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Revealing Pre-service Teachers' Mind Maps on STEM Education through STEM Images*

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Abstract

STEM education (based on the integration of the science, technology, engineering and mathematics disciplines) has recently been an integral part of education system and curriculum in many countries aiming to be more technologically competitive in this age of innovation. While the importance of STEM education has gradually increasing in education system with the complexities of today's world, revealing pre-service teachers' mind maps on STEM education and preparing them for STEM education is a crucial issue since the readiness of the teachers affects the quality of education. In this context, the aim of this study is to reveal pre-service science and mathematics teachers' mind maps on STEM Education through STEM images. The research group consists of 6 pre-service teachers (3 of them are pre-service science teachers (PST) and 3 of them are pre-service mathematics teachers (PMT)) who are 4^{th} grade level students from a public university in Istanbul, Turkey. In current research, case study design was used. The data of study were collected through drawings and focus group discussion. The data were analyzed with thematic analysis through Integrated Teaching (IT) Framework. As a result, 41 codes about pre-service teachers' mind maps on STEM education were determined under 14 categories of 5 themes of IT Framework. The results of this study are crucial in terms of having potential to guide educational policy makers, curriculum developers, researchers and in-service and pre-service teachers about STEM education.

Keywords: Mind Maps on STEM Education; Pre-Service Mathematics Teachers; Pre-Service Science Teachers; STEM Education; STEM Images

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INTRODUCTION

One of the most important aims of education system is to raise our students with key skills and competences which are required for today's complex life. In this age of innovation, we should give students an education to make them be able to think, be able to explain what they think, be able to make research and analyze what they get. In recent years, many countries around the world strive to organize their education system to be more technologically competitive and they build the capacity of students to become more innovative by developing their 21st century skills such as critical thinking, creativity, problem-solving, collaboration etc. At this point, STEM education (based on the integration of the science, technology, engineering and mathematics disciplines) has been an integral part of our education system and curriculum in Turkey as well as in other countries to enhance students' in-depth understanding of each discipline, key skills and competences like inquiry, problem solving, critical thinking, communication and collaboration needed for their both daily and professional lives. While the importance on STEM education has gradually increasing in education system with the complexities of today's world, revealing pre-service teachers' mind maps on STEM education and preparing them for STEM education is important issue since the readiness of the teachers affects the quality of the education. In this context, the purpose of the current research was to reveal pre-service teachers' mind maps on STEM Education. That is, how pre-service teachers structure STEM Education in their minds was investigated in this study.

Research question of study

(1) What are the pre-service science and mathematics teachers' mind maps on STEM education?

STEM education

STEM education has been defined in many different forms ever since it has become a greater focus in learning environments. However, it is obvious that there is a need to better define what STEM education is rather than defining only the terms: science, technology, engineering, and mathematics in parentheses (Brown, Brown, Reardon & Merrill, 2011). STEM education is an interdisciplinary approach that brings four disciplines of science, technology, engineering and mathematics together in a real-life context (Bybee, 2010; Corlu, Capraro and Capraro, 2014) with the learning approaches required to find a solution to a problem (Fioriello, 2010; Lantz, 2009). Merrill (2009) stated that "STEM teaching and learning focuses on authentic content and problems, using hands-on, technological tools, equipment, and procedures in innovative ways to help solve human wants and needs." According to Martín-Páez et al (2019), STEM education help students improve deeper understanding of each STEM discipline contextualizing concepts. STEM education also focuses on motivating students and improving their integrated STEM knowledge and skills (Rinke et al., 2016). According to National Science Board (2007), STEM education can contribute to improve critical thinking, analytical thinking and problem-solving skills of students by leading to better real-world connections. Although the emphasis on STEM education has been increasing day by day in education system, most of the teacher education programs have not been making enough effort to prepare pre-service teachers for STEM education. Ejiwale (2013) stated that one of the important barriers to successful implementation of STEM Education is poor preparation and shortage in supply of qualified STEM teachers. It is critical issue to prepare pre-service teachers for teaching STEM-subjects (Honey et al, 2014) since it is expected that todays' teachers should be able to raise students knowing how to solve problems that they will face in their careers as scientists and engineers (Wang et al, 2020). Preparing teachers for STEM education should be a national priority since the readiness of the teachers affects the quality of the given education and also teachers are the determinants of the *"quality and quantity of K-12 STEM education"* (Nadelson et al., 2012, p.69). Radloff and Guzey (2016) emphasized that it should be known how pre-service teachers conceptualize STEM education for creating effective pre-service teacher trainings for STEM.

Literature review

Perceptions of STEM education

Developing pre-service teachers' conceptions of STEM education is one of the most critical points to create effective STEM based training in future classrooms. If pre-service teachers' conceptions improve, they can feel more comfortable with STEM implementations (Radloff and Guzey, 2016). In the literature, there are several studies which were conducted on teachers' perceptions, views, attitudes and professional development on STEM education (Asghar et al., 2012; Corlu, Capraro and Corlu, 2015; Dare et al, 2019; Han et al., 2015; Nadelson et al., 2013; Ring et al., 2017; Stubbs and Myers, 2016). Bell (2016) stated that the teacher perception, personal knowledge and understanding on STEM education, was associated with the effectiveness of STEM implementation in the classroom environment. From this perspective, Asghar et al. (2012) reported a professional development program to improve secondary science and mathematics teachers' abilities in teaching STEM education through problem based approach. Nadelson and colleagues (2013) also implemented a professional development program for elementary teachers and investigated their attitudes and efficacy for teaching inquiry-based STEM. In addition, some studies investigated in-service and pre-service teachers' views, understanding or mental readiness on integrated STEM education (Corlu, Capraro and Corlu, 2015; Eroğlu and Bektaş, 2016; Han et al., 2015; Radloff & Guzey, 2016; Stubbs and Myers, 2016; Wong et al., 2016) and were conducted with science and mathematics teachers generally. These studies revealed that in-service or pre-service teachers showed positive attitudes or represented the importance of STEM education; but they have some difficulties to transfer their knowledge into implementation in classroom setting. In other words, they encounter some challenges while implementing STEM and they do not exactly know how they should be deal with them. It can be seen that the professional development is needed for both in-service and pre-service teachers, because it provides to build self-construction of pre-service teachers in order to understand and implement STEM education while in-service teachers can develop their existing skills in terms of STEM teaching. At this point, teachers need to interpret the curriculum flexibly, and they should be able to go outside the curriculum in terms of their students' readiness and interests. Sanders (2009) stated that teachers are responsible for integrating their subject area with other STEM disciplines beyond being expert on their own subject area. From this perspective, in order to achieve effective STEM implementations, understanding and assessing teachers' readiness in terms of pedagogical and content knowledge is important. In other words, STEM education requires that teachers should be able to utilize natural and active exchanges of knowledge, skills, and beliefs between all STEM disciplines (Corlu, Capraro and Capraro, 2014).

Studies show that in most of the schools, STEM disciplines are thought in a disjointed manner and so STEM cannot integrated in an effective way (Atkinson and Mayo, 2010) and also STEM education generally focuses on the science and mathematics disciplines by ignoring the engineering and technology while implementing integrated curriculums (McDonald,2016; English, 2015). However, in this digital world engineering and technological skills are also needed for future life (Hernandez et al., 2014). Namely, students should be educated based on these skills in order to adapt to future living conditions and to be successful in new business areas with the ability of assessing the problems based on different disciplines. At this point, STEM education has a crucial role in training technologically and scientifically literate individuals with reasoning and creative thinking skills, and with self-esteem (Uğraş and Genç, 2018). From this perspective, Wang at al. (2011) stated that "teachers in different STEM disciplines have different perceptions about STEM integration and that leads to different classroom practices" (Wang at al., 2011, pp.1). So, teacher education programs should focus on science, technology, engineering and mathematics disciplines together and teachers from different disciplines should work in a collaborative manner (Uğraş and Genç, 2018) in order to make the learning authentic. Brown, Brown and Merrill (2011) also introduce that teachers from different disciplines should collaborate and share their experiences on their expert area on a daily basis. In this way, the aims of STEM education can be also achieved in an effective way.

To get the opinions of teachers in different disciplines about STEM education is important to understand that how they structure different concepts in their minds in an individual and unified way. That is why; this present study aims to reveal the mind maps of pre-service teachers from different disciplines on STEM education in terms of the conception of each STEM areas individually and in an integrated manner.

All of these statements are required for a quality STEM education, but it is important that teachers are mentally ready for such an educational approach or not. One of the best ways to expose teachers' mind maps is visuals and some studies were conducted by using visual materials to determine teachers' perceptions on STEM education (Akaygün and Aslan-Tutak, 2016; Sümen and Çalışıcı, 2016). In the research of Akaygün and Aslan-Tutak (2016), they studied with pre-service chemistry and mathematics teachers and determined their conceptions by the posters prepared in groups before and after the implementation. In Sümen and Çalışıcı's study (2016), STEM education activities were performed as part of an environmental education course with pre-service primary school teachers and their views were taken by mind maps. Both of the studies showed that pre-service teachers have a rich conceptual structure regarding STEM education and also associate STEM fields both with one another. On the other hand, in the literature, little attention is given on revealing the views or perceptions of pre-service teachers from different disciplines. Under the light of previous studies in the literature and definition of STEM education, this present study focused on mind maps of pre-service teachers from different disciplines (science and mathematics departments which are related with STEM disciplines).

Conceptual framework

In qualitative studies, researchers use some frameworks while analyzing research data to ensure the academic rigor and trustworthiness (Creswell, 2007; Denzin & Lincoln, 2008; Miles et al., 2014) and also to organize the condensed research results in a meaningful way. Moreover, the frameworks -theoretical or conceptual- also guide the study results to be more valuable, thought provoking, and resourceful for the other researchers.

In this manner, frameworks which are derived from related concepts ensure a logical structure for researchers while revealing themes or codes derived from study results (Savin-Baden and Howell Major, 2013) and helps researchers to determine the key points or concepts for their studies. From this perspective, STEM: Integrated Teaching (IT) Framework (Corlu, 2014, 2017; Corlu, Capraro & Capraro, 2014) guided this qualitative study as conceptual framework.

STEM: Integrated Teaching (IT) framework

STEM education is defined as an interdisciplinary approach that integrates at least two STEM the disciplines together according to their specific knowledge and skills and also it is shaped as a result of experiences of students and teachers (Corlu, Capraro & Capraro, 2014). In the light of this definition of STEM, STEM: Integrated Teaching (IT) Framework was constructed around four domains (Figure 1).

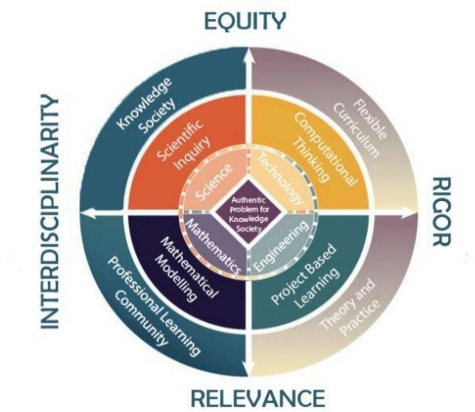

Figure 1 STEM: Integrated Teaching (IT) Framework (Corlu, 2017)

These domains from outer to inner layer are principles, social products, cognitive process and scope and sequences (Corlu, 2017). Firstly, the integrated teaching principles are determined as equity-relevance and interdisciplinarity-rigor. Equity-Relevance advocates that each student's interest and life experiences should be considered. Interdisciplinarity-rigor also focuses on making interdisciplinary applications without neglecting the specific knowledge and skills of main discipline (Aşık, Doğança Küçük, Helvacı and Corlu, 2017).

As second domain, the social products include knowledge society, professional learning community, flexible curriculum in classroom, and theory and practices. According to this framework, knowledge society should not be limited to school environment. That is, when knowledge is applied outside of the school or in real-life conditions, knowledge society can be created. Beyond this, teachers are a part of professional learning community and so they should bring and place learning culture to their school. Also, teachers should make some investigations on STEM and should implement them in their lessons in collaboration with researchers or teachers. Finally, the curriculum should be flexible while applying STEM in classrooms, that is, it should be dynamic and open to change (Aşık, Doğança Küçük, Helvacı and Corlu, 2017; Corlu, 2017).

The cognitive processes domain includes scientific inquiry, project-based learning, computational thinking, and mathematical modeling. These processes are related with the STEM disciplines (science, technology, engineering and mathematics) which create the last domain of the framework, scope and sequences.

Lastly, Authentic Problem of Knowledge Society (APKS) which is a type of information-oriented, open-ended problem is centered in the framework (Aşık, Doğança Küçük, Helvacı and Corlu, 2017; Corlu, 2017).

From these perspectives, pre-service science and mathematics teachers' STEM images or concept maps in their minds and interview were investigated based on STEM: Integrated Teaching (IT) Framework (Corlu, 2017) in order to reveal pre-service teachers' mind maps on STEM education through STEM images.

METHODOLOGY

Research design

Case study design, one of the qualitative methods, was used in this research. Case study is a research methodology that investigates a phenomenon within its real-life context and provides an in-depth descriptive and exploratory analysis of individuals, groups or events to researchers (Yin, 2013).

This study is a descriptive and exploratory analysis of six pre-service teachers' images about STEM Education in their minds. In the scope of the study, initially, both pre-service science and mathematics teachers were asked to visualize and draw images about STEM Education in their minds. After each pre-service teachers drew, researchers assessed the drawings. Then, focus group discussion was conducted with participants to collect in-depth data about pre-service teachers' mind maps on STEM Education. The focus group discussion was guided by researchers with open-ended questions (Appendix A) and pre-service teachers' deep understandings about STEM education were revealed.

Research group

The research group of current study consists of 6 pre-service teachers (3 pre-service science teachers and 3 pre-service mathematics teachers) who are 4th grade level students from a public university in Istanbul, Turkey. The sample was chosen from pre-service science and mathematics teachers who participated to 'STEM Education Program' during five months in STEM center. In this center, pre-service teachers gained knowledge and experiences about STEM Education as both theoretically and practically. They learned to design and implement the lesson based on STEM approach. Pre-service teachers participated in this research voluntarily.

Data collection

The data was collected in two steps after pre-service teachers participated to 'STEM Education Program' during five months in STEM center. In the first step of data collection process, pre-service science and mathematics teachers were asked for drawing about their STEM images in their minds and it took approximately 20 minutes. After researchers assessed pre-service teachers' drawings, they prepared open-ended questions (Appendix A) and made focus group interview with pre-service teachers. The focus group discussion with six pre-service teachers took approximately 42 minutes. During discussion, researchers recorded pre-service teachers' responses and dialogues with each other.

Data analysis

Pre-service teachers' drawings about STEM education and transcribed discussions were assessed with thematic analysis through Integrated Teaching (IT) Framework which was constructed around four domains of STEM (Corlu, 2017). In data analysis process, codes were created based on the categories under the themes of IT Framework. The themes represents the domains of IT Framework and categories consist of principles in accordance with these themes. The determined codes from collected data were grouped for each principle and this analysis was approached in a deductive way (Creswell, 2007; Savin-Baden and Howell Major, 2013) which is a thematic analysis of data from predetermined framework (Frith and Gleeson, 2004). That is, according to the categories under themes of IT Framework, codes were determined from pre-service teachers' drawings and views about STEM Education on transcript of focus group discussion.

Results

As a result of data analysis, 41 codes about pre-service teachers' mind maps on STEM education were determined based on 14 categories under 5 themes of IT Framework. The whole research results in terms of themes, categories and codes were represented in table 1.

Table 1. Pre-service Teachers' Mind Maps on STEM Education

Themes	Categories	Codes
Authentic Problem for Knowledge Society (APKS)		- Real world relevance - Problem solving - Concretization - Presenting a purpose
Principles of STEM Education	Equity-Relevance	-Students' learning ability -Multiple intelligence
	Interdisciplinarity-Rigor	-Making connections among events -Using multiple disciplines -Using STEM as a tool
Social Products of STEM Education	Knowledge society	-Interpretation ability -Versatile growth -Qualified individuals
	Professional learning community	-Interdepartmental meeting
	Flexible curriculum	-Timing -Direction on curriculum about STEM implementation -Flipped learning
	Theory and Practice	-Visualizing learning -Readiness of teachers -Lack of application -Theory into practice
Cognitive Process in STEM	Scientific inquiry Project based learning Computational thinking Mathematical modeling	-Higher order thinking -Rationality -Meaningful learning -Tools *(Modeling, Concept maps, Experiments, Direct instruction, Asking questions)* - STEM as a method
Scope and Sequences of Integrated Teaching *(Role of disciplines in STEM)*	Science	-Physics -Chemistry -Biology -(Lab) experiments -Scientific inquiry -Scientific enterprise -Understanding natural world
	Technology	-Device *(microscope, computer, 3D writers)* -Augmented reality -Human benefit *(digital world, robotics)*
	Engineering	-Human benefit (purpose), -Product/structures *(prototype, machines)* -Process *(design and construction)* -Human endeavor
	Mathematics	-Using language or tools -Understanding and using pattern/algorithm -Analytical thinking

DISCUSSION AND CONCLUSION

The aim of this study was to reveal pre-service science and mathematics teachers' mind maps on STEM education through drawings and focus group discussion. In the light of this aim, 41 codes were determined under 14 categories which are derived from 5 themes *(APKS, Principles of STEM, Social products, Cognitive process, Scope and sequences) of* IT Framework (Table 1). In this part, determined codes from pre-service teachers' drawings and quotations about STEM education in transcripts were discussed under each theme in detail.

The Theme of Authentic Problem for Knowledge Society (APKS)

Authentic Problem for Knowledge Society (APKS) is a type of problem which is related with real-life and also based on 21st century interests of students and teachers; and takes place in the center of STEM lessons. Also, it should be a well-defined problem which is focused on the 21st century dynamic and complex structure of life and also it should not direct the students to a single predetermined correct solution (Corlu, 2017). From this definition, four codes were determined from pre-service teachers' drawings and views in interview. In some of the participants' drawings (Figure 2 & Figure 3), it was seen that they placed the APKS at the center and one of them defined it as a lost key which means it should be found or solved.

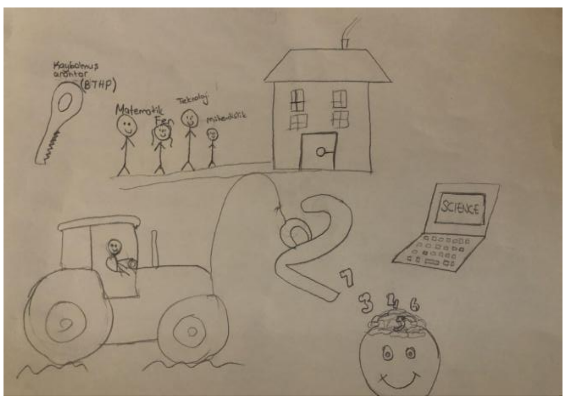

Figure 2 Drawing of PST2 on STEM

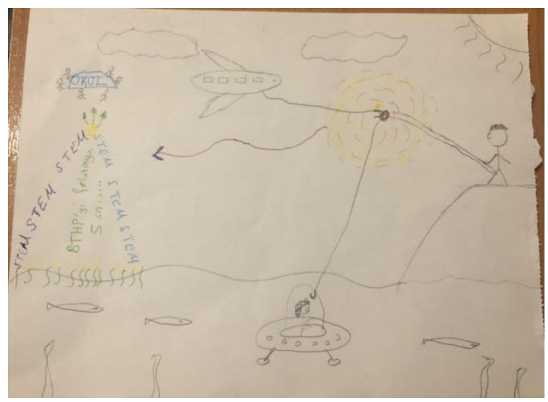

Figure 3 Drawing of PMT3 on STEM

Beyond this, during the interview some of the participants' views on APKS are as the following:

PST2: "Starting point of STEM"

PMT1: "... APKS is a problem that I encounter in daily life, how do I create a solution."

PST4: "...The most beautiful part of STEM is that it presents a problem to you, giving the child a purpose. So your goal is to solve this problem."

PMT5: "...We had written a question about how to fit the luggage in the hangars of Turkish Airlines (THY), so we had done research on the internet, then the child used his mathematical skills and got a new knowledge and solved a problem. It's what we call an APKS."

From these quotations, we can see that pre-service teachers related the APKS with real world problems that should be solved to reach a purpose. Beyond this, some of them thought that APKS is something that concretize the issues occurring around us: *PST2: "...I think it's something we use to concretize, because children can imagine, but they find it difficult to perceive in a concrete way... In fact, this is an application we combine it in this way."* In the literature, the importance of problem statement in STEM education was also stated (Aşık et al., 2017; Morrison, 2006; Bybee, 2010). As understood from its name, the problems should be also authentic to make connections with real-world situations (Herrington & Oliver, 2000; Aina, Aboyeji & Aboyeji, 2015). At this point, Mims (2003) stated that *"Authentic learning is a pedagogical approach that allows students to explore, discuss, and meaningfully construct concepts and relationships in contexts that involve real-world problems and projects that are relevant to the learner"* (Mims, 2003, p.2). That is why; in the light of the pre-service teachers' views on APKS, the results related to the literature have emerged. That is, while implementing STEM lessons, a problem should be centered in this process to make more meaningful learning with a real-world related purpose. From these perspectives, four general codes were emerged for APKS domain: Real world relevance, problem solving, concretization and presenting a purpose.

The Theme of Principles of STEM Education

According to IT Framework, there are some principles that guide the teachers while implementing integrated teaching and also provide balance to them in their actions towards STEM. These principles are: Equity-Relevance and Interdisciplinarity-Rigor (Corlu, 2017). In the light of these themes, four codes were emerged from data. All of the participants stated and defined STEM as an interdisciplinary approach in both their drawings (Figure 4, 5 and 6) and the interviews. That is, they took all of the STEM disciplines in relation and also presented some examples for STEM and implementation process.

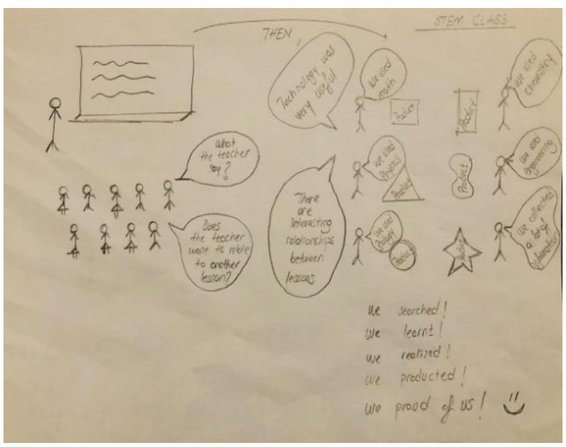

Figure 4 Drawing of PMT1 on STEM

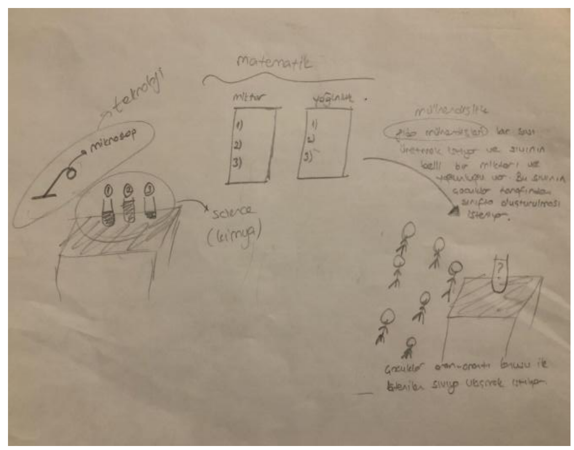

Figure 5 Drawing of PMT5 on STEM

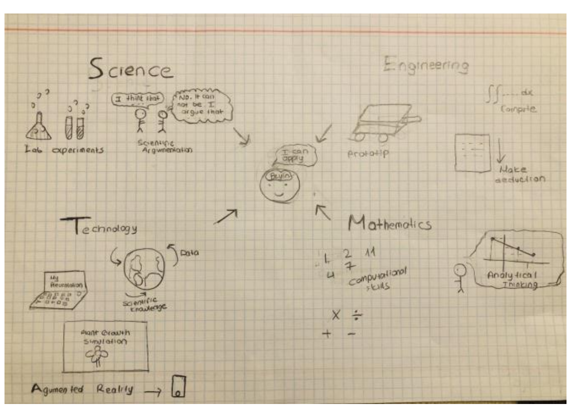

Figure 6 Drawing of PST4 on STEM

From these drawings, we can understand that participants know about the meaning of STEM which combines different disciplines within a concept and also during this process, they also aware of that students make some research, realize the situation and produce a product. In addition, during the interview, they stated STEM as a whole and also some problems on implementing STEM or what is STEM or not:

PST4: "You know how continents on the Earth are separated from each other by earthquakes or volcanic activities. It's like STEM. You know, like the parts of a whole, in fact, we take them apart, but in fact, it's all one. It [STEM] is building up a whole."

PMT1: "I think we can't separate one from another. We use it somehow. Only in this class is a small group. But when we look at the whole, I think it is all in essence."

Therefore, participants think that STEM can be taken as a whole and it cannot be separated within its disciplines. Also, they argue that they must be experts in their field or have a deep knowledge of their fields: *PST2: "...I think this depends on the knowledge and creativity of the teacher."* At this point, it can be concluded that interdisciplinarity or using different disciplines together is important in STEM education but also teachers should have deep knowledge on their own subject area. Moreover, each student's interest and life experience should be considered as stated in IT Framework (Corlu, 2017) and participants also pointed this situation in their drawings and also interview: PST6 stated that *"None of the individuals are equal, but they must have equal rights."* When we look at the PST6 drawing (Figure 7), it is seen that girls should be also included in STEM education especially on engineering discipline. At this point, in the literature, it is also stated that the lack of women in STEM fields has been an important issue (George-Jackson, 2011; Griffith, 2010; Shapiro & Williams, 2012; Owens et al., 2018; Yang & Gao, 2019).

Figure 7 Drawing of PST6 on STEM

From these results, participants think that students have multiple intelligence level and so each of them is unique and their learning abilities are different. But also they should have the same rights in their lives since they are a part of a knowledge society. So, STEM education should be given all students without separating them by learning levels or genders, because with the help of STEM education, they make connections between events they encounter in their daily lives and prepare themselves for their future by using their STEM knowledge and skills.

The Theme of Social Products of STEM Education

According to IT framework, there are social products of STEM education which are knowledge society, professional learning community, flexible curriculum and theory and practice (Corlu, 2017). When pre-service teachers' drawings and interviews were assessed in these themes, 11 codes were determined in total. Drawings showed us that the participants were aware of that knowledge society is one of the products of STEM education. Pre-service teachers showed the knowledge society such as school environments in their drawings (See in Figure 3 and 4). Also, it is understood from the interview that they think that students create the knowledge society and in order to ensure qualified individuals, STEM education is needed by providing versatile growth of them. Some of pre-services' opinions were given at below.

PMT1: "...after we give these skills to the students, what we actually raise is in the information society."

PST4: "...More qualified individuals can grow. They can be individuals who can think and apply many things at the same time."

In addition to knowledge society, pre-service teachers mentioned about professional learning community which were placed in IT Framework (Corlu, 2017). Wang, Moore, Roehrig and Park (2011) concluded in their research that the STEM integration professional development programs improve both teachers' deeper understandings of the subjects they teach and integration of STEM disciplines. As it is understood from interviews, pre-service teachers also think that professional learning community is important part of STEM education. They especially emphasized that interdepartmental meetings contributes to acting together, effective communication and planning among different disciplines.

PMT1: "... Everyone does not good at every discipline. That is, some people good at mathematics, some people good at science, others good at different disciplines. With interdisciplinary studies, people get support from each other. For example, science teachers get support from mathematics teachers or vice versa."

PMT3: "... People having professions about STEM disciplines like scientists, physicists, chemists, biologists, mathematicians, engineers forms of professional learning community."

PST6: "... For example, when two teachers such as science and mathematics teachers come together and prepare activities together, they know what they do in their lessons better. Acting together is so important."

Flexible curriculum is another important theme as stated in IT Framework (Corlu, 2017). During interviews, the participants underlined that the curriculum should be flexible. Timing, direction on curriculum about STEM implementation and flipped learning were emphasized by them. According to Corlu, Capraro and Capraro (2014), four STEM disciplines can be understood as interrelated formation by educators with integrated curriculum. From the interviews, it was understood that participants think that teachers consider four STEM disciplines separately and have difficulty in integrating these disciplines. However, pre-service teachers especially stated that teachers from different disciplines should study and plan the lessons together and integrate these disciplines thanks to flexible curriculum.

PMT1: "...Curriculum prepared by government should be because students prepare for exams but every school or teacher can change the place of subjects. For example, when science teachers teach friction, mathematics teachers can teach fractions at priorly or the same time. Relevant subjects can be taught simultaneously. The places of subjects can be changed flexibly."

PMT3: "...Curriculum may offer options. That is, same subject, same content, same objectives but different activities, more creative, such as STEM based. Teachers can choose themselves. Curriculum can be more meaningful if it is like that. "

PST4: "...For saving of time, flipped learning can be applied. For instance, teachers want students to watch videos and get ready for activities at home. In this way, students can perceive faster and activities were done more quickly in the lessons. "

PST2: "...When I was in teaching practice, for example, when science teacher was going to teach circulatory system, she realized that students did not know respiratory system because there was not in new curriculum. However, if students do not know respiratory system, they cannot grasp circulatory system which includes the functions of lungs exactly. Therefore, she designed activity about respiratory system and then teach circulatory system. Teachers' decision about the place of subject is so important."

According to IT framework, theory and practice is another social product of STEM education. In this research, pre-service teachers mentioned about visualizing learning, readiness of teachers, lack of application and theory into practice. Corlu, Capraro and Capraro (2014) emphasized in their research that pre-service science and mathematics teachers should have more opportunities to practice for their profession in teacher education programs. Pre-services referred this issue in focus group discussion.

PST2: "...In our schools, there is a lot of theoretical knowledge in science and mathematics but experiments and practices are very few.

PST6: "...For example, students must be capable of mathematical computing of circuit design. They can do this in theoretically but can they design a new circuit in practice?"

PMT5: "... In theory, results cannot be seen concretely. However, when theory turns into practice, we can see what and how we do. For example, when we practice, we can observe how we can practice and realize the mistakes and solve problems or invent new things. In this way, we learn to cope with the difficulties.

The Theme of Cognitive Process

In this methodological integration called as integrated cognitive process methods, scientific inquiry in sciences, computational thinking in technology, project-based learning in engineering, and mathematical modeling in mathematics have been proposed. However, it should be kept in mind that teachers and students are expected to concentrate on knowledge and skills specific to their courses, not on these methods (Aşık et al., 2017). In this manner, pre-service teachers also stated various methods that can be used in STEM lessons such as modeling, concept maps, experimentation, direct instruction and asking questions. They also have drawn attention to the methods that rely on meaningful learning rather than memorization.

PMT5: "I think it provides higher order reasoning. That is, it's like having a system where the child can explain things in a really reasonable way. Maybe that's why it's not just memorization; it's like a comprehension-based thing."

PMT3: "...different tools can be used to make something reasonable."

Beyond this, some of the pre-service teachers also stated that STEM can be also a method in itself: *PST2: "...and there's a perception like that STEM is a new teaching method."*

PST6: "Actually I think of it as something. We use STEM by combining other methods. So, it can be a teaching method in itself."

At this point, it can be concluded that pre-service teachers have different views on the implementation methods of STEM education in the classroom setting. Uğraş and Genç (2018) found in their study that most adequate STEM education methods are the problem based approach, project based approach and engineering based approach in practice which are the most mentioned integrated methods in STEM education literature. Beyond this, participants also gave importance on the experience of teachers in the implementation process of STEM: *PMT1:"In fact, we can choose a lot of methods. So, it depends on the teacher, you can integrate what you want."* Nathan and colleagues (2010) also found that successful integration of disciplines in the classroom depends on the attitudes and experience of teachers towards the STEM education. So, the results of this study are related with the literature on the cognitive process of STEM education. Also according to participants' views, on the basis of cognitive process in STEM implementation, students' higher order thinking, rationality and meaningful learning can be affected in a positive way.

The Theme of Scope and Sequences of Integrated Teaching (Role of disciplines in STEM)

STEM disciplines as Science, Technology, Engineering and Mathematics form the scope and sequences of integrated teaching. In the light of these disciplines, participants drawings and interview transcripts were analyzed and, for each discipline different codes were emerged (Table 1). For science discipline, participants relate it with physics, chemistry, biology, as natural science, in general. Beyond this, some of them expressed laboratory experiments, scientific argumentation and also understanding the natural world (see in Figure 5 and 6). American Association for the Advancement of Science (AAAS) (1990) defined some dimensions for science discipline: understanding natural world, scientific inquiry, and scientific enterprise. Dimension of understanding natural world represents that science is related with the natural world and defines the situations occur around us through knowledge gained by patterns in nature. Scientific inquiry dimension focuses on the methods that are used to understand the nature through collection and analysis of evidences. Finally, scientific enterprise dimension implies the performance of individuals while acting in institutional, social, and ethical aspects (AAAS, 1990). So, these dimensions also emerged as code for this study.

For technology discipline, some technological tools (microscope, computer, 3D writers), digital world, augmented reality emerged as codes. Technology broadly refers to *"the tools created by human knowledge of how to combine resources to produce desired products, to solve problems, fulfill needs, or satisfy wants"* (Koehler and Mishra, 2008, p.5). That is, technology can be used as a tool to solve the problems. In this manner, participants' views and drawings on technology discipline focused on the devices for human benefits. In the same manner, engineering discipline was also related with some machines, prototype or designs and so these results show us that technology and engineering are effective in practice or application process in STEM education. One of the participants stated that *PST4: "I think that science and math is the side of the problem that is interested in defining it. The application side is also the engineering and technology. I think we can classify it like that."*

Finally, mathematics was seen as a tool to understand the world or scientific phenomenon and requires analytical thinking while solving the problems. National Research Council (NRC) (1989) also defined the mathematics as *"Mathematics reveals hidden patterns that help us understand the world around us. ...mathematics today is a diverse discipline that deals with data, measurements, and observations from science; with inference, deduction, and proof..."* (p. 31). In the light of the data, participants' views were also similar with this definition:

PMT1: "mathematics offers a language for you as well as technology for science, which I think is like an alphabet. But what is science is a discipline that explains what is *present in mathematics, something similar to what I see in technology, what I can do in everyday life, what we can produce."*

PST4: "You also make it easier for a child to relate to the real world, for example when you do something related to math, or when you add something about science."

Beyond taking disciplines individually, participants also related them with each other. That is, they believe that the interdisciplinary connections will help students to understand the topics covered, and provide permanent learning. In addition, seeing the practical uses of mathematics will also help students like mathematics more:

PST6: "*The child says that I do not like math, because he cannot do theoretically in mathematics. But when they use mathematics in science, they can feel that they can do something with mathematics in reality."*

PMT5: "For example, the child loves to play with the Legos, and so, when you add mathematics to Legos with STEM, children may learn mathematics without noticing them."

At this point, Corlu and colleagues (2014) also stated that mathematics used in science helps to contribute toward STEM education to be integrated. From this perspective and quotations, also drawings (Figure 2 & 6), interdisciplinarity was the common mentioned statement by participants for STEM education. That is, for this theme it was concluded that participants thought the discipline should be integrated with each other and also it is not necessary to combine all of them to be a STEM activity. So, participants have enough theoretical knowledge on STEM education but they do not know how to implement them in a classroom setting exactly. So, the role of each discipline is important for scope and sequences for integrated teaching.

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Appendix A. STEM Focus Group Questions

1. What comes to your mind when ‘STEM Education’ is said?

2. Can you define STEM Education?

3. What do you think about the aims of STEM Education? What can be done to achieve these aims?

4. Why STEM Education is important at these days? What can be the causes to begin to use STEM Education? What are your opinions?

5. In your drawings, you referred ‘Authentic Problem of Knowledge Society (APKS)’ and integrated with STEM Education. What is ‘Authentic Problem of Knowledge Society(APKS)’? What is the place and importance of APKS in STEM Education?

6. What can you say about STEM (Science-Technology-Engineering-Mathematics) disciplines? Which teaching methods can be preferred while teaching these disciplines?

7. What dou you think about the aims of teachers in STEM Education?

a) What comes to your mind when it is said ‘Knowledge Society’? In STEM Education, who forms’ Knowledge Society’? Is it restricted with school?

b) Who forms ‘Professional Learning Community’? What is the place and importance of this community at interdisciplinary teaching-learning process?

c) What can be the effects of STEM Education in theory and practice?

d) What kind of curriculum should be implemented in STEM Education?

8. What is ‘Equity-Relevance’ principle in STEM Education? Can you evaluate in terms of students?

9. Can you evaluate STEM Education in terms of ‘Interdisciplinarity’ principle? How the context among disciplines should be formed?

10. What can be the advantages and disadvantages of STEM Education for a short and long time?

11. Do you prefer STEM Education in your classses? Why?

12. In general, is there anything you want to add about STEM Education?