

Investigate the Evaluations of Prospective Teacher on STEM Education, Based on Their Experiences with Planning and Implementing STEM Activities

Ali BOZKURT [1], Melike ÖZYURT [2]

<http://dx.doi.org/10.17220/mojet.2019.04.006>

[1]alibozkurt@gantep.edu.tr,
Gaziantep University, Faculty of
Education, Department of
Mathematics and Science
Education, Turkey

[2]melikeozyurt@gantep.edu.tr,
Gaziantep University, Faculty of
Education,, Department of
Primary Education

ABSTRACT

This study intends to investigate the evaluations of prospective teachers on STEM education, based on their experiences with planning and implementing STEM activities. The research's study group, designed qualitatively, is composed of 18 prospective teachers who graduated from the department of mathematics, 16 prospective teachers who graduated from the department of chemistry, 9 prospective teachers who graduated from the department of physics engineering and one prospective teacher from the department of textile engineering. STEM education programs carried out within the scope of the research lasted for 12 weeks, with four hours per week. Prior to the training programs, it was determined whether the prospective teachers had previous knowledge of STEM. After six weeks of training, study groups were formed which were composed of prospective teachers from different branches. Each study group performed what they thought was an STEM activity. A structured interview was undertaken with the teams following completion of the activities. The content analysis method was used to analyze the data gathered from the interviews. As a result of the research, it was determined that the applicability of the activity, compliance with the disciplines of STEM, being instructive and the features of the learning outcome are the selecting criteria in determining STEM activities applied. Prospective teachers mentioned a few problems they encountered during the activities. It was found that the participants thought to implement STEM activities in their professional teaching routes, but some participants had reservations about the preparation stage and In this context, the most obvious drawbacks about the preparation phase of the activities are the material supplementation and the preliminary preparation of the activities. The drawbacks regarding the implementation process were caused by concerns such as time consuming activities, in efficient implementation of STEM activities, lack of cooperation between students, lack of active participation of students and a lack of materials.

Keywords: STEM education, Planning and implementing STEM Activities, Prospective teachers

INTRODUCTION

STEM (Science, Technology, Engineering, Mathematics) education has gained importance in many countries in recent years in order to keep up with innovations in a constantly changing world and to raise forward-thinking individuals that can respond to the requirements of the age. STEM education aims to develop high-level thinking skills in students by focusing on at least one of the disciplines of science, technology, engineering and mathematics, and associating the focused discipline or disciplines with other STEM disciplines. (Smith & Karr-Kidwell, 2000; Berlin & Lee, 2005; Apedoe, Reynolds, Ellefson & Schunn, 2008; Chen, 2009; Moore, Stohlmann, Wang, Moore, Roehrig & Park, 2011; Wang, Tank & Roehrig, 2013). In doing so, the objective is to enable students to use different disciplines in conjunction with each other, increase their interest in future potential careers and support their development in line with the needs of the country (National Research Council, 2011; Gonzalez & Kuenzi, 2012; Zollman, 2012). Another objective of STEM education is to improve students' ability to provide realistic solutions to real life problems through the implementation of active learning and teaching approaches (Kennedy & Odell, 2014), and by encouraging students to use their knowledge of STEM disciplines through a holistic approach (Bybee, 2010; Corlu, 2012; STEM Task Force Report, 2014; Voutour, 2014).

STEM education has strategic importance for a country to maintain its competitiveness on an international scale (Corlu, Capraro & Capraro, 2014). Because STEM is considered as a fashionable trend, but rather a necessity to raise highly skilled people with a say in science and technology. There is a need for innovative brains who have learnt different disciplines in an integrated manner through STEM education. However, it is clear that there are some obstacles to the successful implementation of this kind of education. Among these obstacles include a lack of qualified STEM teachers, a lack of investment in the professional development of teachers, a lack of inspiring environments for teachers, a lack of support by schools, a lack of collaborative research on STEM areas, imperfections with the methods for presenting content and student assessment, and a lack of practical teaching of students (Ejiwale, 2013). In addition to this lack of resources in schools particularly with respect to engineering discipline of STEM (Roehrig, Moore, Wang & Park, 2012) (Roehrig, Moore, Wang and Park, 2012) and negative teacher attitudes towards STEM trainings due to the time constraints of STEM disciplines (Asghar, Elington, Rice, Johnson and Prime, 2012) Lee and Strobel, 2012), can also be considered as other obstacles.

STEM education's primary focus is on integrated teaching of different disciplines rather than developing materials or producing learning outcomes (Hernandez Bodin, Elliott, Ibrahim, Rambo-Hernandez, Chen & Miranda, 2014; STEM Task Force Report, 2014; Hacioglu, Yamak & Kavak, 2018). However, the current corpus of literature on STEM also perpetuates some misconceptions. Some of these misconceptions are: STEM education can only be delivered through Lego and toys, STEM education is only applicable to Physics courses, STEM is only suitable for exceptionally talented children, STEM requires working with expensive equipment, only science experiments, coding or maker activities count as STEM (Yildirim & Selvi, 2016; Akgunduz & Akpınar, 2018). STEM education, on the other hand, should not be seen as making students assemble sets of expensive parts, writing codes in blocks, moving a vehicle with these codes, or switching on/off a led bulb (Aygen, 2018). On the basis of all these considerations, teachers should be qualified in the teaching of the integrated disciplines for proper STEM education, have the necessary pedagogical training and have the self-confidence that they can make this happen (Corlu, 2012). In this context, study groups were formed from prospective teachers after a professional development training program on STEM. The groups were asked to develop or choose a STEM activity and implement it. An answer was sought to the following research question after the activities were completed:

- What are prospective teachers' evaluations of planning and implementation processes for STEM activities?

In this context, prospective teachers' evaluations of planning and implementation processes for STEM activities were examined. Evaluation is, the intent in doing so was to find out what made the participants choose certain STEM activities over others, learn the process of obtaining materials and equipment for the activities, shed light on the challenges with carrying out the activities and gather opinions on the applicability of STEM activities.

When current scientific research in the field of STEM education is examined, it is seen that studies are mostly focused on determining the effects of the components of STEM education such as attitudes (Gulhan & Sahin, 2016; Karakaya & Avgin, 2016), scale adaptation / development (Buyruk & Korkmaz, 2016; Koyunlu Unlu, Dokme & Unlu, 2016; Yildirim & Selvi, 2015), integrated teaching (English, 2017), engineering design and applications' impact on students' academic achievement (Yildirim & Selvi, 2017). On the other hand, there are also studies that look at STEM practices from the point of view of teachers, prospective teachers (Judson & Sawada, 2000; Capobianco, 2011; Cavas, Bulut, Halbrook & Rannikmae, 2013; Cinar, Pirasa & Sadoglu, 2016; Hacıoglu, Aygen, 2018; Kutlu & Bakirci, 2018; Ozbilen, 2018; Tekerek & Karakaya, 2018; Thibaut, Knipprath, Dehaene & Depaepe, 2018b; Du, Liu, Johnson, Sondergeld, Bolshakova & Moore, 2019) and students (Gulhan & Sahin, 2016; Pekbay, 2017), where their contributions to students developing 21st century skills are examined (Moomaw & Davis, 2010; Hacıoglu, Yamak & Kavak, 2016; Akgunduz & Akpinar, 2018).

The necessity of interdisciplinary approaches and collaborative work in consideration of new challenges posed by the 21st century requires the design of learning environments where students can conduct STEM research from an early age. The need for qualified teachers to run those environments is also obvious (Brophy, Klein, Portsmouth & Rogers, 2008; Corlu, 2012; Stolhmann, Moore & Roehrig, 2012; Eijawale, 2013; Guzey, Tank, Wang, Roehrig & Moore, 2014; O'brien, Karsnitz, Sandt, Bottemley & Parry, 2014; Deghaidy & Mansour, 2015; Mcdonald, 2016; Ozbilen, 2018; Lee, Hsu & Chang, 2019). In this regard, the examination of prospective teachers' evaluations concerning the planning and implementation of STEM activities will help increase awareness on STEM implementations and contribute to the literature in the field.

RESEARCH METHOD

Research Model

This study, in which evaluations of prospective teachers about STEM activity planning and implementation experiences were examined, designed as a qualitative research. In this context, participants without any previous knowledge of STEM education were educated before being asked to plan and implement STEM activities. After completion of the activities, structured interviews were undertaken using the Assessment Form for the Planning and Implementation of STEM Activities to assess prospective teachers' views of their own STEM activity planning and implementation processes and their opinions on STEM education overall.

Participants

The study was conducted with 29 female and 15 male prospective teachers receiving the special education methods course offered within the scope of pedagogical training, at an education faculty. Of these prospective teachers, 18 graduated from the faculty of mathematics, 16 from the department of chemistry, 9 from the department of physics engineering, and 1 graduated from the department of textile engineering.

Collection of Data

The study data was collected before and after a 12 week training program (6 weeks STEM lectures, 6 weeks implementation of STEM activities) that was delivered 4 hours per week. Prior to the training program, the participants were asked whether any of them had any previous knowledge of STEM education. The participants, who responded that they did not, were then asked what each of the letters in the word STEM represented and none of them gave the correct answer. It was therefore established that the participants had no prior knowledge of the concept of STEM or STEM education itself. Afterwards, the participants were provided training over the internet on the content and fundamentals of STEM education for the first six weeks whereby they found the chance to watch videos of sample STEM activities and review lots of academic studies on the topic. The weekly distribution of the contents of the trainings is given in Table 1.

Table 1. The content of STEM Training

Week	Content
1	Content of STEM trainings and philosophy of STEM

2	General information on STEM approach in education
3	Study on the academic studies on STEM education
4	Study on the STEM activities in STEM education teacher handbook (MEB- YEGİTEK, 2018)
5	Examination of recorded STEM activities on WEB
6	Implementation of a STEM activity (Activity Name: Robotic Hand)

Afterwards, the prospective teachers were asked to prepare and implement STEM activities in a classroom environment over a period of six weeks. Considering that prospective teachers represented different STEM disciplines on the basis of their BA education from different departments, each group was designed to contain at least three participants. Nine groups were formed, where each group contained at least one graduate of mathematics, one graduate of physics engineering and one graduate of chemistry. And in one group, a graduate of physics engineering was replaced by a graduate of textile engineering, making the total number of groups to be 10.

Following a six week training program, each group was asked to choose, prepare and implement an STEM activity. In this context participants are asked to follow given steps:

- A maximum of 70 minutes was allowed for each activity.
- The groups were firstly asked to prepare the materials required for the activities.
- The teacher groups designed the activities as a group study for students.
- The number of participants in each group was determined on the basis of the adequacy of materials.
- Participants were briefed about the expected final product and evaluation criteria.

One activity carried out within this context is illustrated in Figure 1.

DRAWBRIDGE ACTİVİTY

Objective: Build a Drawbridge

Materials: Spaghetti, Adhesive, tape, scissors

Number of participants: Groups of four

Duration: 60 min.

Instructions:

- 1) We would like you to build a drawbridge with the materials at hand.
 - 2) The Assessment criteria for the drawbridge are as follows:
 - Durability 50% (maximum weight carried)
 - Aesthetic design 30% (relative evaluation of the products by participants)
 - Suitability of use of material 20% (relative evaluation of the products by participants)
-

Figure 1 STEM activity for building a drawbridge

As illustrated in Figure 1, instructions were provided on the purpose of the activity, the materials to be used, the duration and what is expected of the participants. Performance assessment was conducted on the basis of the products presented by each group following each activity (Figure 2) and the criteria set out in the activity plan. For instance, concerning the building of a drawbridge, durability had a 50% impact, appearance had a 30% impact and the materials used had a 20% impact.

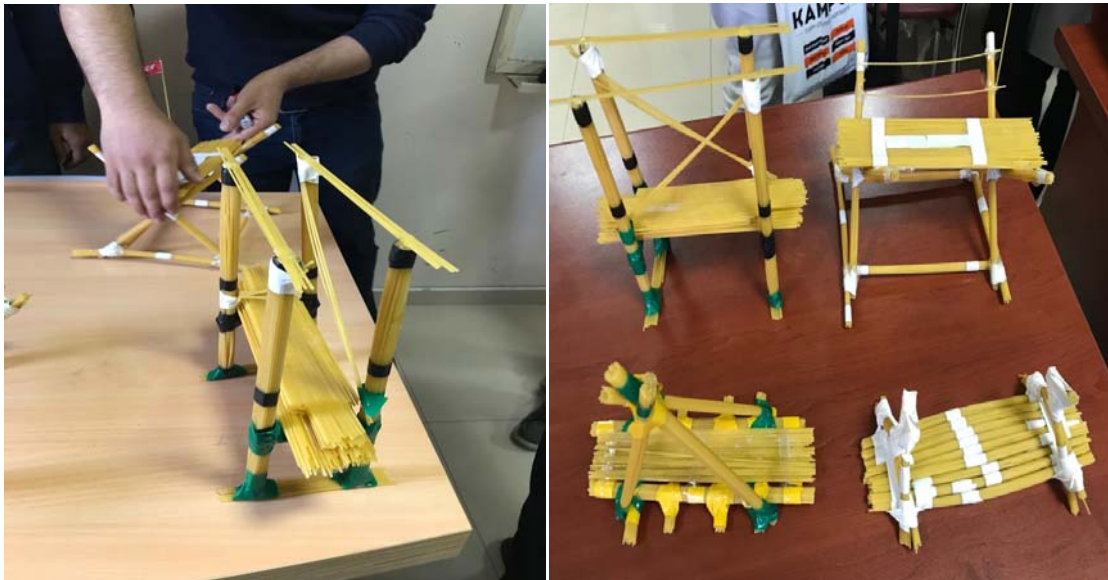


Figure 2. Drawbridge activity products

The groups had no limitations imposed for the STEM activities. But, all activities chosen allowed the use of waste or concrete materials. Following each activity, a structured interview was held with the group conducting the activity using the Assessment Form for the Planning and Implementation of STEM Activities. The Assessment form developed by researchers and for reliability studies of the form. The form was examined by a field expert within the scope of validity studies. It was also examined by a linguist in the context of language validity. The form was made ready for implementation after feedback. The following questions were asked at the interview:

1. Why have you chosen this activity within the scope of STEM training? How did you develop it? How did you obtain the tools and materials?
2. How would you assess the implementation process of your activity? Do you believe you have fulfilled the objectives? Did you experience any challenges during the implementation process? If yes, at what stages?
3. What are your overall views on the applicability of STEM education?
4. Would you consider integrating STEM activities into your teaching routine when you become a teacher? Why?

The activities carried out by the participants were assessed on the basis of their suitability for cooperation, the integration of different disciplines and the varieties of end products. 9 out of 10 activities fulfilling these criteria were assessed as STEM activities. Only one activity was not considered as such. In the activity where participants were asked to create a square out of two rectangular paper tapes, the participants were expected to create circles out of the tapes, stick them to each other and create a hollow square after cutting through them with scissors, starting from an appropriate point. This activity was not considered as a STEM activity considering that there was only one solution for the activity and it only entailed the use of mathematics as a discipline.

Data Analysis

The content analysis method was used to analyze the data garnered from the interviews. Content analysis is the analysis of data by creating codes or categories (Robson, 2001). Within the scope of content analysis, the responses given by the participants to the question of why they considered the activity they chose as a STEM activity, were first analyzed. The obtained categories, codes and sample responses related to these codes are given in Table 2.

Table 2. Analyses related to the reasons why the participants chose certain STEM activities over others

Category	Code	Sample answers
Compliance with STEM disciplines	Compliance with the objectives of STEM	<i>We thought building a drawbridge was the most fitting activity for STEM, and so we decided to go through with it (drawbridge).</i>
	Inclusion of all STEM disciplines	<i>Because it contains elements of Math, Science, Engineering and Technology (Design).. (the fastest going car)</i>
	importance of the activity content	<i>Time is one of the most important concepts in our lives and is precious (hourglass).</i>
	Inclusion of the STEM disciplines of Math and Sci.	<i>Combining science and math gave us this activity (Electroscope activity)</i>
	Expert advice	<i>We decided to carry out this activity with the assistance of a friend studying at the department of Teaching Science. (Electroscope)</i>
	Inclusion of the STEM disciplines of Math and Engineering	<i>We chose this particular STEM activity as we believe it does contain aspects of engineering and math (Hydraulic Lift).</i>
	Inclusion of the STEM disciplines of Math, Engineering and Science	<i>We chose this activity because it contains elements of Math, Science, Engineering and Technology (Design) (the fastest going car).</i>
Applicability	Low-cost	<i>We procured the materials easily from the market as they were simple and cheap (drawbridge activity).</i>
	Easy application	<i>It is the kind of activity that can be conducted easily in favorable circumstances (car made from fruit).</i>
	Accessibility of materials	<i>We made sure that the materials were easy to obtain (hourglass).</i>
	Simplicity	<i>We chose this activity as it is simple, practical and understandable (the fastest car activity).</i>
	Duration of activity	<i>We preferred this activity to other available options as it took much less time to complete (electromagnet).</i>
	Easy to understand	<i>We chose this activity as it is simple, practical and understandable (the fastest car activity).</i>
	Beneficial	<i>We found lots of other activities but they had no purpose, so we stuck to this one (electroscope).</i>
Learning	Educational potential	<i>It is an instructive activity on the non-compressible nature of liquids (Hydraulic Lift).</i>
	Provides permanent learning	<i>Teaching students permanently without them needing to memorize information (car made from fruit).</i>
	Offers ease of learning	<i>We have chosen this activity because it is easier to learn and is more effective in terms of learnability (car made from fruit).</i>
	Provides effective learning	<i>We have chosen this activity because it is easier to learn and is more effective in terms of learnability (car made from fruit).</i>
	Delivering new products	<i>We have chosen this activity to create a new product (electromagnet).</i>
Product properties	Allows product variety	<i>The product variety at the end and advantageous designs in each are a serious achievement (hydraulic lift) .</i>
	Product aesthetics	<i>An activity with potential for students to bring forth an aesthetically appealing product (car from fruit).</i>

As seen in Table 2, results obtained from the analyses related to the reasons why the participants chose certain STEM activities over others were gathered under four categories with 21 codes.

The categories, codes and sample responses related to these codes obtained from the responses of the participants to the second interview question are given in Table 3.

Table 3. Challenges faced by prospective teachers when carrying out STEM activities

Category	Code	Sample answers
Planning	Challenges with obtaining certain materials	<i>We had difficulties with finding certain materials but we obtained them all at the end with support from other groups (catapult).</i>
Introduction	Ambiguity of instructions	<i>We realized that some had trouble with understanding some of the activities (electromagnet).</i>
	Not knowing the working principles of the end product	<i>Initially, the groups asked questions about how hydraulic elevators work (hydraulic lift).</i>
Process	Lack of manual skills	<i>We noticed that some did not have the required level of dexterity for the activity (electromagnet).</i>
	Not being able to piece together a piece of wood	<i>I had difficulties with piecing together pieces of wood (catapult).</i>
	Not being able to decide on the flexibility of the rubber (difficulties with adjustment).	<i>I had difficulties with adjusting the flexibility of the rubber (catapult).</i>
Product	Product aesthetics	<i>We could not bring forth an aesthetically appealing product (electromagnet).</i>
	Not accepting the emergence of an end product different from what was anticipated	<i>We initially found it hard to accept that products different to those we expected were coming out of the process (car from fruit).</i>

As seen in Table 3, challenges faced by the participants when carrying out the STEM activities were gathered under four categories with eight codes.

The categories, codes and sample responses related to these codes obtained from the participants' responses to the third interview question are given in Table 4.

Table 4. Participant opinions concerning the contributions of STEM activities to the learning process

Category	Code	Sample answers
Teaching process	Instructive	<i>Instructive in terms of using and developing simple tools (electromagnet).</i>
	Fun	<i>The activity was quite fun (drawbridge).</i>
	Attention-grabbing	<i>Students found it interesting (rowboat)</i>
	Puts concepts on a concrete basis	<i>Suitable for concretized teaching (electroscope).</i>
	Smooth teaching process	<i>the teaching process was smooth and satisfying (drawbridge).</i>
Learning	Supports permanent learning	<i>To make it more memorable.. (catapult).</i>
	Supports learning	<i>...i believe it is going to be very beneficial (hydraulic lift).</i>
	Producer	<i>i observed them trying out different methods than the usual ones (hourglass).</i>
	Facilitates learning	<i>We have seen how it facilitates learning (hourglass).</i>
	Reinforces learning	<i>Can be used to reinforce what is being taught (hourglass).</i>
Learning process	Creative application	<i>Activity that develops the creative side of children (hourglass).</i>
	Helps with self-development	<i>Highly effective activity that improves children's learning skills (hourglass).</i>
	Active participation	<i>As it makes students more active and sociable ..(catapult)</i>
	Teamwork	<i>It was useful activity that teaches teamwork and races against time (catapult).</i>
	Problem solving	<i>It teaches students problem-solving skills (electromagnet).</i>
	Improves manual skills	<i>The activity will help promote students' manual skills among other things (the fastest car).</i>
	Promotes scientific inquiry	<i>Students learn through discovery (rowboat).</i>
	Inquisitive	<i>STEM raises the inquisitive and curious minds of the future (car from fruit).</i>

As seen in Table 4, participants' views on the contributions of the STEM activities to the learning process were gathered under three categories with eighteen codes.

The categories, codes and sample responses related to these codes obtained from participants' responses to the fourth interview question are given in Table 5.

Table 5. Misgivings of participants about the applicability of STEM activities

Category	Code	Sample answers
Preparation process	Difficulties with obtaining/accessing materials	<i>Can be applied at all times so long as the tools and materials can be obtained (catapult).</i>
	Requires planning and preparation	<i>It requires being prepared in advance (catapult).</i>
	High costs	<i>Lack of resources may make obtaining materials more difficult (hourglass).</i>
	Time-consuming	<i>i think annual plans must be prepared accordingly as they take too much time (rowboat).</i>
Application process	Lack of cooperation between teachers and students	<i>Teachers need to cooperate with students' parents (electroscope).</i>
	Failure to ensure the active participation of students	<i>It should be ensured students take active part in the activities (hydraulic lift).</i>
	Eagerness to do better overshadows learning	<i>Obsessing about being the winner should not preclude learning (catapult).</i>
	Takes too much effort	<i>... it is time-consuming and labor-intensive as opposed to that (car from fruit).</i>

The misgivings of participants about the applicability of STEM activities were gathered under two categories with eight codes.

Reliability of the Study

To ensure reliability, the continuous comparative data analysis method was used in the analysis of data from each research question. Continuous comparative data analysis includes the coding of examined data in inductive categories and the continuous comparison of the data being examined (Ekiz, 2003). The reliability of the analyzes was ensured by two academicians through a full compliance of the codes within the framework of the continuous comparison method. Thus, it was ensured that the codes used in the creation of the tables were consistent.

FINDINGS

This section presents the participants’ evolutions about the application processes of STEM activities, the reasons why they chose certain activities over others, the process of obtaining tools and materials for the activities, the challenges faced with the implementation of the processes and the prospective teachers’ views on the applicability of STEM activities in general.

Findings concerning the reasons why a particular activity was chosen over another

The reasons for the participants’ penchant for certain activities were determined by asking them the question “Why did you choose this activity? How did you develop it?” The opinions of the participants on this topic are given in Table 5.

Table 6. Reasons why the participants chose a particular STEM activity

Category	Code	Drawbridge	Electromagnet	Electroscope	The fastest car	Hydraulic lift	Hourglass	Catapult	Car made from fruit	Rowboat	Total
Applicability	Low-cost	1						1	1	1	5
	Easy application				1				1	1	4
	Accessibility of materials	1	1						1		3
	Simplicity	1		1							2
	Duration of activity	1	1								2
	Easy to understand				1						
Compliance with STEM disciplines	Compliance with the objectives of STEM	1		1			1	1	1		6
	Inclusion of all STEM disciplines				1						2
	Importance of the activity content				1		1				2
	Inclusion of the STEM disciplines of Math and Science						1	1			2
	Expert advice			1							1
	Inclusion of the STEM disciplines of Math and Engineering					1					1
Learning	Inclusion of the STEM disciplines of Math, Engineering and Science	1									1
	Beneficial			1	1						2
	Educational potential					1					1
	Provides permanent learning								1		1
	Offers ease of learning								1		1
	Provides effective learning								1		1
Product properties	Delivering new products		1								1
	Allows product variety				1						1
	Product aesthetics								1		1

As seen in Table 6, the most frequently mentioned codes in the category of applicability, cited among the reasons for the preference of certain STEM activities over others, were low-costs (5) and ease of application (4). In the category of compliance with STEM disciplines, conformity with the objectives of STEM (6) and the inclusion of all STEM disciplines (2) were the most frequently mentioned codes, as reasons for choosing certain activities while usefulness (2) was the most frequently mentioned code in the category of learning. As for the category of product features, the determined codes were “it delivers new products” (1), “it allows for product variety” (1) and “product aesthetics” (1).

Findings concerning the procurement of tools and materials

Following a review of STEM activity plans and the responses to the question “How did you obtain the tools and materials” by the participants, it was established that the participants preferred more easily accessible tools and materials while planning what tools and materials to use for their STEM activities. The participants obtained the materials they utilized during the activities from their own houses, the stationery store or the supermarket. It was also established that tools like tape (5), scissors (3), adhesives (3), balloons (3), plastic bottles (2), drinking straws (2), copper wire (2), retractable carpet knives (2), cardboard (2) and plastic glasses (2) were used in more than one STEM activity.

Findings concerning challenges with implementation of STEM activities

Questions like; “How would you assess the implementation process of your activity? Do you believe you have fulfilled the objectives? Did you experience any challenges during the implementation process? If yes, at what stages?” were asked to determine if the participants experienced any challenges while implementing the activities and what sort of challenges then, if applicable. In all groups that implemented the STEM activities, all participants stated that they fulfilled their objectives with the activities. The participants also stated that they did not encounter any difficulties that could not be overcome in the implementation process of the activities except for some minor difficulties. The categories and codes regarding the evaluations obtained from the participants' views on the difficulties they faced during the process are given in Table 7.

Table 7. Challenges faced by the participants when carrying out STEM activities

Category	Code	Drawbridge	Electromagnet	Electroscope	The fastest car	Hydraulic lift	Hourglass	Catapult	Car made from fruit	Rowboat	Total
Planning	Challenges with obtaining certain materials							1			
Introduction	Ambiguity of instructions		1			1					2
	Not knowing the working principles of the end product					1					1
Process	Lack of manual skills		1								1
	Not being able to piece together a piece of wood							1			1
	Not being able to decide on the flexibility of the rubber (difficulties with adjustment).							1			1
Product	Product aesthetics		1								1
	Not accepting the emergence of an end product different from what was anticipated							1			1

As seen in Table 7, the participants' views on the difficulties they faced whilst implementing STEM activities were gathered under four categories, namely planning, introduction, process and product. While the most frequently repeated code was “not understanding the instructions” in the introduction category (2), no repeated codes were found in the process and product categories. Some codes concerning the difficulties with implementation of the activities were challenges with obtaining the materials (1) in the planning category; a lack of manual skills (1) in the process category, and product aesthetics (1) and “not accepting the emergence of an end product different from what was anticipated” (1) in the product category.

Findings concerning the applicability of STEM activities

Participants' views on the applicability of STEM education activities were determined through the questions “What are your overall views on the applicability of STEM education?, Would you consider integrating STEM activities into your teaching routine when you become a teacher? Why?” All participants responded that they found STEM activities applicable. While some participants mentioned the contributions of STEM activities to the learning process during the interviews, some expressed their misgivings concerning the efficient implementation of these activities. Opinions of the participants concerning the contributions of STEM activities to the learning process are illustrated in Table 8.

Table 8. Participant Opinions concerning the contributions of STEM activities to the learning process

Category	Code	Drawbridge	Electromagnet	Electroscope	The fastest car	Hydraulic lift	Hourglass	Catapult	Car made from fruit	Rowboat	Total
Teaching process	Instructive		1	1	1	1	1			1	6
	Fun	1			1			1	1	1	5
	Attention-grabbing			1				1		1	3
	Puts concepts on a concrete basis			1				1		1	3
	Smooth teaching process	1									1
Learning	Supports permanent learning			1		1	1	1	1	1	6
	Supports learning				1	1	1	1	1		5
	Producer		1		1	1	1				5
	Facilitates learning						1				1
	Reinforces learning						1				1
Learning process	Creative application		1		1	1	1				5
	Helps with self-development		1		1		1				3
	Active participation							1		1	2
	Teamwork						1	1			2
	Problem solving		1					1			2
	Improves manual skills				1						1
	Promotes scientific inquiry									1	1
Inquisitive								1		1	

As seen in Table 8, the opinions of participants concerning the contributions of STEM activities were gathered under three categories, namely teaching, learning and education process. It was determined that STEM activities were found to be instructive (6), fun (5), attention-grabbing (3) and concretizing (3) in the teaching process category; participants thought they provided permanent learning (6), supported learning (5) and encouraged students to be productive (5) in terms of the learning category, while their creative aspect (5) was found to be their most vaulted characteristic in the education process category.

Misgivings of participants about the applicability of STEM activities are illustrated in Table 9.

Table 9. Misgivings of participants about the applicability of STEM activities

Category	Code	Drawbridge	Electromagnet	Electroscope	The fastest car	Hydraulic lift	Hourglass	Catapult	Car made from fruit	Rowboat	Total
Preparation process	Difficulties with obtaining/accessing materials	1	1					1	1		4
	Requires planning and preparation				1			1			2
	High costs						1				1
	Time-consuming							1	1	1	3
	Lack of cooperation between teachers and students				1						2
Application Process	Failure to ensure the active participation of students					1	1				2
	Eagerness to do better overshadows learning							1			1
	Takes too much effort								1		1

As seen in Table 9, codes concerning the misgivings of participants about the applicability of STEM activities were collected under two categories, namely the preparation and implementation process. While procurement of materials (4) and the requirements for planning and preparation (2) were the most

frequently mentioned codes in the preparation category; too much time-consuming (3) and failure to ensure active participation of students (2) were the most repeated codes in the implementation process category.

As opposed to the misgivings given in Table 8, all participants stated that they considered conducting STEM activities when they became teachers. They cited the factors that STEM activities support such as permanent learning (6), they are productive (5), fun (5), help with self-development (3), facilitate learning (2) and allow teamwork (2) to explain why they thought so.

DISCUSSION AND CONCLUSION

On the basis of the findings of the current study, which sought to examine the evaluations of prospective teachers about their experiences with planning and implementing STEM activities, it was established that the applicability of the activity in question, its compliance with STEM disciplines, its teaching potential and the product characteristics were decisive in determining what STEM activity to implement in the classroom. It was also established that the participants gave importance to the low cost of activity materials and their easy accessibility. Obtaining materials is important for the implementation of STEM activities (Stohlmann et al., 2012). As many studies have shown that STEM activities cannot be performed due to reasons such as a lack of materials at schools or inadequate amount of materials at schools (Kutlu & Bakirci, 2018), access to materials only in schools or science centers during limited time periods, or the costliness of materials (Hardy, 2001; Nadelson & Seifert, 2017). However, STEM activities should not be associated with costly materials. All materials used for STEM activities carried out within the scope of this study were easily obtained from teachers' homes, supermarkets or stationery supplies. According to the results of the study, another important criterion in determining the STEM activities to be applied is the compatibility of the activity with STEM disciplines. However, the integration of the four disciplines that make up the STEM is not so easy when designing activities (Alan, 2017). According to Atkinson and Mayo (2010) and Brown, Brown, Reardon and Merrill (2011), although four STEM disciplines are taught separately at schools, there are difficulties with providing STEM education with an integrated approach. It is acceptable that teachers who are experts in their respective fields find it difficult to design activities that cover these four areas. This is due to the fact that it entails a process of developing integrated teaching materials. The steps to be taken in this process are the suitability for cooperation, the integration of different disciplines (Tekerek & Tekerek 2018). In order to deliver effective STEM education in this context, teachers need to have an in-depth knowledge of these disciplines (Eckman, & et al., 2016), cooperate with others (Brown et al., 2011; Ugras & Genc, 2018) and teach students through a sound pedagogical approach (El-Deghaidy & Mansour, 2015).

It was established that there were some minor difficulties in the implementation of STEM activities, but according to the participants' views, these difficulties were not insurmountable. Difficulties related to the implementation of STEM activities can be experienced in all three stages of the implementation process, namely introduction, process and outcome. Among some of these difficulties can be cited as ambiguity of instructions, lack of manual skills on the part of students, lacking product aesthetics and teachers' unwillingness to accept the emergence of an end product different from what was anticipated. Failure to understand the guidelines can be ascribed to the relative inexperience of participants with managing activities designed with an integrated approach outside routine teaching practices (Atkinson and Mayo, 2010; Brown, Brown, Reardon and Merrill, 2011). A lack of manual skills on the part of students can be considered an obstacle to the effective use of the materials, thus causing difficulties with the STEM application process. Because while students who can use the materials effectively find STEM activities easy, students who have difficulties with using the materials experience more challenges (Akgunduz & Akpınar, 2018).

It was established that all participants found STEM activities applicable. The participants thought that STEM activities contributed to the teaching process as they are instructive, fun, attention-grabbing and concretize learning; as well as to the learning process since they provides permanent learning and encourage students to be productive. They also thought these activities contribute to the education process as they promote creativity, encourage students to be more active and allow teamwork. The finding is consistent with the results of other studies in the literature. These studies showed that teachers, when properly introduced to the STEM approach and STEM activities, thought STEM activities were fun, effective and instructive (Altan,

Yamak and Kirikkaya, 2016), and supported scientific process skills and problem-solving skills (Alan, 2017; Aygen, 2018). It was also found that teachers thought that the STEM approach increased students' motivation and interest towards lessons (Cavas, Bulut, Halbhook & Rannikmae, 2013; Hacıoglu, Yamak & Kavak, 2016; Yildirim & Selvi, 2017), that the integrative approach that brings together STEM disciplines was necessary and effective for success in math (Judson & Sawada, 2000), that they positively supported the development of students' reflective thinking skills (Gulhan & Sahin, 2016; Pekbay, 2017), that these activities would allow students to think more broadly, that they would improve their decision-making skills and increase the usage of labs (Kutlu & Bakirci, 2018). Studies conducted with the students found that students had positive perceptions about STEM activities. Gokbayrak and Karisan (2017) found that students found these activities useful in many aspects, while Pekbay (2017) found that students found STEM activities fun and that they collaborated with one another and actively learnt when doing STEM activities. Cho and Lee (2013) found that STEAM activities where STEM and art are combined support middle school students' creativity (creative problem solving and creative personality) and improve learning levels. On the other hand, Bozkurt Altan, Yamak and Bulus Kirikkaya (2016) found that the implementation of STEM activities during lessons increased the academic achievement of students, supported permanent learning and provided meaningful learning while Yildirim and Selvi (2017) argued that the same thing applied to the implementation of these activities together with the complete learning model. In addition to the results from this study, there are also studies showing that with STEM applications, students gain valuable competencies in science and mathematics and can develop 21st century skills such as creativity, critical thinking, collaboration and communication (Moomaw & Davis, 2010; Hacıoglu, Yamak & Kavak, 2016; Akgunduz & Akpınar, 2018). In this context, it can be said that STEM exercises support students' development in many aspects and that teachers and prospective teachers with experience in these activities find them doable.

It was also established that all participants were considering to carry out STEM activities in their professional lives. According to studies conducted by Hacıomeroglu (2018), Ozbilen, (2018) and Cinar, Pirasa and Sadoglu (2016), prospective teachers with a first-hand experience of STEM activities consider integrating STEM activities into their teaching routines in the future. It may also have contributed to the participants' positive feedback on these activities that they receiving an applied STEM training. Because teachers with an applied STEM training develop positive attitudes towards the implementation of the STEM approach in the educational process (Du, Liu, Johnson, Sondergeld, Bolshakova & Moore, 2019; Thibaut, Knipprath, Dehaene & Depaepe, 2018b). However, in his research on engineering-based science applications, Capobianco (2011) found that even though most of the prospective teachers taking part in the research found the process interesting, some of the prospective teachers had concerns about using such activities in their classrooms as they found the implementation or the preparation process too complicated.

It was also found in this current study that the participants considered incorporating STEM activities into their teaching routine but that some had concerns about the prep stage and the implementation process. In this context, it was established that the most remarkable concern regarding the prep stage was the supply of materials and the need for preliminary preparation for the activities; while among the most frequently voiced concerns concerning the implementation stage were the time-consuming nature of the activities, efficient implementation of the STEM activities by the students, lack of cooperation between students, lack of active participation on the part of students and lack of materials. Other studies with similar results regarding the concerns on the part of teachers about STEM activities defined costs, procurement of materials, the time-consuming nature of the activities (Delen & Uzun, 2018; Eroglu & Bektas, 2016; Hacıoglu, Yamak & Kavak, 2016) and lack of teacher equipment (McDonald, 2016; Ozbilen, 2018) as the primary obstacles complicating the implementation process. In her research on the obstacles compromising the successful implementation of STEM education, Eijawale (2013) stated that the lack of good training and professional support of STEM teachers conducting STEM activities constituted a major obstacle for precluding successful STEM practices.

Corlu (2014) and O'Brien, Karsnitz, Sandt, Bottemley and Parry (2014) also state that prospective teachers start their careers without reaching a professional competency in integrated teaching required for success with STEM activities. Similarly, Yildirim and Selvi (2016) found that prospective teachers studying at universities did not have sufficient knowledge and skills about STEM education and found it difficult to

transfer STEM education to actual life scenarios. Moreover, Kutlu and Bakirci (2018) also found that teachers in the field did not have sufficient knowledge about the STEM education, while Brophy, Klein, Portsmore and Rogers (2008) argued that teachers needed professional support on the combination of STEM disciplines around a central topic through pre-service and in-service training programs. Lee, Hsu and Chang (2019), Guzey, Tank, Wang, Roehrig, and Moore (2014), Stolhmann, Moore and Roehrig (2012) found that teachers felt inadequate about themselves when conducting STEM activities in the classroom, particularly those that are engineering-based, while El-Deghaidy and Mansour (2015) found that teachers lacked the skills for integrating technology and the nature of science. In this context, it can be argued that equipment is an important factor for efficient STEM applications and for fulfilling the purpose of the activities.

Suggestions

In this study the STEM activities are limited to those which can be done using waste or concrete materials. In this context, materials such as electronics and robotics support can be given to the practitioners for implementing various STEM activities. Thus, the limitation of STEM activities to be carried out only with cheap and accessible materials can be overcome. In addition to this, it is observed that there are difficulties to integrate more STEM disciplines in STEM activities. To overcome this handicap, teachers can be trained to integrate more STEM disciplines in STEM activities. This study was conducted with prospective teachers, similar research can be carried out with teachers and in classroom settings of secondary or high schools.

REFERENCES

- Akgunduz, D., & Akpınar, B.C. (2018). Evaluation of STEM applications based on science education in pre-school education in terms of students, teachers and parents. *Education for Life*, 32(1), 1-26.
- Alan, B. (2017). Supporting preservice science teachers' integrated teaching knowledge: Preparation training practices to STEM. (Master's Thesis). Firat University Educational Sciences Institute, Elazığ.
- Altan, E. B., Yamak, H., & Kirikkaya, E. B. (2016). STEM training applications in pre-service teacher education: Design based science education. *Trakya University Education Faculty Journal*, 6(2), 212-232.
- Asghar, A., Ellington, R., Rice, E., Johnson, F., & Glenda, M. P. (2012). Supporting STEM Education in Secondary Science Contexts'. *Interdisciplinary Journal of Problem-Based Learning*, 6(2), 85-12.
- Atkinson, R. D., & Mayo, M. (2011). Refueling the U.S. innovation economy: Fresh approaches to science, technology, engineering and mathematics (STEM) education. (pp. 1-178). Washington, DC: The Information Technology and Innovation Foundation.
- Aygen, M. B. (2018). STEM applications for supporting integrated teacher knowledge of science teacher candidates. (Master's Thesis). Firat University Educational Sciences Institute, Elazığ.
- Bakirci, H., & Kutlu, E. (2018). Determining the views of science teachers about the STEM approach. *Turkish Journal of Computer and Mathematics*, 9(2), 367-389.
- Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing Engineering Education in P-12 Classrooms. *Journal of Engineering Education*, 97(3), 369-387.
- Brown, R., Brown, J., Reardon, K., & Merrill, C. (2011). Understanding STEM: current perceptions, *Technology and Engineering Teacher*, 70(6), 5-9.

- Buyruk, B., & Korkmaz, O. (2016). STEM awareness scale (SAS): Validity and reliability Study. *Journal of Turkish Science Education*, 11(1), 3-23.
- Bybee, R. W. (2010). Advancing STEM education: A 2020 vision, *Technology and Engineering Teacher*, 70(1), 30-35.
- Capobianco, B. M. (2011). Exploring a science teacher's uncertainty with integrating engineering design: an action research study. *Journal of Science Teacher Education*, 22, 645-660.
- Cavas, B., Bulut, C., Holbrook, J., & Rannikmae, M. (2013). An engineering focused approach on science education: ENGINEER Project and implementations. *Journal of Science Education*, 1(1), 12-22.
- Cinar, S., Pirasa, N. and Sadoglu, G. (2016). Views of science and mathematics pre-service teachers regarding STEM. *Universal Journal of Educational Research*, 4(6), 1479-1487. DOI: 10.13189/ujer.2016.040628.
- Corlu, M. S. (2012). A pathway to STEM education: Investigating pre-service mathematics and science teachers at Turkish universities in terms of their understanding of mathematics use in science. (PhD Thesis). Texas A & M University, USA.
- Corlu, M. S. (2014). STEM education articles invitation letter. *Turkish Journal of Education*, 3(1), 4-10.
- Corlu, M.S., Capraro, R.M. & Capraro, M.M. (2014). Introducing STEM education: implementations for educating our teachers for the age of innovation. *Education and Science*, 39 (171), 74-85.
- Delen, İ., & Uzun, S. (2018). Matematik öğretmen adaylarının FeTeMM temelli tasarımları öğrenme ortamlarının değerlendirilmesi. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, 33(3), 617-630.
- Du, W., Liu, D., Johnson, C. C., Sondergeld, T. A., Bolshakova, V. L., & Moore, T. J. (2019). The impact of integrated STEM professional development on teacher quality. *School Science and Mathematics*, 119(2), 105-114.
- Eckman, E.W., Williams, M.A. & Silver-Thorn, M.B. (2016). An integrated model for STEM teacher preparation: The value of a teaching cooperative educational experience. *Journal of STEM Teacher Education*, 51(1), 71-82.
- Ejiwale, J. A. (2013). Barriers to successful implementation of STEM education. *Journal of Education and Learning (EduLearn)*, 7(2), 63-74.
- El- Deghaidy, H., & Mansour, N. (2015). Science teachers' perceptions of STEM education: Possibilities and challenges. *International Journal of Learning and Teaching*, 1(1), 51-54. <https://doi.org/10.18178/ijlt.1.1.51-54>
- English, L. D. (2017). Advancing elementary and middle school STEM education. *International Journal of Science and Mathematics Education*, 15(1), 5-24.
- Eroglu, S., & Bektas, O. (2016). Opinions of STEM-trained science teachers about stem-based course activities. *Journal of Qualitative Research in Education*, 4(3), 43-67.

- Gonzalez, H. B., & Kuenzi, J. J. (2012). Science, technology, engineering and mathematics (STEM) education: A Primer. Congressional Research Service. Cited date: 17.04.2019 <https://www.fas.org/sgp/crs/misc/R42642.pdf>
- Gokbayrak, S., & Karisan, D. (2017). Examining the views of 6th grade students about STEM-based activities. *Journal of Field Education Research*, 3(1), 25-40.
- Guzey, S. S., Tank, K., Wang, H. H., Roehrig, G., & Moore, T. (2014). A high quality Professional development for teachers of grades 3–6 for implementing engineering into classrooms. *School science and mathematics*, 114(3), 139-149.
- Gulhan, F., & Sahin, F. (2016). The effect of science-technology-engineering-mathematics integration (STEM) on the perceptions and attitudes of 5th grade students in these fields. *International Journal of Human Science*, 13(1), 602-620.
- Hacioglu, Y., Yamak, H., & Kavak, N. (2016). Teachers' opinions about engineering design based science education. *Bartın University Journal of Education Faculty* , 5(3), 807- 830.
- Haciomeroglu, G. (2018). Examining elementary pre-service teachers' science, technology, engineering, and mathematics (STEM) teaching intention. *International Online Journal of Educational Sciences*, 10(1), 183-194.
- Haciomeroglu, G., & Bulut, A. S. (2016). The validity and reliability study of the Turkish version of the integrated STEM education orientation scale for prospective teachers. *Theory and Practice in Education*, 12(2), 627-653.
- Hardy, L. (2001). Hightechhigh. *American SchoolBoard Journal*, 188(7), 12–15.
- Hernandez, P. R., Bodin, R., Elliott, J. W., İbrahim, B., Rambo-Hernandez, K. E., Chen, T. W., & Miranda, M. A. (2014). Connecting the STEM dots: measuring the effect of an integrated engineering design intervention. *International journal of Technology and design Education*, 24(1), 107-120.
- Judson, E., & Sawada, D. (2000). Examining the effects of a reformed junior high school science class on students' mathematics achievement. *School Science and Mathematics*, 100, 419-425.
- Karakaya, F., & Avgin, S. S. (2016). Effect of demographic features to middle school students' attitude towards FeTeMM (STEM). *Journal of Human Sciences*, 13(3), 4188-4198.
- Kennedy, T.K., & Odell, M.R.L. (2014). Engaging students in STEM Education. *Science Education international*, 25(3), 246-258.
- Koyunlu Unlu, Z., Dokme, İ., & Unlu, V. (2016). Adaptation of the science, technology, engineering, and mathematics career interest survey (STEM-CİS) into Turkish. *Eurasian Journal of Educational Research*, 16(63).
- Lee, J., & Strobel, J. (2010). Teachers' concerns on integrating engineering into elementary classrooms. In *Annual Meeting of the American Educational Research Association*, Denver, CO.
- Lee, M. H., Hsu, C.Y., & Chang, C.Y. (2019). Identifying Taiwanese Teachers' Perceived Self efficacy for

Science, Technology, Engineering, and Mathematics (STEM) Knowledge. The Asia-Pacific Education Researcher, 28(1), 15-23.

McDonald, C.V. (2016). STEM Education: A review of the contribution of the disciplines of science, technology, engineering and mathematics. *Science Education International*, 27(4), 530-569.

Moomaw, S., & Davis, J.A. (2010). STEM comes to preschool. *Young Children*, 65(5), 12-18.

Nadelson, L.S., & Seifert, A.L. (2017). Integrated STEM defined: Context, challenges, and the future. *The Journal of Educational Research*, 110(3), 221-223. <https://doi.org/10.1080/00220671.2017.1289775>

National Research Council. (2011). *Successful K-12 STEM education: Identifying effective approaches in science, technology, engineering, and mathematics*. Washington, DC: NAP.

O'Brien, S., Karsnitz, J., Sandt, S., Bottomley, L., & Parry, E. (2014). Engineering in preservice teacher education. *Engineering in pre-college settings: Synthesizing research, policy, and practices*, 277-299.

Ozbilen, A. G. (2018). Teacher opinions and awareness about STEM education. *Scientific Educational Studies*, 2(1), 1-21.

Pekbay, C. (2017). *The effects of science, technology, engineering and mathematics activities on secondary school students*. (PhD Thesis). Hacettepe University Educational Sciences Institute, Ankara.

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

STEM Task Force Report. (2014). *Innovate: A blue print for science, technology, engineering, and mathematics in California public education*. Dublin, CA: Dedicated to Education Foundation.

Stolhmann, M., Moore, T. J., & Roehrig, G. H. (2012). Considerations for teaching integrated STEM education. *Journal of Pre-college Engineering Education Research*, 2(1), 28-34.

Tekerek, B. & Karakaya, F. (2018). STEM education awareness of pre-service science teachers. *International Online Journal of Education and Teaching*, 5(2), 348-359.

Tekerek, M. & Tekerek, B. (2018). Integrated instructional material and development processes. *Turkish Journal of Education*, 7(3), 156-168.

Thibaut, L., Knipprath, H., Dehaene, W., & Depaepe, F. (2018). The influence of teachers' attitudes and school context on instructional practices in integrated STEM education. *Teaching and Teacher Education*, 71, 190-205.

Ugras, M., & Genc, Z. (2018). Pre-School Teacher Candidates' Views about STEM Education. *Bartın Universitesi Egitim Fakultesi Dergisi*, 7(2), 724-744.

Voutour, J. (2014). What is STEM education? Definition and programs. Cited date: 24.04.2019 <http://championmovement.com/what-is-stem-education>.

- Wang,H., Moore, T.J., Roehrig, G.H., & Park, M.S. (2011). STEM integration: Teacher perceptions and practice. *Journal of Pre-College Engineering Education Research*, 1(2), 1-13. DOI:10.5703/1288284314636.
- Yildirim, B., & M. Selvi, M. (2015). Adaptation of Stem Attitude Scale To Turkish, *Turkish Studies - International Periodical for the Languages, Literature and History of Turkish or Turkic*, 10(3), 1107-1120.
- Yildirim, B., & Selvi, M. (2016). Examination of the effects of STEM education integrated as a part of science, technology, society and environment courses. *Journal of Human Sciences*, 13(3), 3684-3695.
- Yildirim, B., & Selvi, M. (2017). An experimental study on the effects of STEM applications and mastery learning. *Theory and Practice in Education*, 13(2), 183-210.
- Zollman, A. (2012). Learning for STEM literacy, STEM literacy for learning. *School Science and Mathematics Journal*, 112(1),12-19.