2. Participants' Perceptions on Relationships between STEM Areas

7.2.1. In-Depth Analysis of Relationship

All participants were asked to describe each STEM area in STEM-A open-ended questionnaire and participants who described at least one STEM area by using the relationships between STEM areas in each sections and subsections of STEM-A open-ended questionnaire were asked to describe STEM areas in semi-structured interviews through STEM related cases. Besides this, interviewees were asked to explain how the relationships between STEM areas were in Case 3 (3D Printers) and in Case 4 (Night Flies). The data revealed four type of relationship; (i) Plain Relationship, (ii) Working Together, (iii) Dependence, and (iv) Position.

In here, plain relationship states double or quart relationship between STEM areas. Participants expressed science-technology and engineering-technology relationships as double relationship. On the other hand, they stated that STEM areas were interrelated. Science-mathematics, science-engineering, engineering-mathematics, technology-mathematics relationships were not discussed in this sense. It is possible to say that science-technology and engineering-technology relationships came more visible to participants because science technology relationship was emphasized in participants' K12 education. They took their science courses under the name of science and technology, so their experiences with this course lead them to think about the existence of the relationship between science and technology. Similarly, engineering and technology are the areas, which are generally handled together in daily life. So, to use the areas together like that plays a role in making people to think about the relationship between them. This thinking may be the first step of inquiry about relationships between these areas and more because in the first

element of inquiry, which is questioning, people are expected to reach a greater understanding of a problem or a situation (Callison and Baker, 2014). Therefore, a person who think about the relationship between science and technology may inquire relationship phenomena and reach deep explanations of this relationship and also could see other relationships between STEM areas.

Another type of relationship between STEM areas was based on their togetherness while working. In this type of relationship, double, trio, and quart togetherness of areas were stated for working together. Participants expressed that science and mathematics work together on one side and engineering and technology work together on other side to contribute to the issue given in STEM related cases. Working of three areas was stated as science, engineering and mathematics works together to make technology. Quart togetherness in working was seen as all STEM areas works together and makes equal contributions. In double working of STEM areas, an exact integrity of STEM areas doesn't exist. For trio working of STEM areas, it can be said that it closer to integrity however the may not be always to produce technology. Therefore, the perspective of together working of all STEM areas should be gained. Designing integrated teaching education programs for preservice teachers who study in STEM areas can provide it. Çorlu (2012) found that pre-service mathematics and science teachers, who were educated in integrated teaching education program, outperformed peers in the departmentalized teacher education program in terms of their integrated teaching knowledge, which is crucial for STEM education.

Participants also stated dependence of the STEM areas. According to data, this dependence occur in three ways; (i) Cyclic, (ii) Chain and (iii) Mutual. In cyclic dependence, STEM areas were dependent to each other in cyclic way. There was no beginning and end for this type of relationship. Figure 7.1 describes the cyclic dependence of STEM areas.

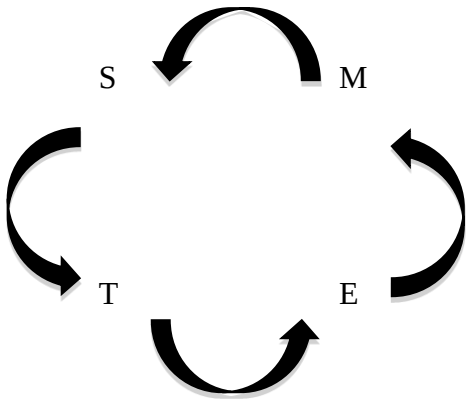

Figure 7.1. Cyclic Dependence of STEM Areas.

As seen in the figure, science is dependent to mathematics and technology in dependent to science and so on. However, in this type of relationship, a certain STEM area has direct relationship with only two STEM areas so other relationships can be said absent.

In chain dependence, STEM areas were dependent to each other like a chain. For example; it begins with mathematics and goes on engineering, technology, and science in respectively. There is beginning area in chain dependence. Figure 7.2 illustrates chain dependence. As in cyclic dependence, chain dependence has only certain relationships. So it is more static compared to cyclic dependence because there is always the same beginning in doing STEM.



Figure 7.2. Chain Dependence of STEM Areas.

Therefore relationship understandings like chain and cyclic need to be enhanced by integrative approaches. STEM areas should not be taught in isolation just as in the real world or in the work life (as cited in English, 2016). In other words, it can be said that if STEM areas were presented isolated in education then the relationships between them became blurred. Maybe, only one or two form of

relationships can be seen as found in the research and it couldn't be said that it reflects STEM.

Mutual dependence was stated, as STEM areas were mutually dependent to each other. In this type of relationship, it is possible to say that all one-to-one interactions between STEM areas were mentioned. STEM areas support each other both with their differences and their similarities. Dugger (1993) stated the relationships between STEM areas by focusing on the similarities and differences of the areas. For example he describes the relationship between science and technology as:

> "Science and technology are different, yet there are symbiotic areas where both overlap and contribute to each discipline. Technology is much more than applied science and science is quite different from theoretical technology. When one alters the natural world using technology, it impacts both science and technology. Science is dependent upon technology to test, experiment, verify, and apply many of its laws, theories, and principles. Likewise, technology is dependent upon science for its research, laws, principles, and knowledge base."

The mutual relationship in the study describes such relationship between areas. All areas were related to each other and the mutual relationship can be illustrated as in Figure 7.3.

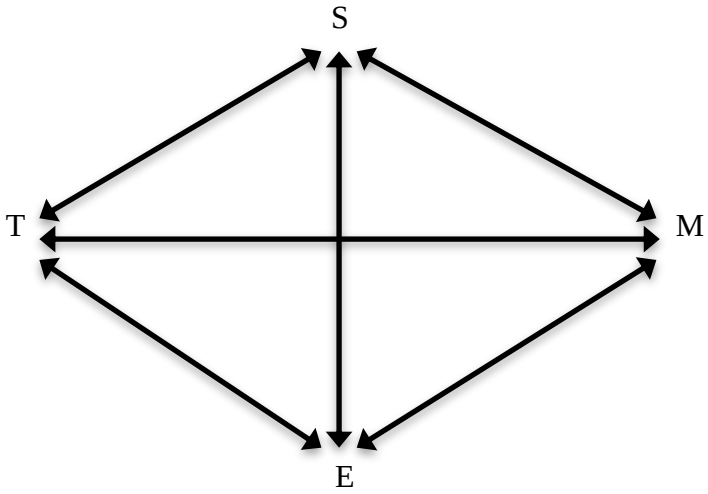

Figure 7.3. Mutual Dependence of STEM Areas.

The last type of relationship was position. It states how STEM areas were positioned to each other in participants' descriptions of relationship between STEM areas. It was defined in three ways; (i) Inclusion, (ii) Intertwined, and (iii) Identity. In inclusion, the outstanding description was that engineering includes science, technology, and mathematics. Figure 7.4 illustrates the inclusive relationship.

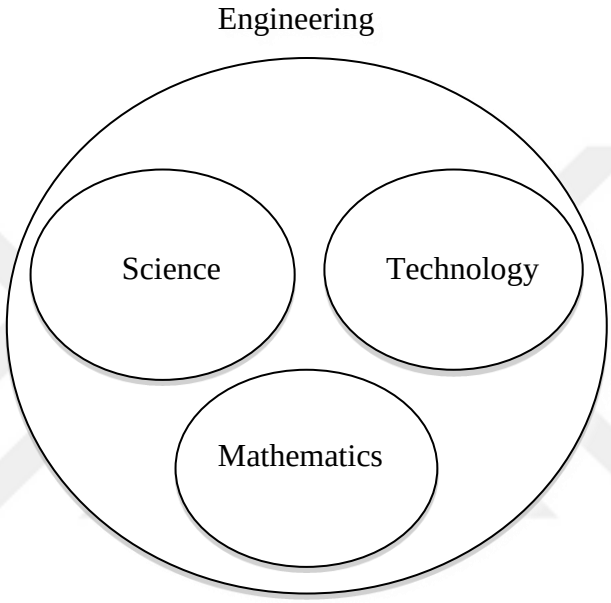

Figure 7.4. Inclusive Position of STEM Areas.

For intertwined position, participants stated that four STEM areas were together such that it is difficult to separate them. So, it is hard to draw boundaries between science, technology, engineering, and mathematics. Figure 7.5 illustrates the intertwined position of STEM areas.

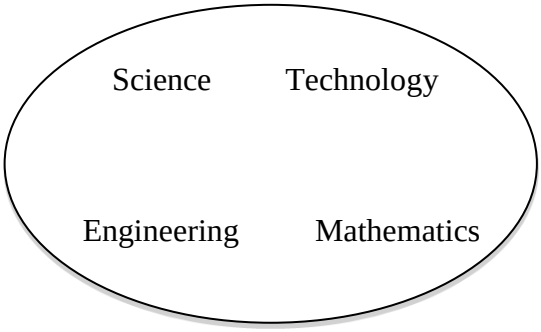

Figure 7.5. Intertwined position of STEM areas.

This description of relationship between STEM areas can be identified also as integrated. Because, Satchwell and Loepp (2002) state that integrated instruction is any program in which there is an explicit assimilation of concepts from more than one discipline. Similarly, for integrated STEM, intertwined position presents us the idea that each area should be combined inseparably. When a concept was thought within the context of integrated STEM, it should have a meaning for each STEM area. It should be described holistically. Finally, in identity, some areas were stated as identical. In here, engineering and technology was seen as identical. Figure 7.6 illustrates identical position of STEM areas.

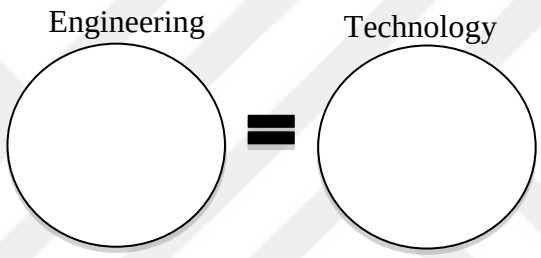

Figure 7.6. Identical position of STEM areas.

Engineering and technology have most in common and they were strongly fed by each other. However there are differences. To handle them together is important so that NAEP (National Assessment of Educational Progress of America) made change about technological literacy assessments. NAEP committee recommended a change in title of the framework from technological literacy to technology and engineering literacy in 2014. So, from one side, it is important to take hand them together, from other side generally expressing engineering and technology together may result in people's mind conceptualization of them as identical. As mentioned before, both the similarities and differences keep STEM areas naturally together, therefore to enable well understanding of STEM it is better to be aware of these similarities and differences of STEM areas.

7.2.2. Direction of the Relationship

Participants stated the interaction between STEM areas on each other. This interaction was stated as effects of STEM areas. The type of relationship in here was in the form of affection. There were one-way and two-way effects. When STEM areas were asked to define separately in STEM related cases in STEM-A semi-structured interviews, participants generally described the relationship in one way. In here, only area of science has all two-way effects; science-technology, technology-science, science-engineering, engineering- science, science-mathematics, and mathematics-science. They can be more familiar to science and its concepts.

The effects of technology and mathematics on each other didn't emerged. Technology didn't have both one-way and two-way effects with mathematics. Participants didn't state how technology affects mathematics or how mathematics affects technology when STEM areas were asked separately. Mathematics has only two-way effect with science and one-way effect with engineering. Two-way science-mathematics effects may be said easy to be described by the participants compared to other area effects because in Turkey's educational system, interdisciplinary approaches between science and mathematics courses are supported. Also, MoNE of Turkey (Ministry of National Education) designs science and mathematics curriculum so that related concepts were given in parallel times to support the outcomes of each course (MoNE, 2009). However, mathematics has only one-way effect with engineering. This one-way effect stated that mathematics affects engineering but there was no statement about the reverse. When the word meaning of engineering in Turkish considered, this finding came meaningful. Because, the origin of the word engineering in Turkish, which is "Mühendis", came from Arabic word "Hendese" which means geometry and Mü-hendis means the person who knows geometry (Keleş, 2015). On the other hand Keleş (2015), states that the word engineering came from latin and the meaning of it is to "contrive, to desire" so such difference between the culture determines the people's point of view to engineering and engineers.

However, when the interview participants were asked to define relationship between STEM areas, all type of two-way effects was expressed for each area. In this sense, it can be said that presenting the STEM areas separately may lead participants not to think these areas holistically. When STEM areas were separated, it was seen that meaningful and important parts were disappeared. In here, it can be said that the whole is greater than the sum of its parts for integrated STEM (Akaygün & Aslan-Tutak, 2016). So, STEM is beyond the mere collection of science, technology, engineering, and mathematics. Interview results showed that if STEM was taken hand holistically, then all interactions between STEM areas were expressed.

7.3. STEM Education

The participants of the study were from teaching departments related to STEM areas. There is no teacher education program for engineering area in Turkey, so they were from science teaching, technology teaching and mathematics teaching departments. Since participants' experience of STEM or STEM education was wondered, participants were asked about their experiences related to projects in STEM areas, STEM, and STEM education. However, results of the study showed us that 73% of the participants didn't experience any project related to STEM areas, STEM, or STEM education. 10% of the participants stated that they attended projects in STEM areas. Furthermore, 10% of them explained they did STEM projects, and the percentage of participants who took place in STEM education was 9%. The participants of this research were expected to be the implementers of STEM education, so their experience in STEM and STEM education is crucial. It is known that prior experiences of teachers have an important role in their teaching after graduation (Remillard, 2005). This suggests that there is an experience in STEM education need in teacher education programs in especially STEM related teaching departments (Stohlmann *et al*., 2012).

Besides the importance of having experience in STEM or STEM education, collaborative actions is important in STEM education (Brown, *et al*., 2011). In this sense, participants were asked at the end of the STEM related cases about their teacher

roles. For the Case (Microbiological Corrosion), they were asked how they act as science/mathematics/technology teacher who wants to make a project about preventing microbiological corrosion's effects on daily life. And for the Case 2 (Radioactive Verbs), participants were said that think that you read this scientific news and pay attention to it and they were asked that in such a case how they would use this scientific news in their teaching. Only 4% of the participants explained action plans, which are in collaboration with other STEM areas for the Case 1, and similarly, 4% of them stated that they could collaborate with other STEM teachers in total. However, when participants who gave meaningful answers (n=162) to the question of Case 1 were considered, the percentage of the participants who expressed collaboration was 5%. For Case 2, 127 participants gave meaningful answers to the question and percentage of collaboration answers in meaningful answers was 6%. The approach of preservice teachers in the study shows us that there can be a need in experiencing collaboration with people from different areas. This can be interpreted as limited collaboration experience of participants. This result is in a sense parallel with results about area relationships. OECD (2010) states that innovation rarely occurs in isolation so that it needs interaction of areas and collaboration. If the collaboration experience of participants were provided then the relationships between STEM areas may be experienced.

8. LIMITATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

In this section**,** limitations of the study and future research on STEM, and STEM education were provided. In this study, convenient sampling technique were used for the accessibility of the participants and the study was done with one public university's preservice teachers who study in STEM related teaching departments. Therefore, further research can be done with preservice teachers of other universities. Also, the literature about STEM and STEM education may be improved by designing and conducting studies with teachers in STEM related areas. The university that was the subject of this study hasn't teaching biology program in its faculty of education. So it can be better to include also preservice teachers who study biology in further research.

This study aimed to investigate participants' perceptions of relationships between STEM areas through STEM related daily topics. Two different data collection methods were used in the study. It would be better to include another methods such as observation. On the other hand, the study is not a correlational or experimental study. The results of this study may inform an experimental study designed to investigate underlying factors in seeing the relationships between STEM areas or a correlational study conducted to reveal the relationships between any variable in this subject.

Besides, in the second phase of the research, participants who stated relationships between STEM areas in the first phase of the research were interviewed. In further research, the participants who never stated relationships while defining or describing STEM areas could be interviewed and the comparison can be done for two groups.

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APPENDIX A: DEMOGRAPHIC INFORMATION FORM

İsim Soyisim:

Okul Numarası:

İletişim adresi (e-posta):

DEMOGRAFİK BİLGİ FORMU

Lütfen aşağıdaki soruları cevaplayınız veya "✓ " ile işaretleyiniz.

1) Cinsiyetiniz: _____ Erkek _____ Kadın

2) Yaşınız: _____

3) Bölümünüz/Programınız : _____

4) Üniversitedeki döneminiz: _____

5) Genel not ortalamanız (GPA): _____

6) Mühendisler ile nasıl bir aşinalığınız var? Tüm uygun seçenekleri işaretleyiniz.

_____Mühendisim.

_____Kız arkadaşım/Erkek arkadaşım mühendis.

_____Bazı mühendislik dersleri aldım.

_____Mühendis arkadaşım var.

_____Ailemde mühendis var.

_____Mühendisler ile iletişimim oldu.

_____Bir mühendisin ne yaptığı hakkında çok az bilgim var veya hiç yok.

_____Diğer (Lütfen açıklayınız) _____

_____

7) Fen, teknoloji, mühendislik ve/ya matematik ile ilgili herhangi bir projede/çalışmada görev aldınız mı?

_____Evet _____Hayır

Evet ise, lütfen proje(ler)inizden birini seçiniz, projenizi ve deneyimlerinizi kısaca açıklayınız. (Göreviniz, katıldığınız zaman (orta okul/lise/üniversite) vb.)

_____

_____

8) Okul sonrası programlara/aktivitelere katıldınız mı? (Gönüllü çalışmalar, öğrenci kulüp aktiviteleri, kurslar, seminerler...) _____Evet _____Hayır

Evet ise, lütfen kısaca açıklayınız. (Ne hakkındaydı, rolünüz neydi vb.)

_____

_____

Figure A.1. Demographic Information Form.

APPENDIX B: STEM AWARENESS OPEN-ENDED QUESTIONNAIRE

FeTeMM'e İlişkin Açık Uçlu Sorular

Bölüm 1: Aşağıdaki soruları cevaplayınız.

1) Aşağıdaki alanlar sizin için ne ifade ediyor? Tanımlayınız.

a. Fen (Science):

b. Teknoloji (Technology):

c. Mühendislik (Engineering):

d. Matematik (Mathematics):

2) FeTeMM eğitimini (fen, teknoloji, mühendislik, matematik eğitimi) (İng.: STEM Education) duydunuz mu? Evet Hayır

a. Cevabınız "Evet" ise, tanımlayınız.

b. Cevabınız "Hayır" ise, sizce ne olabilir?

Figure B.1. STEM Awareness Open-Ended Questionnaire.

Bölüm 2a: Verilen metini okuyarak metine ilişkin soruları cevaplayınız.

Mikrobiyolojik Korozyon

Korozyon, metal veya metal alaşımlarının bulunduğu ortam ile kimyasal veya elektrokimyasal tepkime vererek bozunması ve tahribata uğraması olayıdır. Suyun yüksekten daha düşük seviyeye akışı gibi, bütün doğal olaylar da mümkün olabilen en düşük enerji seviyeli hale ulaşacak şekilde gerçekleşir. Bu bakış açısıyla, demir ve çelik de daha düşük enerjili hale dönüşürken, doğal ortamlarda mevcut oksijen ve su ile birleşerek, orijinal demir cevherinin kimyasal yapısına benzer şekilde, pasif korozyon ürünü olan demir oksitleri (pas) oluşturur. Deprem, iklim değişiklikleri vb. doğal afetler gibi korozyon da içme suyu, petrol ve doğal gaz boru hatları, köprüler, yapılar, konutlar, otomobiller gibi hemen hemen her yapıda riskli ve oldukça maliyetli hasarlara sebep olmaktadır. Korozyon, her yıl milyarlarca dolar kayba yol açan en ciddi sorunlardan biri olarak bilinmektedir.

Korozyon harcamaları üzerine ABD, İngiltere, Japonya, Avustralya, Kuveyt, Almanya, Finlandiya, İsviçre, Hindistan ve Çin'i de içine alan çok sayıda ülkede çeşitli araştırmalar yapılmıştır. Yapılan araştırmalardan çıkarılan ortak sonuç, ülkelerin yıllık korozyon harcamalarının Gayri Safi Milli Hasılanın (GSMH) % 1'i ile % 5'i arasında değiştiğini göstermektedir. Türkiye için bu konuda yapılmış resmi bir çalışma bulunmamaktadır. Mikrobiyolojik etkiden kaynaklanan korozyon olarak bilinen bir diğer adıyla biyokorozyon olarak da ifade edilen mikrobiyolojik korozyon (Microbiological Influenced Corrosion, MIC); mikrop, bakteri ve mantar gibi mikroorganizmalar tarafından başlatılan veya hızlandırılan korozyondur. 100 yılı aşkın bir süre önce ortaya çıkarılan MIC'in, modern endüstriyel sistemler için ciddi bir problem olduğunun farkına son 30 yılda varılmıştır. Mikrobiyolojik korozyon, metal ve yapı malzemelerine olan korozyon zararlarının yaklaşık % 20'sini oluşturmaktadır. Dünya genelinde MIC'in direkt olarak sebep olduğu zararın yıllık 30– 50 Milyar $ mertebesinde olduğu tahmin edilmektedir. ABD sanayi, boru hatlarında meydana gelen korozyonun % 15-30'unu oluşturan MIC ile mücadele etmek amacıyla, sadece doğal gaz endüstrisinde yılda 1,2 Milyar $ harcama yapmaktadır. Özellikle enerji ve petrol sanayinde, mikrobiyolojik korozyondan kaynaklanan yangın problemleri gibi zaman zaman ciddi hasarlarla sonuçlanan bir çok soruna yol açmaktadır.

http://www.metalurji.org.tr/dergi/dergi169/d169_4045.pdf adresinden uyarlanmıştır.

Figure B.1. STEM Awareness Open-Ended Questionnaire (cont.).

Soru 1: Okuduğunuz metinde Fen (Science), Teknoloji (Technology), Mühendislik (Engineering), Matematik (Mathematics) alanları nasıl yer almaktadır?

a. Fen (Science):

b. Teknoloji (Technology):

c. Mühendislik (Engineering):

d. Matematik (Mathematics):

e. FeTeMM alanları dışında bu konunun ilgili olduğunu düşündüğünüz alanlar var mıdır? Varsa ne şekilde ilgilidir?

Soru 2: Mikrobiyolojik korozyonun günlük hayattaki etkilerini azaltma üzerine bir proje gerçekleştirmek isteyen bir matematik/fen/teknoloji öğretmeni olarak nasıl bir yol izlersiniz? Ne tür desteğe ihtiyaç duyarsınız?

Figure B.1. STEM Awareness Open-Ended Questionnaire (cont.).

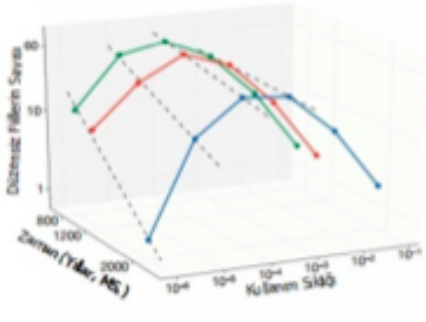
Bölüm 2b: Verilen metini okuyarak metine ilişkin soruları cevaplayınız.

Radyoaktif Yüklemler

Geçmiş zamanının sonu 'ed' ile biten (Ör: yardım etti – *helped*) normal yüklemlerin yanısıra, kural dışı yüklemlerin geçmiş zaman formlarının ne olacağının belli olmaması (ör: *get-got*; *buy-bought*) İngilizce öğrenmeye başlayanların kabusudur. Ama hâlâ pes etmemiş olanlar sevinebilirler. Harvard Üniversitesi'nden bir matematikçi, yardımlarına koşuyor. Tabii biraz beklemeleri gerekecek.

Erez Lieberman adlı matematikçinin arkadaşlarıyla gelişirdiği formül, kuraldışı bir yüklemin ne zaman normal yüklemler safına katılacağını öngörüyor. Formül, yüklemlere (Parçacık fiziğinde kararsız ağır parçacıkların, radyoaktif bozunmayla daha küçük ama kararlı parçacıklara bölünmesinde olduğu gibi) "yarılanma ömürleri" biçiyor. Yani belli bir gruptaki kural dışı parçacıkların yarısının ne kadar sürede normal yüklemlere dönüşeceğini hesaplıyor. Yarılanma ömrü, yüklemin ne kadar popüler olduğuna bağlı: ne kadar sık kullanılıyorsa, normale dönüşmesi o kadar uzun zaman alıyor.

Örneğin, '*have*' ve '*hold*' yüklemlerinin geçmiş zamanları kural dışı ('*had*' ve '*held*'). Ama have yükleminin kullanımı, 'hold'unkinden 100 kat daha fazla. Dolayısıyla, 'held' in 'holded' haline dönüşmesi için geçecek zamanın yalnızca 5,400 yıl olmasına karşılık, 'had'in 'haved' haline gelmesi, 7 kat daha uzun zaman alacak, yani 38.800 yıl sonra gerçekleşecek. Formülünü oluşturmak için Lieberman, Eski İngilizce'den çoğu artık normalleşmiş olan 177 kuraldışı yüklem seçmiş ve bunları modern İngilizce'de hangi sıklıkla (normal biçimde) ortaya çıktıklarına göre gruplara ayırmış. Normalleşmiş formların modern dilde ortaya çıkış sıklığıyla, kural dışı formların kayboluş süreleri arasında da bir ilişki belirlemiş.



Bundan sonra, düzenli fiile dönüşecek düzensiz fiillerin, '*slink*' (sürünerek ilerlemek, sinsice yürümek) gibisinden az kullanılanlar olması bekleniyor. Belki de birkaç bin yıl sonra da "*That was an interesting story I just readed*" (Az önce okuduğum, ilginç bir hikayeydi) demek normal olacak. Burada daha ilginç olan, kuraldışı yüklemlerin en ilginçlerinden biri olarak tüm zaman kipleri hep aynı olan olan (*read*) yükleminin de normale dönüşü anlamına gelmesi. Ne diyelim, bu televizyon çağında okumak da artık o kadar sık kullanılan bir yüklem olmuyor sanki.

http://www.biltek.tubitak.gov.tr/haberler/matematik/s-485-10.pdf adresinden uyarlanmıştır.

Figure B.1. STEM Awareness Open-Ended Questionnaire (cont.).

Soru 1: Okuduğunuz metinde Fen (Science), Teknoloji (Technology), Mühendislik (Engineering), Matematik (Mathematics) alanları nasıl yer almaktadır?

a. Fen (Science):

b. Teknoloji (Technology):

c. Mühendislik (Engineering):

d. Matematik (Mathematics):

e. FeTeMM alanları dışında bu konunun ilgili olduğunu düşündüğünüz alanlar var mıdır? Varsa ne şekilde ilgilidir?

Soru 2: Radyoaktif fiiller ile ilgili bu haberi okudunuz ve ilginizi çekti. Bir matematik/fen/teknoloji öğretmeni olarak dersinizde bu konuya yer vermek isteseniz, nasıl yapardınız?

Katkınız için teşekkürler.

*Bu çalışmanın sonuçları hakkında bilgi almak isterseniz ozencsecil@gmail.com adresinden iletişime geçebilirsiniz.
**Araştırmada katılımcıların isimleri gizli tutulacaktır.

Figure B.1. STEM Awareness Open-Ended Questionnaire (cont.).

APPENDIX C: STEM-A SEMI-STRUCTURED INTERVIEW PROTOCOL

FeTeMM Farkındalığı Görüşme Soruları

Merhaba hoş geldin. FeTeMM ile ilgili görüşme yapmayı kabul ettiğin için teşekkür ederim.

(i) Öncelikle kendini kısaca tanıtabilir misin?

(ii) FeTeMM kısaltması ile (İngilizce: STEM) daha önce karşılaştın mı?

a. Evet ise; Açılımı nedir? Nerede ve nasıl karşılaşmıştın hatırlıyor musun? Peki, nasıl tanımlarsın?

b. Hayır ise; Sence FeTeMM (fen, teknoloji, mühendislik, matematik) nedir? Sen nasıl tanımlarsın?

(iii) Fen, teknoloji, mühendislik ve matematiği kısaca ve ayrı ayrı tanımlar mısın? *(Örneğin fen nedir? Senin için ne ifade ediyor?)*

----------**FeTeMM'e İlişkin Birinci Okuma Metni Veriliyor**----------

3D Yazıcılar

Prototipleme (ilk üretim), imalatı yapılacak ürünün imal edilmeden önce ön şeklinin veya modelinin oluşturulması olarak tanımlanabilir. Ön şekil prototiplemede, yanlış geometriler, yanlış malzeme seçimi ve işlemler tasarım aşamasına dönülerek düzeltilir, müdahale edilir. Nasıl bir ürünün ortaya çıkacağı henüz tasarım aşamasındayken görülmüş olur. Prototipler ve bazı son ürünler, günümüzde özel 3D baskı makinaları ile başlangıç noktasından katman katman yüzeye çıkarak oluşturulur. 3D Baskı; bir yazıcı kullanılarak bilgisayar destekli tasarım (CAD) programları yardımıyla tasarlanmış herhangi bir elektronik veriyi kalıp, model vb. araç gereç ihtiyacı duymadan 3D verisini makineye göndererek kat kat malzeme ekleyerek 3 boyutlu fiziksel parça imalatı yapmaktır. Tasarımcı makinaya üç boyutlu CAD yazılımının stereolitografi biçimi denen endüstri standart dosyasını gönderir. Bu program ile iletişim kurabilen 3D baskı aleti, dosyayı okur, modeli paralel enine kesitlere bölerek 0,03-0,2 mm (20-200 μm) kalınlığındaki tabakalar inşa eder, önceki enine kesit üzerinde biriktirir. Bu işlem: sıvı, toz veya plastik ham madde ile oldukça kısa zamanda gerçekleştirildiğinden endüstride kullanımı hızla artmaktadır. Bu süreç birçok uygulama için ekonomiktir.

Figure C.1. STEM-A Semi-Structured Interview Protocol.

1) Sence, *3D Yazıcılar* metninde bahsedilen konuyu düşündüğünde fen, teknoloji, mühendislik, matematik alanları nasıl yer almaktadır?
2) Sence, *3D Yazıcılar* bu dört alandan en çok hangisi ile ilişkilidir? Neden?
3) Sence, *3D Yazıcılar* fen, teknoloji, mühendislik, matematik alanlarından en az hangisi ile ilişkilidir? Neden?
4) Peki metinde anlatılan *3D Yazıcılar* örneğinde bu dört alan birbiri ile nasıl ilişkilidir?
5) Fen, teknoloji, mühendislik, matematik alanlarından kişileri düşünelim. Sence, bu kişiler *3D Yazıcılar* üzerine olan çalışmalara nasıl katkıda bulunurlar?
6) *3D Yazıcılar* konusu ile ilgili çalışan bir kişi olsaydın, ne gibi bilgi ve becerilere ihtiyaç duyardın? Neden?
7) *3D yazıcıları* bir öğretmen olarak eğitimde kullanmak için bir ekip kuracak olsan, nasıl bir yol izlersin? (kimlerden oluşur, bilgi-beceri donanımları, yöntem, nasıl birlikte çalışırlar vb.)
8) *3D Yazıcılar* ile ilgili gerçekleşecek olası bir gelişme sence hangi alanları etkiler? Nasıl?

Figure C.1. STEM-A Semi-Structured Interview Protocol (cont.).

----------**FeTeMM'e İlişkin İkinci Okuma Metni Veriliyor**----------

Gece Uçuşları

İngiltere'nin Reading ve Leeds Üniversitelerinden araştırmacıların ortaklaşa yaptıkları bir çalışma, küresel ısınma bakımından gece uçuşlarının, gündüz yapılanlara göre daha olumsuz etkili olduğunu ortaya koydu. Çalışmaya göre etki, kışın daha da artıyor.

Uçuşların ısınmaya katkısı, uçuş sırasında ortaya çıkan ve gökyüzünde beyaz çizgiler halinde seçilebilen bulutsu yoğuşma izleri aracılığıyla gerçekleşiyor. Yerden en az 8 kilometre yükseklikte oluşabilen ve sahte bulutlar diyebileceğimiz bu izlerin iklime iki etkisi var; ancak bunlar birbirine zıt. Birincisi, ısıyı atmosferde hapseden 'battaniye' etkisi, ikincisi de Güneş ışınlarını uzaya yansıtmalarıyla gerçekleşen "serinleme" etkisi. Bu iki etki gündüzleri belirli ölçüde dengelense de, ısınma etkisi diğerini biraz aştığı için, küresel ısınmaya daha fazla katkısı oluyor. Ancak asıl sorun, Güneş'in yokluğuna bağlı olarak, serinleme etkisinin ortaya çıkmadığı gece saatleri. Etkinin kışın daha da güçlü olmasının nedeniyse, çok yüksek mesafelerde havadaki nemin daha yüksek olmasına bağlı olarak yoğuşma izlerinin de artması. "Uçuşların iklime genel etkisi, şu anda çok da fazla değil" diyor Leeds Üniversitesi'nden Piers Forster. "Ancak, hızla artmakta olan hava trafiği, bu etkileri daha ayrıntılı biçimde ele almayı gerekli kılıyor."

Figure C.1. STEM-A Semi-Structured Interview Protocol (cont.).

1) Sence, *Gece Uçuşları* metninde bahsedilen konuyu düşündüğünde fen, teknoloji, mühendislik, matematik alanları nasıl yer almaktadır?
2) Sence, *Gece Uçuşları* bu dört alandan en çok hangisi ile ilişkilidir? Neden?
3) Sence, *Gece Uçuşları* fen, teknoloji, mühendislik, matematik alanlarından en az hangisi ile ilişkilidir? Neden?
4) Peki metinde anlatılan *Gece Uçuşları* örneğinde bu dört alan birbiri ile nasıl ilişkilidir?
5) Fen, teknoloji, mühendislik, matematik alanlarından kişileri düşünelim. Sence, bu kişiler *Gece Uçuşları* üzerine olan çalışmalara nasıl katkıda bulunurlar?
6) *Gece Uçuşları* konusu ile ilgili çalışan bir kişi olsaydın, ne gibi bilgi ve becerilere ihtiyaç duyardın? Neden?
7) Bir uçuş firmasında çalışıyorsun ve gece uçuşlarının oluşturduğu bu etkiyle ilgili (firmanızın uçuşlarını da değerlendirerek) senden bir rapor hazırlaman ve çözüm sunman istendi. Bu raporu hazırlama ve çözüm bulma sürecinde konuyla ilgili nasıl yol izlerdin ve destek alırdın?
8) *Gece Uçuşları* ile ilgili gerçekleşecek olası bir gelişme sence hangi alanları etkiler? Nasıl?

Figure C.1. STEM-A Semi-Structured Interview Protocol (cont.).