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Research Article

Pre-service Teachers' Mind Maps and Opinions on STEM Education Implemented in an Environmental Literacy Course

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Abstract

This study aims to implement a science, technology, engineering, and mathematics (STEM) education approach in an environmental education course. The research involved the design and implementation of STEM activities by researchers, as part of the environmental education course taught in the second year of a Primary School Teaching undergraduate program. In this study—a case study using qualitative research methods—after the implementation of STEM activities, some mind maps and the views of the pre-service teachers regarding STEM education were examined. A total of 42 pre-service teachers participated in the study and an examination of their mind maps showed that they have a rich conceptual structure regarding STEM education and also associate STEM fields both with one another and with environmental education. In the interviews conducted following the activities, the pre-service teachers stated that they found STEM education to be efficient, easy to retain, and fun.

Keywords

Environmental education • Environmental literacy • STEM • Pre-service teachers • Mind maps

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As the world undergoes rapid industrialization and globalization, environmental pollution and other ecological problems are rapidly increasing. As a result, the importance of increasing individual levels of environmental literacy is emphasized by researchers (Roth, 1992; Scholz, 2011). Environmentally literate individuals know and care about the workings of the earth's natural systems and the impact of human activities on these systems (Teksöz, Şahin, & Ertepınar, 2010). Prior studies from around the world concentrate on topics such as environmental education, students' environmental perceptions, knowledge and attitudes, and being connected with nature. Many of these studies claim that students' and pre-service teachers' knowledge about and attitudes toward the environment are far from satisfactory and that levels of connectedness to nature of students is low and that environmental education has many shortcomings (Atasoy & Ertürk, 2008; Ernst & Theimer, 2011; Kaya & Gündoğdu, 2007; Lieflander, Fröhlich, Bogner, & Schultz, 2013; Teksöz et al., 2010). Thus, a recommendation arising from this literature is that environmental education should be given priority at all levels of education from preschool to college; moreover, all students should be taught environmental literacy.

21st Century Skills and STEM Education

According to Wagner (2008), students in the 21st century must be able to generate new knowledge and apply this knowledge to new situations and problems rather than memorizing existing knowledge. On the basis of interviews conducted with many business leaders, Wagner (2008) identified seven crucial skills in which students need to develop expertise: 1. Critical thinking and problem-solving; 2. Collaboration across networks and leading by influence; 3. Agility and adaptability; 4. Initiative and entrepreneurialism; 5. Effective oral and written communication; 6. Accessing and analyzing information; and 7. Curiosity and imagination. These skills, dubbed "21st century skills," are a combination of knowledge, skills, literacy, and expertise that students require to achieve success at work and in life (P21, 2015). These 21st century skills are focused on basic school curricula and 21st century themes, followed by life and career skills, learning and innovation skills, and information technology skills (P21, 2015). STEM education, which has been popular in our country, Turkey, and worldwide in recent years, could be given as an example for supporting the 21st century skills of students and implementing an effective environmental education. As STEM education is an innovation-focused educational approach, emphasizing technological development and orienting students towards career planning, it can be interpreted that it contributes to the development of 21st century skills. However, more research and inference based on data are needed.

STEM: Science, Technology, Engineering, and Mathematics Education Approach

STEM education refers to teaching and learning in the fields of science, technology, engineering and mathematics, and typically includes all formal and informal education activities, at all levels of education (Gonzalez & Kuenzi, 2012). Bybee (2013) states that there is a paradox about the meaning of STEM, and its meaning is not clear and distinct. Some definitions refer to the four disciplines while others emphasize only one of the disciplines. Sometimes, STEM is seen as four disciplines that are distinct but equal. One general definition of STEM education is as follows: "STEM literacy is the ability to identify, apply, and integrate concepts from science, technology, engineering, and mathematics to understand complex problems and to innovate to solve them" (Balka, 2001, p. 7). According to Bybee (2013), STEM-literate individuals have the following competencies: acquiring knowledge, attitudes, and skills to identify questions and problems in life situations, explain the natural and designed world, and draw evidence-based conclusions about STEM-related issues; understanding the characteristic features of STEM disciplines as forms of human knowledge, inquiry, and design; having awareness of how STEM disciplines shape our material, intellectual, and cultural environment and willingness to engage in STEM-related issues and with the ideas of science, technology, engineering, and mathematics as a constructive, concerned, and reflective citizen.

The aim of STEM education is to create a STEM-literate society, and an innovation-focused labor force that has 21st century skills, and that is able to conduct advanced research and development (Bybee, 2013). The focus on innovation involves the integration of diverse STEM skills, transcends disciplines and the need for the education to go beyond the individual disciplines (Çorlu, Capraro, & Capraro, 2014). Pitt (2009) says STEM education is encouraging students to study science and mathematics, especially for professions in the fields of technology and engineering. The interdisciplinary curriculum in STEM education is a holistic approach that relates the content of one discipline to another using a theme, topic, or issue and links the disciplines by emphasizing relationships and connections (Jacobs, 1989). The integration in STEM is achieved by giving equal emphasis to all four content areas, or by focusing on one and using the others as a context for the teaching of the discipline in focus (Moore, Stohlmann, Wang, Tank, & Roehrig, 2013). Thus, STEM education is connected to life via a collaborative approach, and includes knowledge, skills and beliefs constructed at the intersection of more than one STEM subject area (Çorlu et al., 2014). Moreover, the fact that mathematics is used in science or mathematically rigorous science education contributes toward STEM education to be integrated (Çorlu et al., 2014).

Why STEM Education?

In the race for economic development, governments around the world constantly reform their education systems to improve education standards, and to make sure their students' knowledge and skills compare favorably with those of other nations (OECD, 1999). STEM education has its roots in this reformist perspective. In many countries, increasing interest is focused on STEM and STEM disciplines. It is criticized about it have to be done to resolve societal needs for new technological and scientific advances; economic needs for national security; and personal needs to become a fulfilled, productive, and knowledgeable citizen (Çorlu, 2014; Zollman, 2012). According to these criticisms, STEM education will be successful in equipping individuals with an interdisciplinary approach to the fields of science, technology, engineering, and mathematics, and the relevant knowledge and skills for the changing expectations of 21st century economies. This is possible only by fostering interdisciplinary knowledge, skills, and values that are relevant to real life (Çorlu, 2013). Thus, achieving and maintaining scientific and economic leadership of a country can be related to supporting STEM education (Şahin, Ayar, & Adıgüzel, 2014).

In recent years, several pieces of legislation have been introduced with the purpose of improving STEM education in the United States (Kuenzi, 2008). Millions of dollars of investment have developed STEM education since the 1990s, and with this extraordinary financial support, encouraging progress has been achieved in college STEM education, thanks to public–private partnerships (Labov, Singer, George, Schweingruber, & Hilton, 2009). Many systems and strategies have been proposed for effective STEM education, and numerous studies have examined the effectiveness of, and shortcomings and problems encountered in, STEM education (Capraro & Nite, 2014; Donner & Wang, 2013; Johnson, 2012; Labov et al., 2009). It has also been argued that an integrated teacher education program could train pre-service teachers able to implement STEM education so that they can increase students' innovation capacities (National Research Council, 2011).

Çorlu (2014) argues that, to improve its innovation capacity, Turkey needs a qualified labor force with expertise in science, technology, engineering, and mathematics, and many education policy documents in Turkey lend political support to STEM education. Most of the students in Turkey show low achievement levels, especially in science and mathematics (Sarıer, 2010). Thus there are so many difficulties in maintaining a high quality integrated STEM education in Turkey; these difficulties depend upon many factors, including the type and category of schools and the implementation of the present syllabus in Turkey (Adıgüzel, Ayar, Çorlu, & Özel, 2012).

Research Questions

Studies show that most teachers lack the integrated teaching skills required to provide an effective STEM education when they begin their professions (Çorlu, 2014). Some researchers argue that regional problems seen in STEM fields sometimes result from problems with access to undergraduate STEM programs and with the quality of STEM teachers and that is why universities can be part of the solution with regards to the problems encountered in STEM education (Hagedorn & Purnamasari, 2012). The purpose of this study is to implement the STEM approach in an undergraduate environmental education course, and contribute to the literature on the implementation of STEM education in different fields. Within this framework, answers will be sought to the following research questions:

1. At the end of the environmental education course offered on the basis of STEM education, how can pre-service teachers' mind maps be described regarding STEM education?

2. At the end of the environmental education course offered on the basis of STEM education, how can pre-service teachers' views of the activities be identified?

Methods

A case study using qualitative research methods was used in this study. Merriam (2009, p. 43) described the case study as "an in-depth description and analysis of a bounded system." In qualitative research, case study is related with intensively studying an event (Glesne, 2012). The study involved the development and implementation of STEM-based activities for an environmental education course. Following the activities, pre-service teachers' mind maps were described, and their views regarding STEM education were identified.

Sampling

The study was conducted at the Faculty of Education of a university in North Anatolia during the fall semester of the 2014–2015 academic year. A total of 42 pre-service teachers, attending the second year of the Primary School Teaching program, participated in the study and were determined through purposive sampling. Of the participants, 31 (74%) were female and 11 (26%) were male. Data on mind maps were collected from all participating pre-service teachers. A total of six interviews, conducted with four female and two male pre-service teachers, were determined through convenience sampling.

Procedure

STEM education activities were performed as part of the environmental education course with pre-service primary school teachers. STEM education subjects identified by Bybee (2010), on the basis of PISA 2006 results, included topics such as biodiversity, ecologic sustainability, pollution control, and soil loss, under the *Environmental Quality* category. The contents of the environmental education course, selected for STEM activities in this study, overlap with the STEM topics proposed by Bybee. For the Waste and Recycling module of the environmental education course, STEM-based environmental education activities were developed and implemented over a four-week period. Prior to the start of the activities, pre-service teachers were informed about the STEM education approach and the study to be conducted.

The stages followed in the development of the activities were as follows. First, literature on the STEM approach to education was reviewed, and previous studies on the subject were examined in detail. Expert opinion on the topic was sought, and the methods and techniques used in environmental engineering were examined. Using technology as appropriate, environmental issues in the activities were then associated with mathematics and engineering fields. In STEM education, knowledge and skills specific to the discipline in focus are integrated with at least one other STEM discipline during teaching, and the close connections between mathematics and science makes STEM an integrated teaching method (Çorlu et al., 2014). Expert opinion was sought regarding the activities designed using these steps. A panel of five faculty members, two from science, one from mathematics, and two from environmental engineering, shared their views, which were taken into consideration in the final version of the activities. The following activities were performed with pre-service teachers in the environmental education course:

1. Introduction to Environmental Pollution
2. Consequences of Environmental Pollution
3. Decomposition Times for Different Types of Waste
4. Recycling, Material Analysis, and Cost Analysis
5. Waste Management and Public Awareness
6. Recycling Project Development

The pre-service teachers worked in groups during the activities in the drama studio. Smith, Douglas, and Cox (2009) argue that developing close connections between students, and between teachers and students, using cooperative learning methods is necessary in STEM education as developing positive peer relationships

is essential for school achievement. Thus, this study used various active learning methods such as creative drama, activity-based teaching, teaching with simulations, cooperative learning, and project-based learning. The first activity, *Introduction to Environmental Pollution*, involved creative drama on the importance of environment and environmental pollution. Improvisations, in line with the purposes of the course, formed the basis of creative drama activities. Students were given the opportunity to display their creativity, and improvisations emphasizing the relationship between mathematics and science, and associating them with engineering, were encouraged. In the activity on *Consequences of Environmental Pollution*, videos and simulations on waste, environmental pollution, and its consequences were used. Short videos were shown at the beginning, followed by general information on simulations and their use in the course, and websites with simulations, were presented. A couple of simulations on environmental pollution were shown, and the pre-service teachers were given an opportunity to engage with the material. In the activity on *Decomposition Times for Different Types of Waste,* the students were asked to pose and solve mathematics problems on the decomposition times of waste. The ability to pose such problems is as important as the ability to solve them; moreover, contemporary approaches to mathematics education put a lot of emphasis on problem-posing activities to develop students' math skills (Dede & Yaman, 2005). In this activity, the decomposition times of different types of waste were written on the board, and pre-service teachers were asked to pose various problems, making use of these times. Each group then shared the problem that they designed with the class. In the activity on *Recycling, Material Analysis, and Cost Analysis*, the students were asked to form groups and prepare plans on recycling, using floor plans of a sample school. Working on detailed floor plans, each group placed a number of recycling bins in suitable places, and later explained the rationale behind their plan to the whole class. Following this, pre-service teachers were asked to bring an actual recycling bin from the school to the classroom, sort and weigh the items found in the bin, and conduct a material analysis by calculating the percentage of each waste category. By doing this, they had a tangible idea of the amount and types of waste produced at a school. The students were then asked to calculate the total amount of each waste type produced in a week, month, and year, depending on the number of recycling bins they had placed in their plans. They were also provided with the prices of scrap materials and asked to calculate the value of the scrap that would be wasted, in the absence of recycling bins, over a week, month, and year. It was observed that the activity was effective in helping students realize the large amount of scrap material that is wasted in the absence of recycling. In the activity on *Waste Management and Public Awareness*, students were shown a map of the İlkadım county of the province of Samsun and asked to prepare a recycling plan for the county. Pre-service teachers were asked to form groups, and design activities for schools, public education centers, universities,

shopping malls, and neighborhoods, to raise public awareness so that the recycling system works effectively. Each group chose one of these places, and designed a project for raising awareness regarding waste and recycling among the visitors to that place. The projects were then presented to the class. In the *Recycling Project Development* activity, groups of students were assigned different types of waste, and asked to prepare a project proposal involving the recycling of that material. Groups were required to conduct research on the type of waste assigned, how to recycling it, the projects already implemented by municipalities, how to design a recycling machine, and prepare a drawing of that machine using Google Sketchup. The pre-service teachers conducted comprehensive research on environmental pollution, waste, and recycling. They interviewed education faculty administrators, municipal administrators, and experts; visited recycling facilities; made video recordings of the recycling steps; drew recycling machinery; designed posters; prepared reports on existing projects; and presented their findings to the class.

Data Collection Tools

Mind maps. Mind maps were used to identify pre-service teachers' mind structures regarding STEM education, the concepts they associate with STEM education and the connections between these concepts. Davies (2011) argues that the technique of mind mapping allows students to use their imagination and to discover the connections between concepts. He defines mind maps as networks of related concepts, drawn with the purpose of unearthing creative connotations between ideas. Following the activities, the 42 pre-service teachers who participated in the study were given sheets of paper and colored pens and were asked to draw the concepts regarding STEM education. The effects of the activities performed on their mind structures were determined through mind maps.

Student interviews. Semi-structured interviews were conducted with the pre-service teachers in order to gather their views on the STEM education used in the environmental education course. A semi-structured interview form was prepared, making use of the relevant literature. Expert opinion was sought regarding the questions on the interview form, and revisions were made accordingly. The questions on the interview form were as follows:

1. What benefits do you think you have derived from the STEM activities performed in the environmental education course? Alternatively, what are the educational advantages and disadvantages of STEM activities?

2. Do you plan on using STEM education when you become a teacher? Why? Explain its short- and long-term benefits.

Data Analysis

In the study, mind maps drawn by the pre-service teachers were analyzed using content analysis, which is a qualitative data analysis method. In content analysis, similar data are grouped together using certain codes and themes, organized, and later interpreted in a manner easy for readers to follow (Yıldırım & Şimşek, 2011). The mind maps were first assigned unique identification numbers, and then analyzed one by one to generate the codes in line with the purposes of the study. The emerging codes were then compared, the necessary adjustments made, and their frequencies counted. When the mind maps were coded, a conceptual structure emerged. At the second stage, similar codes were combined under a single category to create themes. When all the mind maps were analyzed, a total of 46 codes emerged, categorized under six broad themes. In the generation of codes and themes, care was taken to create a meaningful structure that was able to represent the dataset.

Each of the semi-structured interviews conducted with the pre-service teachers at the end of the activities lasted 15 minutes. The interviews were recorded using a voice recorder, transcribed using Nvivo 10 software, and analyzed. Transcripts were first read to create an initial coding scheme. All transcripts were then re-read in detail, codes were revised as necessary, new codes were added, and similar codes were combined under a single theme. Codes and themes were given their final shape, going back and forth between the raw data and the coding scheme at each stage. In what follows, extensive quotations are used to help with the interpretation of the codes and themes.

Consulting experts is an effective means of improving reliability in qualitative analysis. An expert on research topic and qualitative methods can be asked to examine the research and give their opinion (Yıldırım & Şimşek, 2011). To improve the reliability of the qualitative data collected in this study, an expert was asked to examine the analysis carried out on data from the mind maps and interviews. Revisions were made following the expert's recommendations on the data set, the codes, and the themes. An effort was made to reach an agreement between the researcher and the expert on the codes to be used. The data analysis was given its final structure and coding was made using a common perspective, avoiding the potential for prejudice and misunderstanding.

Findings

The Pre-Service Teachers' Mind Maps on STEM Education

Table 1 reports findings on the pre-service teachers' mind maps on STEM education.

Table 1
Pre-Service Teachers' Mind Maps on STEM Education

Theme	Code			f
Natural Science	**Physics**	Physics		21
		Space		9
		Light		4
		Speed-motion		2
		Gravity		2
	Chemistry	Chemistry		22
		Experimental tools		6
		Elements-compounds		6
		Drugs		3
		States of matter		1
	Biology	Biology		22
		Objects	Animate	13
			Inanimate	5
		Microscope		9
		Cells		2
Technology	Computer			20
	Technological tools			17
	Invention			15
	Telephone			13
	Internet			10
	Communication			5
	Ease of use			5
	Production			3
	Consumption			2
Science	Laboratory-Experiment			26
	Scientific method			11
	Scientist			11
	Progress			10

Theme	Code	f
Mathematics	Numbers	29
	Operations	18
	Symbols	14
	Problems	12
	Negative feelings	11
	Make-up exam	11
	Teachers	7
	Intelligence	6
	Puzzle	3
Environment	Nature	19
	Pollution	12
	Recycling	5
	Global Warming	5
	Water	4
	War	1
Engineering	Construction	22
	Drawing-Architecture	16
	Machinery	14
	Industry	9
	Agriculture	9
	Hard work	7
	Factory	7
	Electricity-Electronics	6
	Money	5
	Nuclear Plant	4

Pre-service teachers' mind maps regarding STEM education were concentrated around six themes: natural science, technology, engineering, mathematics, environment, and science (Table 1). *Physics (21), chemistry (22),* and *biology (22)* were the codes mostly combined under the theme natural science. Under physics, the most frequently mentioned topic was *space (9);* under chemistry, *experimental tools (6),* and *elements-compounds (6)* were the most frequently mentioned topics, and under biology, *animate objects (13)* was the most frequently mentioned topic code. *Light, speed, motion, gravity, drugs, states of matter, objects, microscope,* and *cells* were the other codes included in the natural science theme.

Computer (20) was the most frequently mentioned code under the technology theme, followed by *technological tools (17), invention (15), telephone (13), Internet (10), communication (5), ease of use (5), production (3), and consumption (2).* Under the theme of mathematics, *numbers (29), operations (18),* and *symbols (14)* were the most frequently mentioned codes. *Problems, negative feelings, teachers, intelligence,*

and *puzzle* codes were also mentioned. Under the engineering theme, the major codes of *construction (22), drawing-architecture (16), machinery (14), industry (9)* were mentioned. Under the theme of environment, the codes of *nature (19), pollution (12), recycling (5), global warming (5)* were mentioned. *Laboratory-experiment (26)* was the most frequently mentioned code under the theme science. The codes of *scientific method (11), scientist (11),* and *progress (10)* were also mentioned. Figure 1 reproduces a sample of the mind maps drawn by the pre-service teachers.

Figure 1. A sample of mind map.

Pre-Service Teachers' Views on STEM Education Activities

The pre-service teachers' views on STEM education were analyzed and identified using their responses to the interview questions.

Pre-service teachers' views on the educational advantages and disadvantages of STEM activities. Most of the pre-service teachers defined class sessions that included STEM activities as more effective, more fun and easier to remember, thanks to the groups formed, the cooperative learning environment created, and the interdisciplinary connections made (for the visual demonstration and relationships of codes in Figure 2). In addition, some of pre-service teachers stated that the activities performed helped create environmental awareness, support creative thinking and made the sessions effective. For example:

> I am bored in the environmental education course. These four weeks, however, with the STEM education in particular, I had some fun. If other methods were used to teach environment, they might not have been as easy to remember. With these activities, I learnt better. The time it

takes for waste to decompose, what can be done with regards to recycling… Thanks to these activities, we have come up with ideas that we would never think of in other classes. They made the course more effective.

Another pre-service teacher stated that he realized, thanks to this course, the close connections between science, technology, engineering, and mathematics and the extent to which these disciplines shape our daily lives:

[In this course] I realized how these are interconnected. Without mathematics, there is no engineering. As science progresses, so does technology, and as technology progresses, people are more productive. These are all interconnected, really.

Some of the pre-service teachers said that many different activities involving science, mathematics, and engineering-related technology were performed during the course, which were very motivating and useful because the activities made them see the practical uses of engineering. For example:

Mathematics, engineering, science, these are all separate disciplines. We have realized that science involves mathematics and that engineering involves mathematics, thanks to this course. These activities helped us realize how [these fields] are related to and connected with one another, and that technology in fact involves them all. This course developed that awareness.

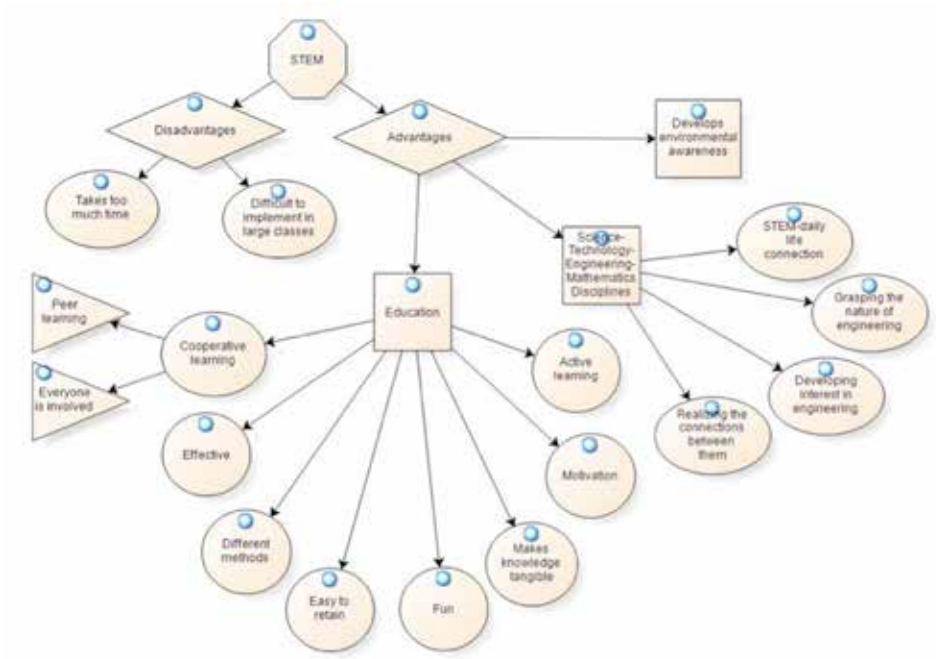

Figure 2. Codes that emerged from an analysis of pre-service teachers' views on educational advantages and disadvantages of STEM activities.

The pre-service teachers also identified some disadvantages of STEM activities: "taking too much time" and "being difficult to implement in large classes" were identified as the main disadvantages (Figure 2). As cooperative learning groups are important in STEM education, activities were performed in groups and different methods such as creative drama, teaching with simulations, and project-based learning were used. Owing to the activities around a single topic of environmental education are outnumber and taking long time these opinions might have been identified as disadvantages by pre-service teachers. Maybe different studies with STEM education would clarify their opinions. Some examples of their opinions are presented here:

> However, it may not work because it takes too much time. But it teaches more effectively in a short time.

> The disadvantage is that in large classes it might be difficult to implement, class time may not be sufficient. It is difficult to work in groups and have the groups perform the activity. [This method] can be implemented only with a certain number of students.

Pre-service teachers' views on using STEM education when they become teachers. All the pre-service teachers confirmed that they would use STEM education when they become teachers. They said they believe that the interdisciplinary connections made in the sessions where STEM education is used will help students get a better grasp of the topics covered, and retain more of their learning. In addition, they said seeing the practical uses of mathematics will also help students like mathematics more. Figure 3 reports the codes of pre-service teachers' responses to this question.

> The reason students are cold towards science and mathematics is that they think these disciplines do not have any practical uses, they don't know where they are used. If they realize that mathematics has practical uses, that it might come in handy in the future, they will be more interested, like it more, and study harder.

Some of pre-service teachers stated that this method will help students become interested in the profession of engineering, and might affect to make conscious decisions about choice of profession. For example:

> I think STEM education should be used, I would use too [when I become a teacher]. Kids may forget what they learn, but by forming associations between STEM fields, retaining knowledge is easier and they learn better. Engineering needs students who have organization and planning skills. If students realize that their simple designs are related to engineering, they might become interested in engineering as a profession. They would see it as doable, and be more interested. It would help them develop self-confidence. In our country, engineering is a bit exaggerated, people keep talking about how difficult it is. The more we are able to avoid painting it as difficult, the more we are able to prove to the kids that they can do it, the more they will like engineering.

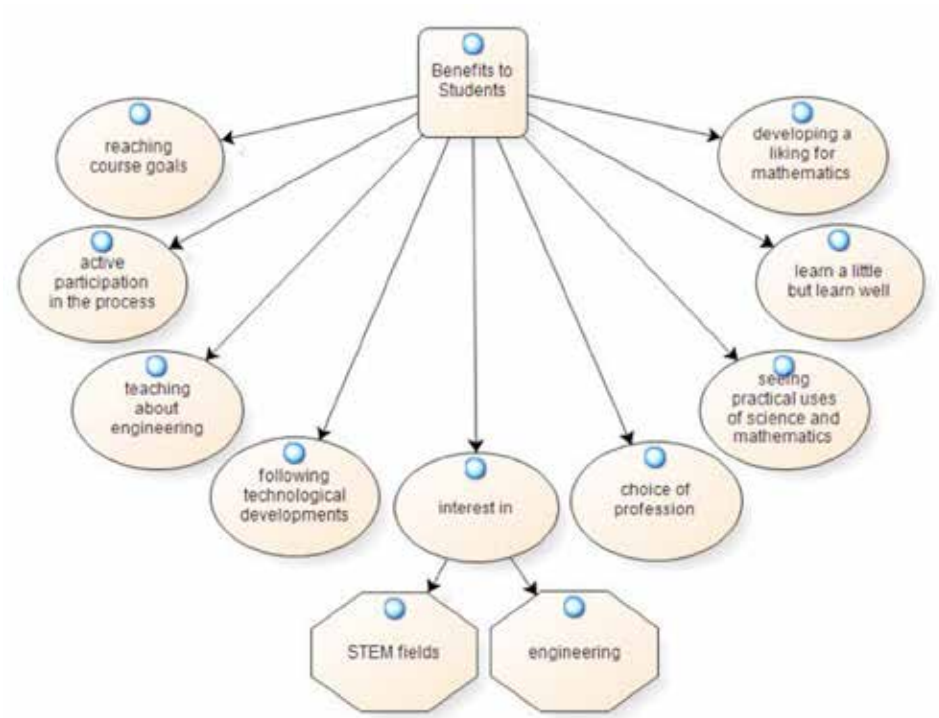

Figure 3. Codes that emerged from an analysis of the pre-service teachers' views on the contributions of STEM education they would use when they become teachers.

Discussion

STEM education draws a lot of interest and millions of dollars of investment around the world, making it an increasingly large proportion of education programs (Labov et al., 2009). Particularly in the United States, STEM is an important area of focus for global competition (Breiner, Harkness, Johnson, & Koehler, 2012). This study implemented STEM education as part of an environmental education undergraduate course, determined pre-service teachers' mind structures and opinions about STEM education. An analysis of the pre-service teachers' mind maps regarding STEM education identifies many codes under the themes natural science, technology, engineering, mathematics, environment, and science. The pre-service teachers stated that, thanks to the education provided, they were able to associate the fields of science, technology, engineering, and mathematics both with one another, and with daily life and environmental education. It was observed that they developed a very comprehensive and detailed mental vision regarding STEM fields. Mind maps subjects varied from construction, architecture, and drawing to money; from environmental problems to the scientific method and experiments; from mathematics make-up exams to technological inventions; and from nature to water and wars. The mind maps drawn showed that the pre-service teachers associated STEM education with environmental education and

with the theme of *science*. These comprehensive and detailed mind maps indicate that the STEM education developed their *communication skills, curiosity and imagination*, provided them with *flexibility in thinking*, and improved their 21st century skills, as identified by Wagner (2008). The cooperative learning environment developed during the activities is directly related to the 21st century skill of *collaboration*, and the data they collected, solutions they provided, and projects they designed are related to the 21st century skills of *critical thinking and problem-solving* and *accessing and analyzing information*; both indicating the presence of these skills and contributing to their further development. Bybee (2010) argues that STEM education provides teachers with opportunities to develop their students' 21st century skills. In addition, with this study, it can be thought that the activities also contributed to the development of the 21st century skill of environmental literacy (by P21, 2015) of the pre-service teachers.

When asked to express their views on STEM education, pre-service teachers emphasized its benefits and effectiveness compared with other courses and indicated that they adopt this approach. The participants stated that the activities helped them realize the extent to which the fields of science, technology, mathematics, and engineering are interrelated and an integral part of daily life. An environmental education course with STEM education can be useful for training pre-service teachers in not only STEM but also environmental education. In environmental education courses, varied learning methods such as cooperative learning, project-based learning were implemented in the activities. The pre-service teachers stated that these methods improved class participation, made the class sessions more effective, and was successful in creating environmental awareness. Other studies in the literature also underline the importance of cooperative learning environments and the interest developed in STEM fields following the activities (Şahin et al., 2014). STEM project-based learning and cooperative learning environments help students achieve self-regulated learning, develop their personality, stimulate their creativity, develop individualized group responsibility, and maximize their learning potential (Capraro & Çorlu, 2013; Capraro & Slough, 2008). All the participants said they would recommend STEM education for all levels of education, and that they would use STEM education when they become teachers.

STEM education covers formal and informal education activities at all levels of education, from preschool to postdoctoral research (Gonzalez & Kuenzi, 2012). Most education programs have a hierarchical and progressive format. STEM education in middle school would provide a good foundation for STEM education at high school (Capraro & Nite, 2014). STEM education from primary school onwards would help train engineers of the future. As Çorlu et al. (2014) argue, in order to increase Turkey's international competitiveness and to develop expertise in these fields STEM education should encompass all levels of education, and teachers should be trained accordingly.

Integrating STEM education into existing education programs is not easy, and it cannot be achieved overnight: introducing STEM education takes time and its continued use requires a cultural change (Suchman, 2014). As a result of this study, it is recommended that pre-service teachers are trained about STEM so they can encourage their students to be interested in STEM fields and choose professions related to this. Further studies must be conducted on integrating STEM education with education curricula.

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