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A Theoretical Study on STEM Education: Proposal of Two Applications

STEM Eğitimi Üzerine Bir Teorik Çalışma: İki Uygulama Önerisi

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ABSTRACT: As communication technology develops rapidly in the 21st century, it is easy to reach knowledge. At this point students should be able to create their own knowledge by researching, analyzing and synthesizing rather than asking the questions they can reach via internet. Real life problems may not be solved according to a single discipline. Therefore, it would be beneficial for us to transfer the climate and teamwork to the disciplines as a whole for the students. The purpose of this study is to present the importance and unexplained parts of STEM education through literature scan and especially to suggest STEM practices which mostly deal with mathematics classes. This study is a theoretical study and document analysis technique from qualitative research methods was used in the study. The study was prepared in terms of theory and it was presented to be an example for the other researchers. There are two sample practices together with their objectives in this study. While SCRATCH coding program was used in one of the applications and the other application was structured on isoperimetric theorem.

Keywords: STEM education, engineering, mathematics-based STEM, Scratch, coding, isoperimetric theory.

ÖZ: 21. Yüz yılda iletişim teknolojisi hızla geliştiği için bilgiye ulaşmak kolaylaşmaktadır bu noktada öğrencilere internet üzerinden ulaşabilecekleri sorular sormak yerine araştırarak analiz ederek ve sentezleyerek kendi bilgilerin oluşturmalarına fırsat verilmelidir. Gerçek yaşamda birçok değişkenden oluşan bir problemle karşılaşan öğrencilere, derslerde tek bir değişken üzerinden problem çözmeyi öğretmek gerçek yaşamla okul dersleri arasında uçurum oluşturacaktır. Gerçek yaşam problemleri tek bir disipline göre de çözülemeyebilir. Dolayısıyla öğrencilere disiplinleri bir bütün olarak ele alma iklimini ve ekip çalışmasını aktarmamız faydalı olacaktır. Bu çalışmanın amacı, STEM eğitiminin önemini ve açıklanamayan kısımlarını literatür taraması ile sunmak ve özellikle matematik dersleriyle ilgilenen STEM uygulamalarını önermektir. Bu çalışma teorik bir çalışmadır ve çalışmada nitel araştırma yöntemlerinden elde edilen doküman analiz tekniği kullanılmıştır. Çalışma teorik açıdan hazırlanmış ve diğer araştırmacılar için örnek teşkil etmesi adına sunulmuştur. Çalışmada iki örnek uygulama kazanımları ile birlikte yer almaktadır. Uygulamalardan birinde SCRATCH kodlama programı kullanılmış ve diğer uygulama izoperimetrik teoride yapılandırılmıştır.

Anahtar kelimeler: STEM eğitimi, mühendislik, matematik ağırlıklı STEM, Scratch, kodlama, izoperimetrik teorem.

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Introduction

Is STEM a new teaching approach or a philosophy? Maybe both of them because we still do not have precise methods about how to practice STEM and clear definitions which are accepted universally on STEM education. Besides, STEM is not a new concept as you think. Although it was first expressed by the director of The National Science Foundation, Ramaley (Breiner, Harkness, Johnson & Koehler, 2012), it seriously started to become the subject of the studies after Obama's statement in 2012 about the fact that STEM has to be implemented.

Bybee (2010) states that together with having students ask questions like how tools, equipments or anything that we use work and what kind of benefits technology brings into our lives to make them work and providing motivations which will keep their curiosity alive means STEM is being practiced properly. Moreover, he also added that engineering is directly involved in making innovations and solving problems.

Although in most of the publications, STEM is defined as an upper discipline which corresponds to the first letters, Green (2007) states that in addition to natural sciences, engineering and technology, disciplines like social sciences, psychology, economy and politics have also a place in STEM.

"A military bus has the capacity to take 36 soldiers. 1128 soldiers will be brought to the training field with this bus. According to this, how many buses do we need?". This problem was asked by National Assessment of Educational Progress (NAEP, 1982) to see the real attitudes of the students. Although 70 % of the middle school students who solved the question chose the correct operation to solve the question, only one third of them found the correct solution by interpreting the remainder in the division (Silver, Shapiro, & Deutsch, 1993). For this reason, the suggestion about relating mathematics to real life problems is not new. The studies on this field is increasing both in our country and in the world with the idea that the possibility to overcome students' prejudices like mathematics and science branches have no relation with the real life and to increase their interest to natural sciences will become stronger with STEM education.

There are many publications presenting results like using concrete materials is useful to learn and interpret abstract concepts (Bozkurt & Polat, 2011; Çeken, 2010; Kelley, 2010; Korur, Taşkın, İldemir, Acar, Üstündağ et al., 2014; Kutluca & Akın, 2013). Piaget asserts that the period involving the ages of 7 and 11 is concrete operational period and later on we move on to the formal operational period (Erkan & Ağrelim, 2016). This means that moving from concrete operational to formal operational period corresponds to the middle school time. Therefore, STEM education will make moving from concrete operational period to formal operational period easy for middle school students as it contains concrete studies.

The more Mathematics and Science curricula are given in a unified discipline; more will it be possible for learners to love mathematics and science lessons and to make positive progress towards seeing themselves as scientists (Furner & Kumar, 2007). For a successful research-based mathematics and science teaching; using manipulative (concrete materials), group work, questioning and discussion, using

technologies like calculators and computers are useful components (Zemelman, Daniels, & Hyde, 2005).

If we synthesize the studies stated above, an integrated teaching approach prepared with the help of using concrete materials, handling science and mathematics under a unified discipline, peer work and cooperative learning, questioning skills, debate and technology will appear. If we add them the ability of thinking like an engineer, it will be easier to understand STEM education. The other topics except the part of engineering became the subject of academic studies with either together or separately. In fact, in terms of its content, STEM is not an unknown teaching approach to us, but it makes us, as researchers, excited since STEM approach will bring a fresh blood into education with its engineering part.

It is stated in "A vision for innovation is STEM" report that as STEM promises a teaching which is based on application, it will assist students to gain experience about this subject since students can learn many things through the mistakes that they committed in the activities (Department of Education, 2016). It is also stated in the report that students, with STEM education, can improve their skills like analyzing, synthesizing and organizing information and they will have opportunities to use their own creativity as they wish when they are encouraged to gather information about a national park or a windmill that they have visited before to construct a similar place. The importance of group work is also highlighted in this report.

Thinking like An Engineer

Countries that want to capture the change in technology and want to be the creator of the changing technology give importance to innovation that is to say making a change. Any change or something new in the products contributes to the production. The increase in the production brings welfare and in terms of reaching this welfare enterprising countries make reforms in accordance with the policies that they adopted (Göker, 2000).

The presidents of ExpandEd School, Esther Dyson and Lucy N. Friedman define engineering design as a series of steps used for creating functional products or systems to fulfil the needs and desires of human beings either in the classroom or in the real world. These steps area: stating problems, thinking a solution, making plans, a prototype is created and tested then necessary improvements are made. Engineers either as a student or as professional scientists should analyze a situation to determine the problem. Before collecting equipments and designing a model, they need to be creative and they need brainstorming for the probable solutions. Kelly and Knowles (2016) stated the following steps for thinking like an engineer;

- ✓ It starts with a problem or need
- ✓ They analyze and interpret current solutions with the help of a model or a simulation
- ✓ After analyzing and interpreting current solutions, they decide on the most suitable solution
- ✓ They create a prototype and conduct a performance evaluation
- ✓ After performance evaluation, they decide on either the need or problem according to the results of the test

- ✓ They note the necessary improvements
- ✓ They make improvements about the solution and present the steps.
- ✓ Engineers try to do their best until they become successful.

There are inter-disciplinary studies in science and mathematics teaching (An, 2017; Berlin & Lee, 2005; Lehman, 1994) but there are also studies about science and technology (Daşdemir & Doymuş, 2016; Dimopoulos & Koulaidis, 2016) and about mathematics and technology (Gülburnu, 2013). In this case, the thing that separates STEM from other methods should be engineering or thinking and acting like an engineer.

Asghar, Ellington, Rice, Johnson and Prime (2012) expressed in their studies that people need to have a cooperative approach for their studies. You may need to be a role model to your students for STEM. Teachers should carry out studies displaying that they have team spirit among themselves in order to carry cooperative approach to their students' environment. In addition to this, negative opinions of teachers on STEM education also presented in this study. While a teacher expressed that STEM education forces him as it includes inter-disciplinary approach, another teacher stated that he does not use mathematics or technology for specific problems he cannot use STEM for this special problems.

We realize when we are observing children playing with blocks to form a whole that they are working like an engineer. Children realize the principles of engineering while they are breaking and fixing their toys (Brophy & Evangelou, 2007; Meeteren & Zan, 2010).

According to The National High School Alliance statement, STEM education is not only a new name for traditional science and mathematics teaching. At the same time, it does not mean transferring "technology" and "engineering" layers into the standard science and mathematics curriculum. Instead, STEM is a larger teaching approach than its theoretical components; as it is stated by Janice Morrison from Essential Science Teaching Institute, it is "meta-discipline" (as cited in Kennedy & Odell, 2014).

The Curriculum Compliance for STEM

Teaching programs prepared in 2017 presented to the teachers and academicians to take their opinions about them. When they are analyzed, the new part that attracts attention in the science lesson teaching program is the engineering applications. It was paid attention to link engineering and science.

The common thing in technology & design and mathematics teaching programs is the fact that objectives were addressed in accordance with Turkey qualifications framework. These competencies are clarified as; mathematical competency and competency in science and technology.

Therefore, it can be concluded that a background adopting STEM philosophy is trying to be constructed.

According to the STEM report which was prepare by General Directorate of Innovation and Education Technologies, STEM teaching will be taken into consideration intensively in 7th and 8th grades as required by Ministry of Education 2015-2019 action plan.

According to 2017 teaching program, there is a final unit covering science and engineering applications for each grade level in the middle school.

Although competencies like using technology in line with the objectives stated in the teaching programs, being informed about the technological developments in the world are involved in mathematics teaching program, using technology for each objective was approached flexibly. For instance, while "information and communication technologies are used by students" statement was used in some of the objectives, in the other part of the program there is an expression like "information and communication technologies can be used by students".

It is expected in science teaching program to run science, mathematics, engineering and technology all together while implementing the program. However, it is highlighted in the objectives not to touch mathematical correlations and links. In other words, while it is expected to explain, observe and analyze correlations, this should be done without using mathematical calculations.

Method

This study is a theoretical study and document analysis technique from qualitative research methods was used in the study. A document review involves the analysis of written materials that contain information about the phenomenon or phenomenon intended to be investigated (Yıldırım & Şimşek, 2011). In this context, two applications were prepared for STEM according to STEM discipline and at the same time their practicability in terms of the primary teaching programs renewed after a review by the Ministry of Education was analyzed. SCRATCH coding program was used for preparing one of applications. SCRATCH software which was put into practice by Massachusetts Institute of Technology and which is a project that can be accessed from all over the world via Internet access was used for an activity trial that will enable 7th grade students to learn a rule about regular polygons through discovery method.

On the other hand, the isoperimetric theorem was used for the other application in the study. The isoperimetric theorem can be expressed as follows: "It is the circle having the largest area of all closed planar shapes with the same circumference." (Howards, Hutchings, & Morgan, 1999).

STEM Application Suggestions

Application 1. Science, technology &design lessons were all also utilized in this application which was prepared for the mathematics objective stated as "knows that the sum of the outer angles of all the regular polygons is 3600". It is anticipated that this practice can be implemented at the 7th grade level, by looking at class levels of achievements in mathematics and technology-design courses in Table 1. It is enough to give two lesson hours to this application in order to discover the sum of the code writing and the outer angles of regular polygons.

Table 1

A Suitable Application for All Objectives in the Curriculum of 2017

	Mathematics Objective	**Science Objective:**	**Technology & Design Objective**
Objectives	M.7.3.2.2. Identifies the diagonals of the polygons, their internal and external angles; calculates the sum of the measurements of the interior angles and the exterior angles.	F.6.3.1.1. shows the direction, strike and magnitude of a force affecting an object through drawing.	7. A. 2. Basic Design The purpose of this unit is to have students express their opinions that they formed by using art/design components and design principles through sketches, technical drawings and models etc.

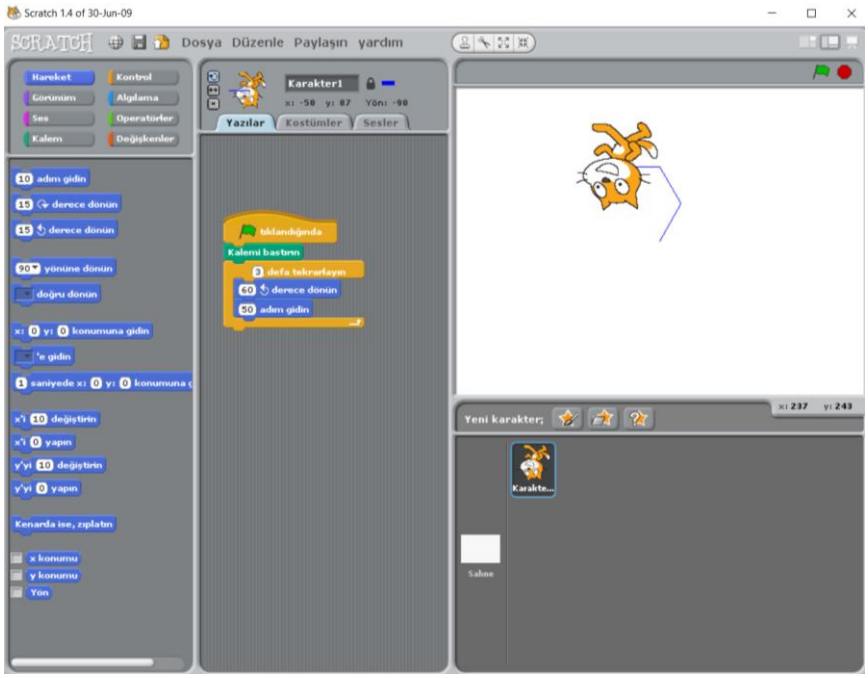
The most commonly known equilateral triangles from regular polygons are square and regular hexagonal. Inner angles are also learnt and kept in mind easily. As the sum of inner angles of the polygons differ according to the number of sides and an inner angle of other regular polygons is not a round number, it is not learnt and kept in mind as easy as a equilateral triangle, square and regular hexogen.

However, if we use square in the application, it will lead a misunderstanding in coding in other words it will shadow to learn what is needed to be learnt clearly because both inner and outer angle of a square is 900.

For this reason, choosing equilateral triangle and regular hexagon will ensure to carry out the study properly.

Ask your students to draw regular triangles and hexagons. Probably they will code as in the following:

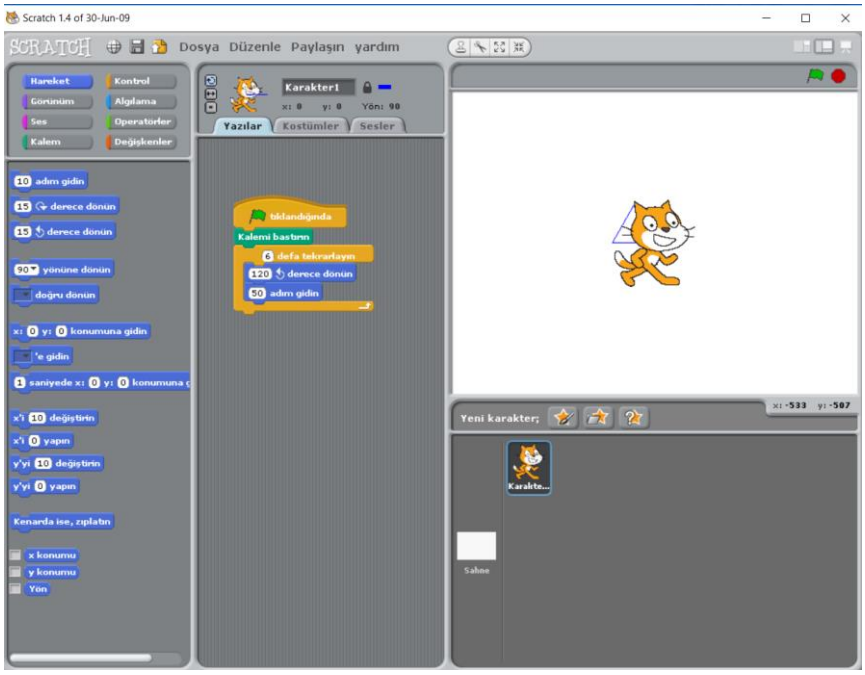
Figure 1. The Probable Codes That Students Will Write



The number of steps depends completely on the student. S/he chooses as s/he wants, but it is good to keep the number of steps large to be able to see the figure. The image that will appear on the screen after this coding will be as in the following.

In addition to this, ask your students to draw a hexagon and most probably the code they will be writing will be as in the following. Please, do not help them when they say "sir, we cannot do it" and try to be patient and wait for them to do what you want from them.

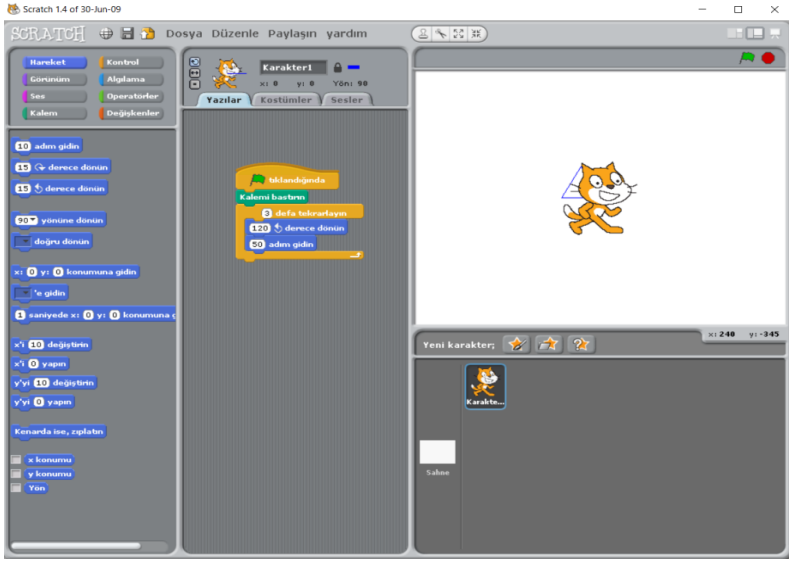
Figure 2. The Probable Coding That Will Come For Drawing Regular Hexagon



As a result of this coding, students will be disappointed again because it will be an image like below.

Wait for your students to discuss these two situations. While students are drawing these two regular polygons, they will think that they need to write codes according to inner angles. Ask your students to calculate the outer angles of these regular polygons and then write a code for these outer angles.

Figure 3. Codes Written For Drawing Regular Triangle (Equilateral Triangle) and the Image Appeared After This Coding



Now we can ask the following question to our student. Why do not we act according to inner angles in writing codes?

Give time to your students to discuss and to find reasonable answers.

If you want to help here, you can talk about movement subject from the science lesson. While moving to a specific direction and strike in the classroom turn and ask your students to calculate the angle of your turn. Similarly, you can also draw an image onto the blackboard for this.

Figure 4. The way of Explaining Angle of the Turn with a Horizontal Axis by Using Science Lesson

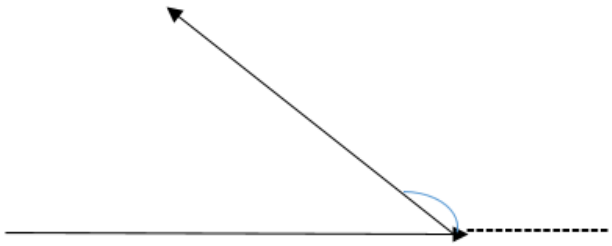
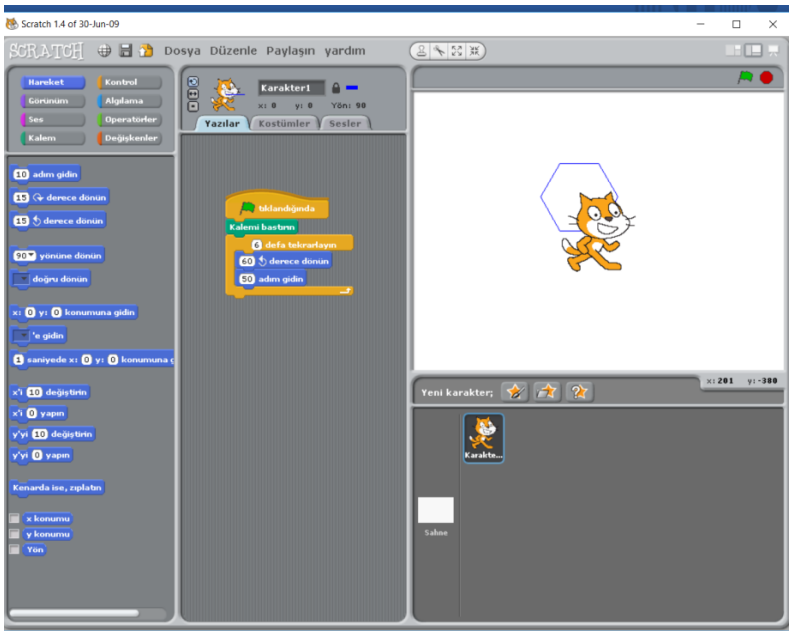


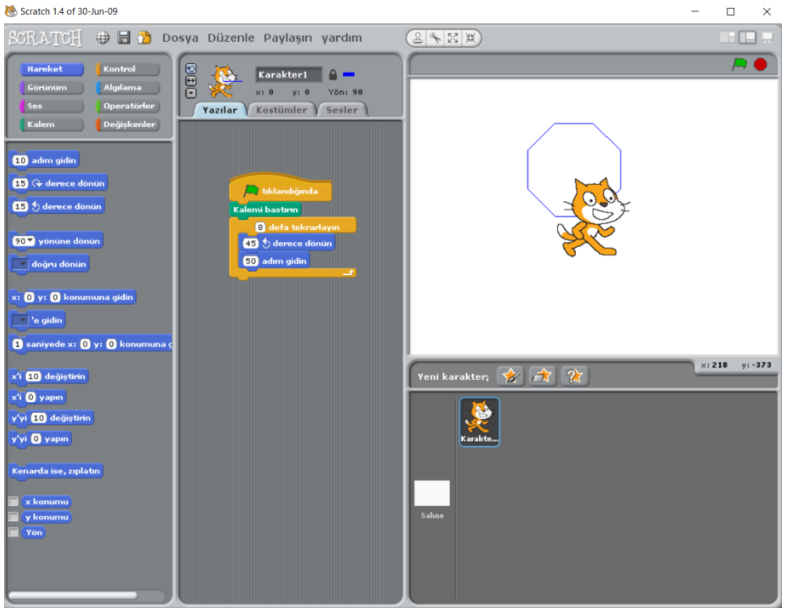
Figure 5. Codes Written for Drawing Regular Hexagon and the Image Appeared After This Coding



While drawing the triangle, the person or object moving to the east changed his or its direction. This changed happened from an outer angle.

When your students understand the logic behind this coding, ask them to calculate the sum of outer angles of both regular hexagon and equilateral triangle. There are three sides and outer angles of each side are 1200. Similarly, there are six outer angles of regular hexagon and each of them is 600. If you wish, you can ask the same for the square so that you can reach a generalization with your students. Finally, ask your students to draw an octagon.

Figure 6. Codes Written for the Regular Octagon



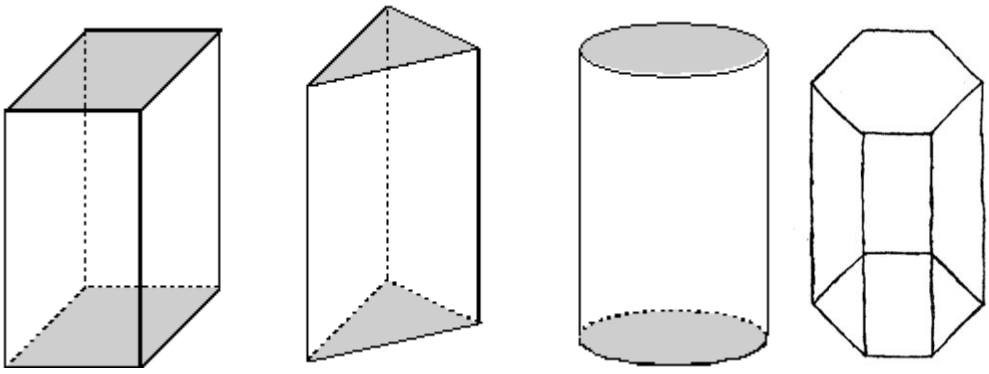
Application 2. The purpose is to make a precise explanation why a cylindrical shape was preferred for the production of the buckets. As in the other application, it is considered appropriate to implement this application in the 8th class because the acquisitions are included in different class levels in this application. The acquisitions of the application were shown in Table 2. As is seen, this practice overlaps with acquisitions at different grade levels in the 2017 primary education curricula. Therefore, this practice can only be implemented in the 8th grade.

Table 2

A Practicable Application for All Objectives in the Curriculum of 2017

	Mathematics Objective	**Science Objective:**	**Technology & Design Objective**
Objectives	M.8.3.4.4. Forms the volume connection of the right circular cylinder; solves related problems. a) Involves studies with concrete models. b) Information and communication technologies can be used. c) Studies about guessing the volume of right circular cylinder are included. d) Studies for correlating volume relation of right circular cylinder to volume relation of right prism are included.	F.4.4.2. Measurable Properties of a Substance Suggested time: 3 hours Topic / Concepts: Mass, Volume F.4.4.2.1. Compares mass and volume of different substances by measuring.	TT. 7. D. 1. 3. Prepares a design plan. The following issues are emphasized; user, material, practice, and paying attention to environmental factors, searching methods and techniques to solve the problem, developing solution suggestions, transforming one of the suggestions to the draft solution which is determined under the guidance of the teacher, determining tools and equipments which are suitable to solution.

Figure 7. Buckets with the Same Height and Same Base-Roof Circumference



The following problem can be created: “Which of these buckets that has an open top and same base circumference and height in the above image will you use to do more work in a short time?”

Here, designing skills are important, as the problem requires making model. For instance, they will design right triangle, right square, right hexagon and right cylinder buckets which have the same perimeter. Even, without using π number…

You should make them search the methods of these. In terms of helping them to find practical solution ways by acting like an engineer, you can ask them how they will calculate the circumference of the circle and tell them what tape measure is.

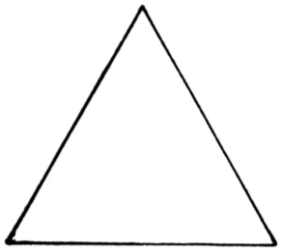
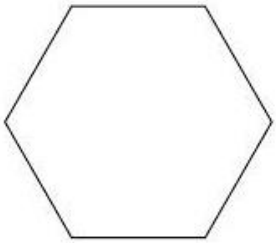
There is a need for volume and science field information. You can ask your students how they will calculate volume practically and give time to your students to discuss amongst each other. They might remember to put some sand or marbles into the buckets that they created. Later on, they make a comparison either according to the number of the same marbles or according to the weight of the sand so that they can find the one that will carry the largest volume.

But, the main issue is the mathematics part. We generally prefer windows as square or rectangular. At this point, ask your students to compare the areas of the shapes that have the same perimeter. For this, you can expect from your students to search the decision story of the prince who exiled from his country about isoperimetric theory. Some students will use circle while selecting the window.

In terms of making verification, ask your students to compare the areas of the regular polygons that have the same length, 12a.

Table 3

Polygons and Circle of the Same Circumference

	If the circumference of an equilateral triangle is 12a then one side of this triangle is 4a. The area is found as $4a^2\sqrt{3}$ by using the $\frac{a^2\sqrt{3}}{4}$ formula.
	If the circumference of a square is 12a then one side of this square is 3a. In this case, the area covered by this square is found as $9a^2$.
	If the circumference of a hexagon is 12a then one side of this hexagon is 2a. The area formula is found as $6a^2\sqrt{3}$ after making calculations with $6.\frac{a^2\sqrt{3}}{4}$.

The objective regarding the comparison of radical expressions is also taught to students by using these calculations. Therefore, this application is suitable to 8th grades.

Students are expected to discover that the area of the regular polygons that have the same circumference becomes larger as the number of the sides increases.

Discussion and Conclusions

As a result of examining the documents related to STEM education in this article, two applications were developed by the researcher. These two STEM trials which were prepared and designed theoretically in the study are mainly related to geometry. For this reason, many STEM applications can be produced about geometry.

In the first application, the acquisition of "the sum of the outer angles of regular polygons is 360 degrees", which is one of the basic principles of geometry with the help of coding, can be obtained by the students. In this regard, the success of solving questions about triangular opening can be increased. Coding is seen as a new way of "thinking" and "producing" (Sayın & Seferoğlu, 2016), so coding in the geometry lesson helps to acquire the gains permanently. It is also necessary to use the laws of physics to explain how robots or characters return, even if they are used in coding geometry lessons. Hence, getting help from science and technology to acquire an achievement in geometry lessons can also provide an in-depth understanding of that achievement.

In the second application, an example of the use of isoperimetric theory in daily life is presented. The isoperimetric theorem is to determine the largest field from enclosed planar curves with equal circumferences. It is a circle with the smallest circumference of any enclosed planar shape with the same area. The second application provides a concrete picture of how the isopectymetric theory can be used in everyday life. Thus, the philosophy of STEM education is reflected by bridging the gap between theory and practice.

When the literature was examined that it is seen that more studies related to STEM should be done. For example, according to English (2016), the researcher discussed the issue of whether STEM education is interdisciplinary, multidisciplinary or transdisciplinary. English emphasizes the fact that although the studies about using engineering, mathematics, science and technology at the same time have increased, the place of mathematics is still unclear. It is pointed out that there should be more balanced and fair research for the STEM disciplines to ensure that the learning outcomes of each discipline in the STEM do not interfere with each other. Since there are different approaches about STEM across the world, it is seen that this issue becomes more complicated.

Although STEM integration is addressed in various teaching programs and policy reports, it is stated that the studies presenting important evidences of the desired learning outcomes is not sufficient.

STEM education should be planned in a way to force students to innovate and invent. STEM education should use real life problems that student can generate models about real life.

While working with STEM discipline, it will be necessary to apply discovery method. By looking at the studies carried out so far and by looking at my study, of course it is not possible to make a generalization like “all the teaching ways and methods which are considered as important take part in STEM discipline”. However, we

still need lots of studies about this issue as STEM is open to be interpreted by many researchers.

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