ACTIVITY IMPLEMENTATION INTENDED FOR STEAM (STEM+ART) EDUCATION: MIRRORS AND LIGHT[1]

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ABSTRACT

In this research, an activity based on 5E model for STEAM education was implemented. The activity plan was designed by researchers for the "Reflection in the Mirror and Absorption of Light" in the 7th grade science class. The research was implemented in a 7th grade group of 30 students in 2017-2018 academic year. Five STEAM focused activities were completed over 5 weeks (20 hours in total). The students performed the activities by applying the engineering design process with group work. Kaleidoscope, reflective sculpture, solar oven, spectroscope, and vehicle of light show designs were generated in the activities. As a result of the observations and interviews made in the research, positive results have been obtained that students made creative designs as much as possible and liked to work with the activities. The activities shared in the article are concrete examples of STEAM education in classroom for teachers and researchers.

Keywords: STEAM, STEM, art, 5E, science activity.

STEAM (STEM+SANAT) EĞİTİMİNE YÖNELİK ETKİNLİK UYGULAMASI: AYNALAR VE IŞIK

ÖZ

Bu araştırmada Fen, Teknoloji, Mühendislik ve Matematik [STEM] eğitimine yönelik 5E modeline dayalı bir etkinlik uygulaması gerçekleştirilmiştir. Etkinlik planı 7. sınıf Fen Bilimleri dersindeki "Aynalarda Yansıma ve Işığın Soğrulması" ünitesine yönelik olarak, araştırmacılar tarafından tasarlanmıştır. Araştırma 2017-2018 eğitim-öğretim yılında 30 öğrenciden oluşan bir 7. sınıfta uygulanmıştır. STEAM odaklı 5 etkinlik, 5 hafta (toplamda 20 ders saati) süresinde tamamlanmıştır. Öğrenciler grup çalışmasıyla mühendislik tasarım sürecini uygulayarak etkinlikleri gerçekleştirmişlerdir. Etkinliklerde temel olarak kaleydoskop, yansıtıcı heykel, güneş fırını, spektroskop ve ışık gösterisi aracı tasarımları yapılmıştır. Araştırmada yapılan gözlem ve görüşmeler sonucunda öğrencilerin olabildiğince yaratıcı tasarımlar ortaya çıkardıkları belirlenmiş ve etkinliklerle uğraşmayı sevdiklerine yönelik olumlu sonuçlar elde edilmiştir. Araştırmanın öğretmenlere ve araştırmacılara yönelik, STEAM eğitiminin sınıf uygulaması hakkında somut bir örnek içerdiği düşünülmektedir.

Anahtar kelimeler: STEAM, STEM, sanat, 5E, fen bilimleri etkinliği.

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INTRODUCTION

Science, Technology, Engineering, and Mathematics [STEM] education might be viewed as one of the most important steps of interdisciplinary approaches in recent years. It has become important in the globalizing world where information and skills in STEM fields play a decisive role in the future of countries (Aydeniz, 2017). "Science and mathematics" education has been transitioned to STEM education since the integration of the four fields promotes students' critical thinking and creativity (Sanders, 2009). For instance, the engineering design process used in the STEM includes iterative and systematic thinking, searching for multiple solutions, analyzing and modeling, and focusing on learning the STEM disciplines' knowledge and concepts (Katehi, Pearson, & Feder, 2009). With STEM education, students can develop new ideas and products by experiencing the way of thinking of the people working in these fields and their points of view about the problems.

After the emergence of the idea of STEM education, there have been additions to these four disciplines to expand the scope. STEAM education, which is the focus of this research, is an approach developed by Georgette Yakman with the addition of the "art" dimension to STEM fields (Ayvacı & Ayaydın, 2017; Batı, Calıskan, & Yetisir, 2017; Braund, 2015; Yakman, 2010). The STEAM abbreviation was first included in the report of the Florida Alliance for Arts Education in 2009 (Allina, 2018). One of the most important reasons for STEAM is the fact that art does not have a different way of thinking from that of the STEM fields, and that many engineers and scientists have shaped their work with artist creativity (Plonczak & Zwirn, 2015; Watson & Watson, 2013). One of the aims of STEAM education is to revive students' creativity and innovation (Daugherty, 2013). The main aims of STEAM education are; ensuring active participation of students by taking individual differences into account (Allina, 2018; Cook & Bush, 2018), supporting the creativity of students (Allina, 2018; Braund, 2015; Sparkes, 2017), developing the students' interdisciplinary thinking (Tenaglia, 2017), and ultimately improving their interest to STEM career fields (Sochacka, Guyotte, & Walther, 2016).

This research was designed according to the Ministry of National Education [MoNE] curriculum published in 2013 which was being implemented in Turkey during the research. The activities were planned for the "Reflection in the Mirror and Absorption of Light" unit in the seventh grade second semester. According to the MoNE (2013) curriculum; there are two standards for the "mirrors" subject and four standards for the "absorption of light" subject. The recommended duration for the unit is 16 lesson hours.

IMPLEMENTATION OF THE ACTIVITIES

The current research was carried out in a state secondary school where the students were in the middle socioeconomic level in Istanbul during the 2017-2018 academic year. There were 30 seventh grade students (16 girls, 14 boys) in the class. The students were divided into six equal groups, in such a way to form heterogeneous groups according to their achievement level and gender. The implementation of the activities lasted for five weeks (20 lesson hours).

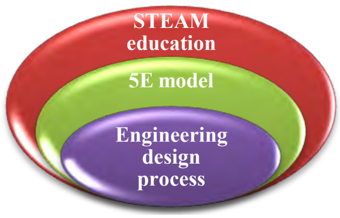

Figure1. The Organization Scheme of Activity Plan

The activities were prepared by the researchers. Aimed at STEAM education approach, the activities consisted of science, technology, engineering, mathematics, and art dimensions. The general theme of the unit activity plan is "Leonardo da Vinci and His Optical Studies." During the implementation of the activities, examples from Leonardo's optical works on the subject substance area were presented in the section "Do you know?" The 5E model was used in constructing the activity plans for STEAM (Figure 1). This model consists of five steps: engage, explore, explanation, elaboration, and evaluation (Bybee et al., 2006). Processes performed in each step are explained in the activity plans. While the activity plan was being implemented, the textbook was used to ensure that the science concepts do not remain on the back. Especially in the two steps (explore and explanation) of the plans, the explanations in the textbook were also used. The textbook used is a seventh grade Science book written by Tuncel (2017). The five steps (ask, imagine, plan, create, improve) of the engineering design process (Cunningham & Hester, 2007; Gulhan, 2016; Dogan, Savran Gencer, & Bilen, 2017) that forms the basis of the designs were applied in the elaboration step of the plans. A diagram of the steps to be follow in engineering design process is presented in Appendix 1 (Gulhan, 2016, p. 50). During the engineering design process, the students try to identify the tool that is required to be done at the "ask" step and try to determine the relationship between the tool and the subject area they discovered in the experiment. At the "imagine" step, the groups discuss how their tool should be and make a drawing of the tool they imagined as the "group drawing." At the "plan" step, the students designate materials that are necessary for the tool and which will be different from other groups as much as possible. The students talk about who will bring which material. The next lesson is the "create" step with the materials brought to the class. The students organize their designs by combining the materials according to the plan they drew together with their group members. In the meantime, the teacher constantly observes the student groups and makes suggestions about the points they are unable to work out. At the "improve" step which is the final step, when there are functional and visual problems or directions that need to be improved, the students make changes to their design with their group members and finalize their tools.

"Product (Design) Evaluation Rubric" developed by Gulhan (2016) was used in the evaluation of the activity products (Appendix 2). If desired, the rubric can be used not only for teacher evaluation but also for peer review.

As a preparation for the activities, the teacher says "We will do our own artistic and scientific designs by thinking like a scientist, optical engineer, mathematician, technologist, and artist in this unit." Firstly, "optical engineering" and "Leonardo da Vinci" are introduced as a pathfinder to the students through his optical studies throughout the unit. The teacher shows Leonardo da Vinci's designs and the well known of his paintings. She states that in this unit the students will make designs with multifaceted thinking like Leonardo. Then she explains the engineering design process and asks students to follow these steps with their group members while making their designs. Activity plans for five topics are presented in the next sub-sections. The first two activities are related to mirrors and the next three are about absorption of light.

The First Activity: Plane Mirrors

The plane mirrors activity was planned to teach the standard "7.4.1.1. Observes types of mirrors and gives examples of their use." and took 4 lesson hours.

Engage. To introduce the mirrors, students are asked the following questions: "Where do we use mirrors in our daily life? Are there different mirror types? What are the image differences between the tall dressing mirror and the side mirror of the cars?" The students think about the role of mirrors in our daily lives and the characteristics of the images. They make a class discussion on this subject.

Explore. The teacher gives each group a plane mirror and the students perform a symmetry experiment. In this experiment, the students use plane mirrors to form images of photographs taken from newspapers or magazines (Figure 2). The students determine the image features on a plane mirror and investigate the questions "Is the image straight or reverse? What is symmetry? How do you see the text in the mirror? What happened as the object moved closer or farther?" The students find out the answers to these questions and reach conclusions with their friends. A worksheet written by a student group is presented in Appendix 3.

Figure 2. Plane Mirror Experiment of Groups

Explain. The students begin a classroom discussion under the guidance of the teacher as to determine whether they have reached the correct conclusions about the image features in the plane mirror. The students watch animations about plane mirrors. The teacher guides the explanation of foundational knowledge of and properties about plane mirrors by using the textbook and by continuing the question-answer interaction with the students. Thus, if the students reach the correct results in the experiment, they reinforce their knowledge and if they reach erroneous results, they correct their mistakes.
As a "Do you know?" explanation, the teacher mentions "Leonardo drew the reflected rays by using the law of reflection in his geometric studies and found that the angle of reflection was equal to the angle of incidence (Topdemir, 2012)."

Elaboration. At this stage, students design kaleidoscope. The teacher introduces the tool to the students and shows the videos about the kaleidoscope in order to support their designs. The students make their kaleidoscopes using the five-step engineering design process. The teacher takes photos of the colorful images formed as a result of the design (Figure 3). A paper towel roll or a crisp box can be used to make the kaleidoscope. Beads or colored papers can be viewed in the kaleidoscope.

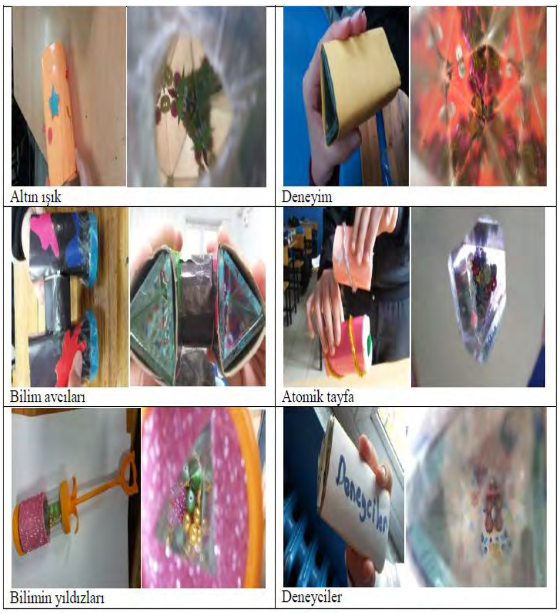

Figure 3. Kaleidoscopes of the Student Groups

Relating to painting art, after making the kaleidoscope, the students draw a coordinate system on a drawing paper. They draw a symmetrical image of a pattern as if there were four intersecting mirrors. They explore intersecting image features using multiple mirrors, and paint symmetrical images of the pattern (Figure 4). Students can also do collage work or can be inspired by Picasso's Cubism movement.

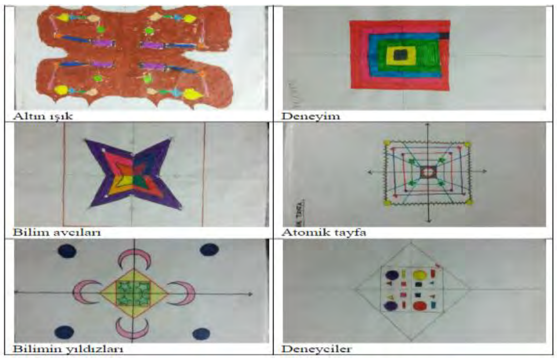

Figure 4. The Symmetry Paintings of the Student Groups

Evaluation. The students solve practice questions related to the subject. The teacher assesses the products with the "Product (Design) Evaluation Rubric" and explains the scores to the students. Students' reflective comments on what they did during the activity are also assessed. Table 1 shows the STEAM dimensions of the activity.

Table 1. STEAM Fields and Contents of the First Activity

Field	Content
Science	Plane mirrors
Technology	Watching the animations
Engineering	Design process (kaleidoscope construction)
Math	Drawing and determining the coordinate system, symmetrical image drawings on paper, mirror-image distance calculations
Art	Painting art- creating images with colored materials, coloring drawings

The Second Activity: Spherical Mirrors

The spherical mirrors activity is aligned with the standards "7.4.1.1. Observes types of mirrors and gives examples of their use." and "7.4.1.2. Compares images that appear in plane, concave and convex mirrors." The activity took 4 lesson hours.

Engage. For the introduction of the spherical mirrors, students are asked the following questions: "Are there other types of mirrors aside from plane mirrors? What are the properties of images?" The students think about in which fields spherical mirrors can be used, differences between images in spherical mirror with images in flat mirror. They make a class discussion related to this subject.

Explore. At the beginning of the exploration, the teacher gives each group a concave and convex mirror and the students investigate the image features in the spherical mirrors. The students investigate the following questions: "Is the image straight or reverse? What happened as the object moved closer and moved farther?" The students find out the answers to these questions and reach conclusions with their friends.

Explain. The students begin a classroom discussion under the guidance of the teacher as to determine whether they have reached the correct conclusions about the image features in the spherical mirrors. The students watch animations about the images in the spherical mirrors. The teacher guides the explanation of foundational knowledge of and properties about spherical mirrors by using the textbook and by continuing the question-answer interaction with the students. As a "Do you know?" explanation, the teacher mentions "Leonardo used concave mirrors to light things and focused the daylight. He showed that the rays were collected along the principal axis in the spherical mirrors. The spherical mirrors were 'burner mirrors' because they gathered the rays into one spot (Topdemir, 2012)."

Elaboration. The teacher shows the sculpture artist Anish Kapoor's artwork called "Cloud Gate (The Bean)" in Chicago. She gives information about this artwork and states that this sculpture is actually a concave mirror that provides reflection. The teacher says "Now let's make a reflective design using a concave and a convex mirror." She indicates that they need to make a reflective design for artistic purposes, rather than constructing a clear view (Figure 5). One group's drawing before the design is given in the Appendix 3. Instead of concave and convex mirrors, metal items such as spoons, pots, coffeepots, or aluminum foil can be used as alternative materials.

The teacher says "Let's continue with the effects of reflection in other fields of art." and makes a connection to literary art. The art of reflection is a figure of speech made by inverting the same phrase in the literature. For example, "Every slope has a flat, every flat has a slope." The teacher tells the students "Create your phrase." The students produce phrases with their group members.

Figure 5. Reflective Sculpture Designs and Literary Expressions of the Student Groups

Another connection made between mirrors and art is related to photography art. The teacher shows examples of photographs which used plane or spherical reflective elements such as mirrors, water deposits, metal objects. The teacher wants students to take a photograph of reflection like these photographs in their daily lives (Figure 6).

Figure 6. The Reflection Photographs Taken by the Student Groups

Evaluation. The students solve practice questions related to the subject. The teacher assesses the products with the "Product (Design) Evaluation Rubric" and explains the scores to the students. Students' reflective comments on what they did during the activity are also assessed. Table 2 shows the STEAM dimensions of the activity.

Table 2. STEAM Fields and Contents of the Second Activity

Field	Content
Science	Concave and convex mirrors
Technology	Watching the animations, taking the photographs
Engineering	Design process (reflective sculpture construction)
Math	Image drawings-geometry
Art	Sculpture art- reflective art, Literary art-reflection, Photograph art- reflection

The Third Activity: Absorption of Light

This activity was planned to teach the standards "7.4.2.1. Discovers that the light can be absorbed by the substance as a result of interaction with the substance." and "7.4.2.4. Exemplifies the innovative applications of solar energy in everyday life and technology, and discusses the importance of solar energy for effective use of resources." The activity took 4 lesson hours.

Engage. To introduce the topic, the students are asked the following questions: "What is the absorption? Is there relation to absorption with colors of substance? What are the effects of absorption on our daily lives?" The students think about situations related to light that they encounter in daily life. They make a class discussion related to this subject.

Explore. At the beginning of the exploration, the students perform the experiment of relationship between temperature and color. For this, the students compare the temperature of objects that are wrapped with black and white fabrics. The students investigate the questions: "Which color caused the temperature to increase more? What is the relationship between temperature change and color?" The students find out the answers to these questions and reach conclusions with their friends. A worksheet written by a student group during the experiment is given in the Appendix 3.

Explain. The students begin a classroom discussion in the guidance of the teacher as to determine whether they have reached correct conclusions about absorption event. The students watch animations about this subject. The conceptual knowledge about the subject is explained by using the textbook and by continuing the question-answer interaction with the students.

Elaboration. The teacher asks "Can we make the solar ovens used by people in ancient times to cook their food? Can we cook or melt the food with the sun?" The students think about alternative materials and the structure of the solar oven. In this activity, by using a mirror, the effect of light can be further increased and the places with heat loss can be painted. The teacher says "Watch the temperature rise of the oven with a thermometer and draw a graph." A thermal camera application which can be downloaded for free to a mobile phone can be used. The students observe the regions in which the heat increases by this technological tool. They make the necessary changes by determining where the heat is lost (Figure 7).

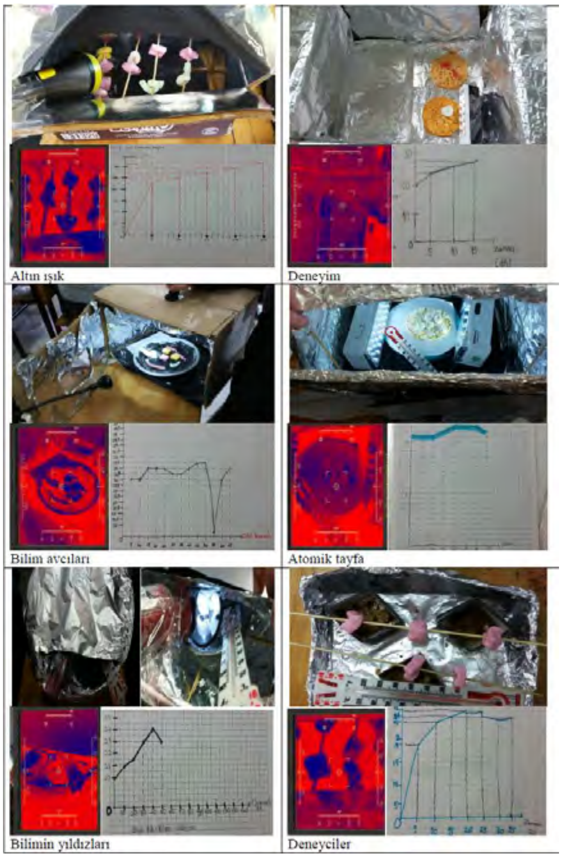

Figure 7. Solar Oven Designs of the Student Groups, Thermal Camera Images, and Temperature-Time Graphs

To make a connection to food art, the teacher says "Let's try to use our solar oven with a material that is easily cooked or melted (such as baking sugar, marshmallow, chocolate, or colored dough in cake molds)." The teacher shows examples from the internet pages and asks the students to make a unique study (Figure 8).

Figure 8. The Food Art Products of the Student Groups

Evaluation. The students solve practice questions related to the subject. The teacher assesses the products with the "Product (Design) Evaluation Rubric" and explains the scores to the students. Students' reflective comments on what they did during the activity are also assessed. Table 3 shows the STEAM dimensions of the activity.

Table 3. STEAM Fields and Contents of the Third Activity

Field	Content
Science	Light absorption of black material
Technology	Watching the animations, thermal camera application
Engineering	Design process (solar oven construction)
Math	Temperature measurement with thermometer, recording the duration, drawing a graph
Art	Food art

The Fourth Activity: White Light

The white light activity was designed to teach the standard "7.4.2.2. Makes inferences related to the result that the combination of all the colors of light is the white light." The activity took 4 lesson hours.

Engage. For the introduction to the subject, students are asked the following questions: "Can there be other colors into the light? Are the colors of light and colors of paint the same?" The students think about the colors in the rainbow. They make a class discussion related to this subject.

Explore. At the beginning of the exploration, the students perform an experiment. In the prism experiment, they use a chandelier crystal or CD to discover the colors that make up the white light. The students draw the rays of the rainbow colors on the paper in order (red, orange, yellow, green, blue, purple) in the end of the prism experiment. The students can also use their creativity to make their own artistic work (Figure 9).

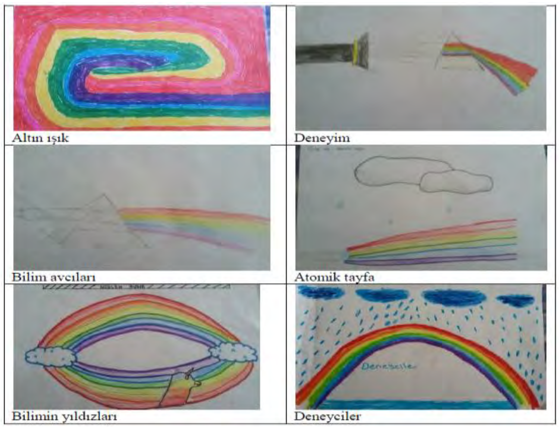

Figure 9. The Rainbow Colors Paintings of the Student Groups

Explain. The students begin a classroom discussion in the guidance of the teacher as to determine whether they have reached the correct conclusions about separation of white light. The students watch animations about this subject. The conceptual knowledge about the subject is explained by using the textbook and by continuing the question-answer interaction with the students. As a "Do you know?" explanation, the teacher mentions Leonardo's experiment with the prism about white light components: *"If you place a glass of water in a sill, with sun rays on the other side, you will see the colors forming in the trace of sun rays passing through the glass and falling into the darkness* (White, 2001, as cited in Topdemir, 2012, p.47)."

Elaboration. The teacher shows the videos related to spectroscope construction from CD to assist in the introduction and design of the tool. The students make their designs using the engineering design process (Figure 10). To make connection to music art, an English pop song called "Lights" is listened in the class.

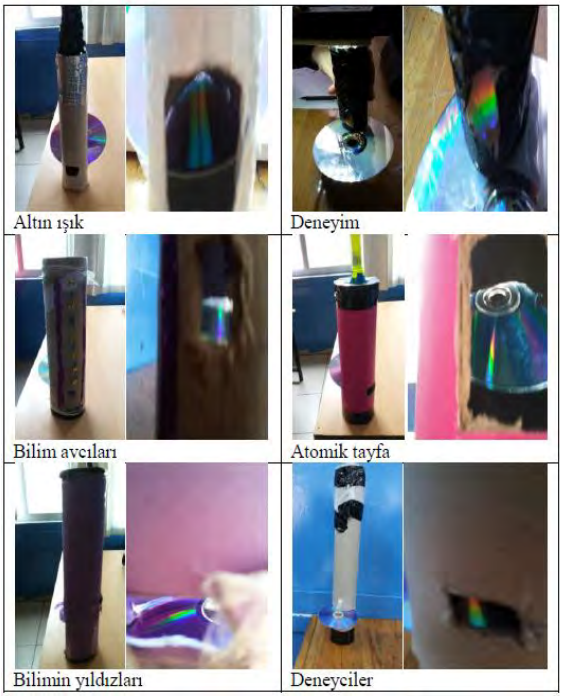

Figure 10. The Spectroscope and Rainbow Views Created by the Student Groups

Evaluation. The students solve practice questions related to the subject. The teacher assesses the products with the rubric. Students' reflective comments on what they did during the activity are also assessed. Table 4 shows the STEAM dimensions of the activity.

Table 4. STEAM Fields and Contents of the Fourth Activity

Field	Content
Science	Splitting the light into colors, prism
Technology	Watching the animations and music clip
Engineering	Design process (Spectroscope construction)
Math	To draw the rays of the rainbow colors refraction in the prism with a ruler- adjustment of the insertion angle of the CD in the spectroscope
Art	Painting Art- drawing the ray Music art

The Fifth Activity: Colored Appearances of Objects

This activity is aligned with the standard "7.4.2.3. Associates the reason of substances to appear black, white, and colored with reflection and absorption of light as a result of making observations." The activity took 4 lesson hours.

Engage. The students are asked the following questions: "What happens when colors come together? Have you seen any colorful light show?" The students think about the colors of substances and which colors can be formed by combining more than one color. They make a class discussion related to this subject.

Explore. The students perform an experiment for examining the colors of light. In this experiment, they paint the upper glasses of torches with different color pencils and thus they detect accent colors formed by combining different colors of light. They reach generalizations about color formation. Then they draw the Venn diagrams about the combination of the primary colors (red, green, blue) and accent colors. (Figure 11).

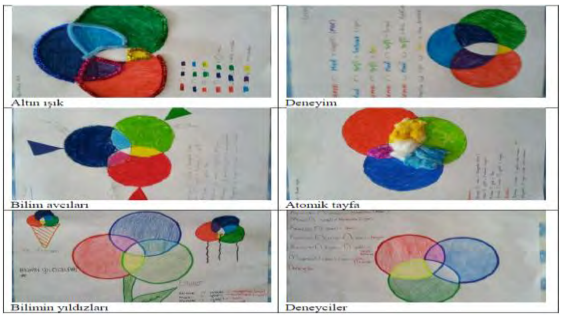

Figure 11. The Venn Diagrams Showing the Combination of Colors of Light

Explain. The students begin a classroom discussion in the guidance of the teacher as to determine whether they have reached the correct conclusions about combining colors of light. They watch animations about this subject. The conceptual knowledge about the subject is explained by using the textbook and by continuing the question-answer interaction with the students.

Elaboration. The teacher explains that colors of light are different from colors of paint. The teacher shows the videos of the walking rainbow experiments created with a mixture of colors of paint. With the marbling art application (*http://f.eba.gov.tr/ebru/*), both technology and art fields are applied together (Figure 12). To make connection with light art, the teacher shows images about the world's first light art museum in Unna, Germany. The teacher says "By covering the glass with a transparent colored material, we can create a light show tool in a shadowy environment using CD's, LED lights, or lanterns. Let's observe the accent colors formed by the combination of different colored lights." The students make their design using the engineering design process (Figure 13). Related to cinema and music arts, the teacher says "Let's compose a song and shoot a clip to our song by using our light show tool." The students shoot music videos with their tools.

Figure 12. The Designs of Student Groups in the Marbling Art Application

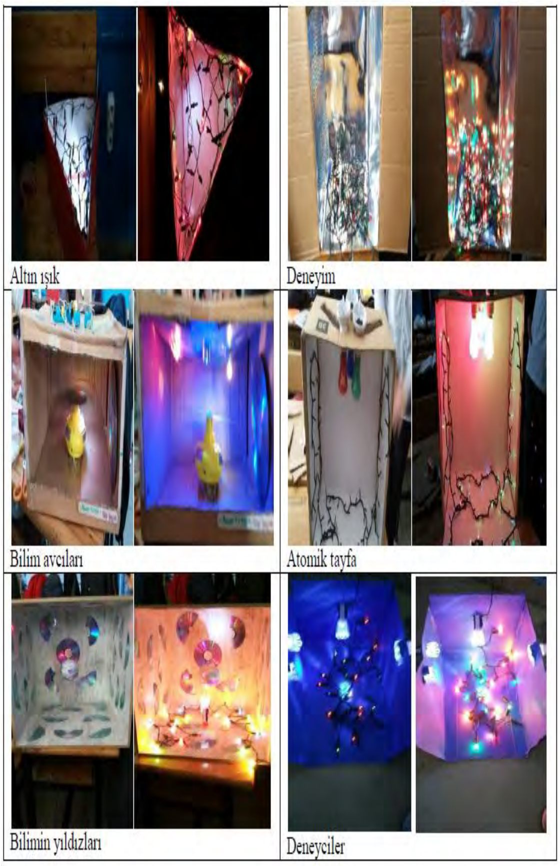

Figure 13. The Images Related to Light Show Tool Design of Student Groups

Evaluation. The students solve practice questions related to the subject. They investigate the use of solar energy in the technology (heating water, obtaining drinking water from sea water) and prepare a poster. The teacher assesses the products with the rubric. Table 5 shows the STEAM dimensions of the activity.

Table 5. STEAM Fields and Contents of the Fifth Activity

Field	Content
Science	Colored appearance of substances
Technology	Watching the animations- Marbling art application
Engineering	Design process (light show tool)
Math	Venn diagram related to combination of colors (intersection A∩B, and union AUB)
Art	Painting, Marbling, Light, Music, Cinema

EVALUATION OF ACTIVITIES

Semi-structured interviews were conducted with a select group of students from each group (six students in total) to evaluate the STEAM activities. In the selection of students, maximum diversity sampling (Yıldırım & Simsek, 2008) was used according to gender and achievement status. Interview questions were prepared by the researchers (Appendix 4) and 4-5 minute interviews were conducted with the students. The answers given by the students in the interviews were analyzed descriptively and the findings were reached.

When the students were asked about their favorite features in the activities; four students (S1, S3, S4, S6) said that they liked the teamwork. Two students (S3, S4) stated that they understood the lesson better. The answer for the S3 coded student is below:

> We understood the lesson better with the activities. We designed new products and tested our products to see what we did. We did it with our friends because it was a group work. Thus, the subject is understood more easily. Because we made the products ourselves, we could fix ourselves when something went wrong.

When the students were asked about features they didn't like in the activities; all of them said that they liked the structure of the activities. But they mentioned that some of their group mates had problems in the implementation phase when they were not interested in making or designing. The answer for the S5 coded student is below:

> There was nothing that did not go well in the activities, so it was all good. But in our

> team some of our friends had the problem of not bringing the stuff on them. That's why we were falling behind 1-0.

When the students were asked to evaluate the activities for their benefits; two students (S3, S4) stated that the activities increased their interest towards STEAM fields and helped them to understand the contributions of STEAM fields to our lives. Two students (S1, S4) stated that they provided better understanding of related science concepts. Two students (S1, S6) commented that the teamwork and communication were useful for them. The answer of the S1 coded student is below:

> I had a better way of expressing my information. I got it better. For example, I learned the features of mirrors. Regarding the skills, I tried to help my friends in many activities and it was really good.

When the students were asked to think about STEAM fields; four students (S1, S2, S4, S5) stated that the art field is one of the most prominent and interesting areas. The answer of the S4 coded student is below:

> Science was more at the front in our designs. We considered the technology in our designs. Our process of designing was about engineering. We had to draw and present our designs. There is also mathematics in engineering. We did some work, we worked with the coordinate system. Art was one of the most important things in our design because it was important to consider art together with engineering, mathematics, and science and to produce artistic work. We integrated a lot of fields with art and put something nice out there. Actually it was art that made it beautiful from the visual side. It's also art that attracts people's attention.

When the students were asked whether they wanted to participate in STEAM activities in future, all students said that they liked the STEAM activities and wanted to engage in such activities in future. Four students (S2, S3, S4, S6) said that they could understand science lessons better in this way. The answer of the S2 coded student is below:

> Yes, this improves our handicraft. It would be a lot of fun. Sometimes we are bored in lessons. When we do things like this fun, we are not bored.

The interview findings showed that the STEAM activities were positively received by the students. However, they experienced some teamwork problems.

CONCLUSIONS and SUGGESTIONS

STEAM (STEM + art) activities prepared according to 5E model were applied in this research. During the activities, it was observed that the students enjoyed the work they did, verbally expressing it to their teacher. Also, as seen in the photographs of the activities, the students achieved positive results in the designs they made and the groups tried to produce original and creative products different from each other. Part of the current research was conducted by Gulhan and Sahin (2018) using an experimental design with control-experimental group. The researchers found that these STEAM activities had a positive effect on students' academic achievement, STEAM attitude, and scientific creativity. Additionally, as a result of the interviews made with the students, it was determined that the students liked the activities; they thought that the activities supported their learning, they had the most attention towards the art field, and they wanted to do STEAM activities again. Ozkan and Umdu Topsakal (2017) also stated that the students had positive views on STEAM activities.

One of the most important features of the STEAM lesson plans created in the current research is that the students can use the materials they can identify and provide easily. Also alternative material suggestions were made to the students during the activities. Some students preferred these alternative materials, while others preferred materials that were not specified by the teacher in order to make a difference from other groups. In future investigations, new and different products can be discovered by using alternative materials and ideas. For a more effective STEAM application, plans can be made where the different subject-matter teachers at the school collaborate and parts of each activity can be done in each lesson, resulting in large design tasks.

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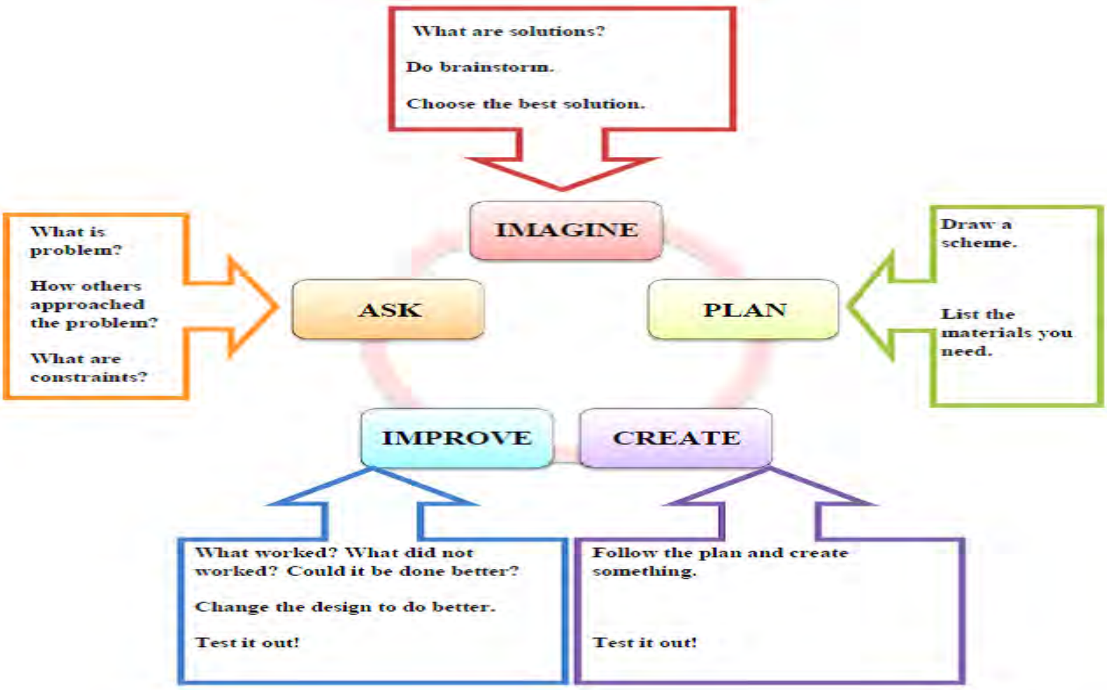
Appendix 1

Engineering Design Process

(Adapted from Cunningham and Hester (2007) and translated to Turkish by Gulhan (2016))



Appendix 2

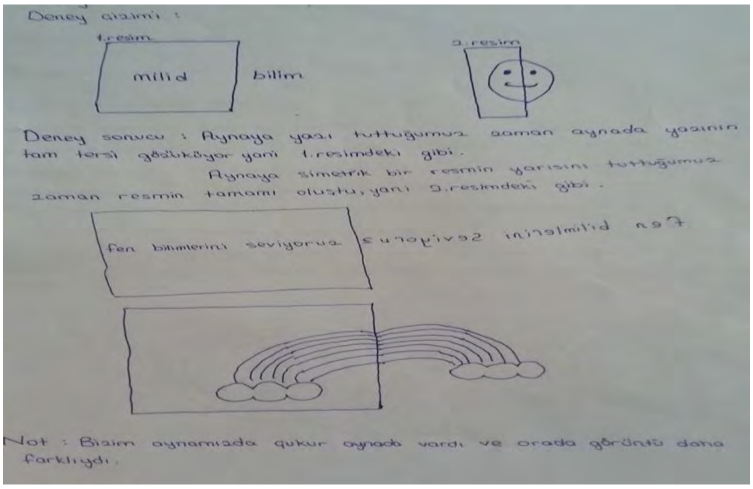
Product (Design) Evaluation Rubric (Gulhan, 2016, p.97).

CRITERIA	**Too weak (1)**	**Weak (2)**	**Medium (3)**	**Good (4)**	**Very good (5)**
Conformity to design purpose					
Originality of design					
Functionality of design					
Visual quality of design					
Conformity to design criteria					

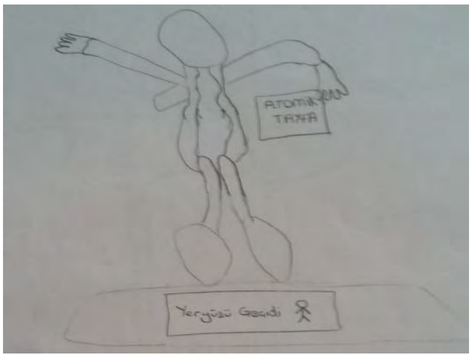
Appendix 3

Samples from Student Worksheets

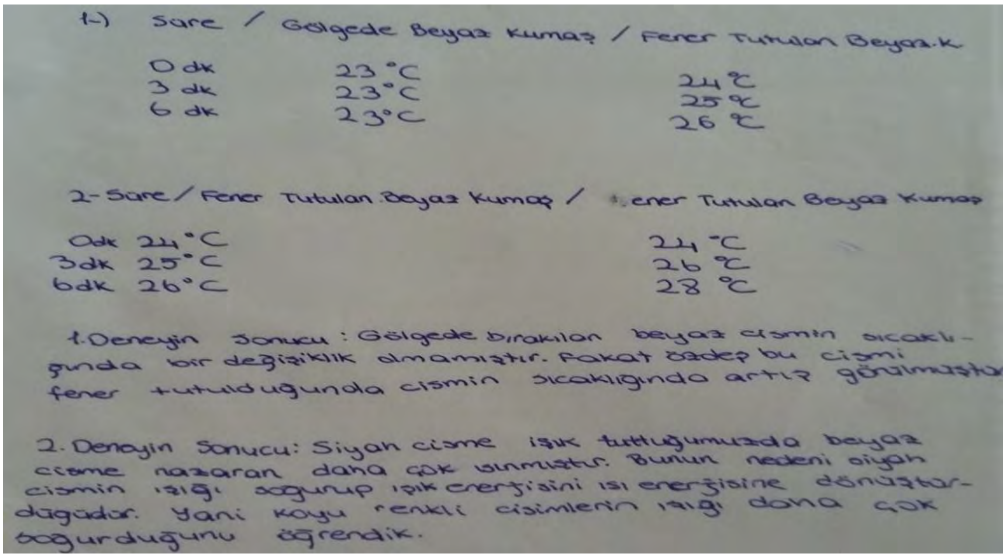
An experiment worksheet of a student group for the first activity



A draw of a student group for the second activity



A worksheet of a student group for the third activity



Appendix 4

Interview Questions

1) What did you like about the activities? Can you explain please?

2) What did you not like about the activities? Can you explain please?

3) Do you think the activities were beneficial for you? Can you explain please?

4) What can you say when you evaluate each STEAM field singly in the activities? Which fields were at the forefront for you?

5) Would you like to participate in similar activities in other lessons or topics?