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A TRANSPORTATION PROBLEM FOR MOVING COMPANIES: AN EXAMPLE ACTIVITY WITH AN ENGINEERING DESIGN FOCUS[1]

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ABSTRACT

This study aimed to present an example activity in which the engineering design process was used. The activity was carried out in an out-of-school learning environment in 12 periods of 40 minutes. Twenty-four students who were in the 6th, 7th or 8th grade, participated in the activity. Students were presented with a design problem in which moving companies must carry out transport operations in high-rise buildings without using the lifts of the buildings. They were then requested to make a design at a scale of 1/20 that can be used to carry goods to the fourth floor of a building. The students used technology (the Arduino program) for developing a solution. This activity enabled integration of the disciplines of technology, engineering, science, and mathematics. Students expressed positive opinions about the activity. The difficulties that students experienced and the suggestions for how to support them are discussed in the paper.

Keywords: engineering design process, STEM, middle school students, out-of school learning.

NAKLİYE FİRMALARI İÇİN TAŞINMA PROBLEMİ: MÜHENDİSLİK TASARIM ODAKLI ETKİNLİK ÖRNEĞİ

ÖZ

Bu çalışmada mühendislik tasarım sürecinin kullanıldığı örnek bir etkinliği ayrıntılı olarak sunmak amaçlanmaktadır. Etkinlik bir proje kapsamında okul dışı öğrenme ortamında 40 dakikalık 12 periyotta uygulanmıştır. Uygulamaya 6., 7., ve 8. sınıfa devam eden 24 öğrenci katılmıştır. Etkinlikte öğrencilere nakliye firmalarının yüksek binalarda apartmanın içindeki asansörleri kullanmadan nakliye işlemini yapmaları gerektiğine dair bir tasarım problemi sunulmuştur. Ardından öğrencilerden bir binanın dördüncü katına eşya taşımak için kullanılabilecek ve gerçek ölçülerin 1/20'si ölçeğinde bir tasarım gerçekleştirmeleri istenmiştir. Mühendislik tasarım süreci çerçevesinde planlanan etkinlikte öğrenciler Arduino programını kullanarak verilen problem durumuna yönelik çözüm geliştirmişlerdir. Etkinlikte teknoloji, mühendislik, fen ve matematik disiplinlerinin entegrasyonu sağlanmaya çalışılmıştır. Uygulama sürecinde öğrencilerin olası çözümlerin geliştirilmesi, en iyi çözümün seçilmesi ve prototip yapımı aşamalarında; birden çok çözüm geliştirmek, grup çalışması yapmak, çözümlerini prototipe aktarmak ve matematiksel model oluşturmak hususunda sorun yaşadıkları belirlenmiştir. Bu sorunların üstesinden nasıl gelindiği hususunda uygulayıcılara çözüm önerileri sunulmuştur. Öğrencilerin etkinlikle ilgili görüşleri makalede paylaşılmıştır.

Anahtar kelimeler: mühendislik tasarım süreci, STEM, ortaokul öğrencileri, okul dışı öğrenme ortamı.

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INTRODUCTION

Science, technology, engineering, and mathematics (STEM) education is an approach that emphasizes production and innovation beyond knowing, learning by doing, and experiencing (Çorlu, 2017). As an approach that brings fore production and innovation in addition to knowing and learning by doing and experiencing, STEM education is adopted in both national and international efforts for developing/improving education (Bozkurt Altan, 2017a; Ercan, 2014; Karahan, 2017; Ministry of National Education [MoNE], 2017, 2018; National Academy of Engineering [NAE], 2010; National Research Council [NRC], 2012; Smith & Karr-Kidwell, 2000). One of the important points of this approach is the necessity that the education on the disciplines of STEM is carried out in an integrated and holistic way (Smith & Karr-Kidwell, 2000). Integrated and holistic approach refers to activities in which the STEM disciplines are intertwined with each other. The literature defining STEM education also frequently emphasizes the importance for students to experience real-life problems that are compatible with their lives or contexts and which have multiple solutions, on the one hand, and to use or improve their knowledge and/or skills about at least two of the STEM disciplines when they seek solutions to these problems, on the other hand (Sanders, 2009; Shaughnessy, 2013). It is often the case that STEM activities involve real-life problems in such a way to provide knowledge and skill about a discipline in focus (NAE & NRC, 2014). To explain it with an example, a teacher who wants to enable learning objectives about the subject of mirrors and reflection in science courses might offer students a problem which requires them to develop a design using knowledge about mirrors and reflection. The teacher might structure the problem-solving process based on the engineering design cycle. But when developing a design, they might also need to form a mathematical model. The disciplines of science, mathematics and engineering are to be used in such a process. However, the discipline in focus is science, and the aim is to develop knowledge about the subject of mirrors.

Another important point to take into account when planning learning environments suitable to STEM education is how the integration of these disciplines will be achieved (Bozkurt Altan, 2017b). To detail it more, "*Science courses already intertwine with mathematics because X=V.t, d=m/V, is not mathematics used for these anyway?", "When we use presentation applications with computers in mathematics courses, is not this a technological integration?", "We had designed a vacuum flask in science courses, is not this how engineering integration occurs?"* To answer such questions, it is important to draw a frame about how to integrate STEM disciplines into the learning process in such a way as to make it possible to plan learning environments suitable to STEM education. Therefore, it is important to focus on how to integrate the STEM disciplines. The literature recommends using processes that are similar to how STEM specialists work in real life (Breiner, Harkness, Johnson, & Koehler, 2012; Chiu, Price, & Ovrahim, 2015; Harrel, 2010; NAE & NRC, 2009, 2014). Those who work in the field of sciences use inquiry processes. Mathematicians use model building frequently in the process of mathematical problem solving (Karahan & Bozkurt, 2017). Then, it is necessary to include inquiry processes in a STEM focused activity involving the science discipline, whereas modelling needs to be included in an activity that involves the mathematics discipline (NRC, 2012). Developing products in the field of technology requires computational thinking (Çorlu, 2017). With engineers, they find solutions to problems by using the design process (Hmelo, Holton, & Kolodner, 2000). In this case, it will be necessary to use applications that will improve computational thinking skills in the activities into which the technology discipline is integrated. In applications involving engineering, on the other hand, the engineering design process should be used (NAE & NRC, 2009). To answer the questions asked at the beginning of this paragraph, integration of mathematics will not have been achieved by performing the four operations in formulas that are used in science courses. Integration of technology as suggested by the idea of STEM education will not have been achieved with a measurement and assessment carried out with a slideshow presentation prepared by a teacher or student in mathematics courses. Likewise, integration of engineering will have been achieved only if the steps of design process have been used for a vacuum flask. To elaborate it further, instead of ensuring the making of a vacuum flask by following certain procedural steps with students, a problem case can be presented that contains certain criteria and limitations they will need when making a vacuum flask. For instance, a lesson can be started with a scenario about the need felt for designing a useful and aesthetic tool which will preserve the temperature of a beverage and which will be made using simple materials. After ensuring that the students define the criteria and limitations involved in the problem, a process can be carried out which will enable them to make solution suggestions and selecting, prototyping and testing the best solution. In this case, a vacuum flask will have been made in the lesson after all, but the engineering design process will have been taken as basis.

The fact that it is easier to integrate other STEM disciplines in activities involving engineering is an important point that is emphasized in the literature (NAE & NRC, 2009; NRC, 2012; Roehrig, Moore, Wang, & Park, 2012; Siew, 2017). This is defined as the unifying role of engineering (Felix, 2010; NAE & NRC, 2009). In other words, it is pointed out that the integration of other STEM disciplines will be easier in the activities where the engineering design process is used. As a matter of fact, engineering, by its nature, requires utilization of the science, mathematics, and technology disciplines. In this case, it would be useful to consider in more detail the engineering design process presented in Figure 1 (Brunsell, 2012; Fortus, Dershimer, Krajcik, Marx, & Mamlok-Naaman, 2005; NAE & NRC, 2009), which is also used in the activity presented in this study:

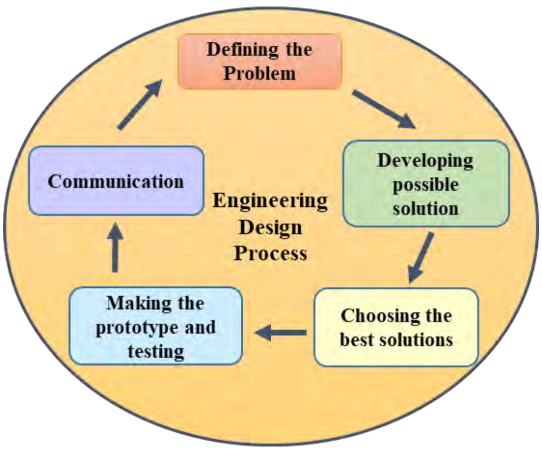


Figure 1. Steps of Engineering Design Process

The engineering design process begins with a problem involving criteria (features that should be in the design) and constraints (barriers to making the best design). In order to define the problem, students are asked to determine the criteria and constraints in the problem. In the next step, it is necessary to produce solutions for the problem and to make research for producing solution. In the next stage, it will be necessary to decide which of the solutions developed is best in terms of the criteria and the constraints. A prototype relating to the preferred solution is made and tested. Finally, students are asked to make a presentation to explain why their solution is best (Brunsell, 2012; Fortus et al., 2005; NAE & NRC, 2009).

The use of the engineering design process to create learning environments suitable for STEM education is included in the international literature, reports, and scientific studies (Hmelo et al., 2000; Moore et al., 2014; NAE & NRC, 2009; Roehrig et al., 2012; Siew, 2017). This situation is reflected in the integration of the engineering design process into science courses as an important emphasis on STEM education in Turkey too (MoNE, 2018). A study conducted with teachers in Turkey notes that science teachers have difficulty in preparing engineering design problems (Bozkurt Altan & Hacıoğlu, 2018). In addition, although the science curriculum makes an emphasis on the integration of engineering discipline, there are no exemplary practices for teachers (MoNE, 2018). Therefore, it is believed that it will contribute to the literature to present exemplary practices for teachers and teacher candidates about how the activities employing the engineering design process are planned and implemented. In this activity, additionally, the implementation process is explained in detail and student feedback is presented. This situation may also help those educators who want to implement the same activity to have an idea about the process.

The activity planned within the scope of this study was carried out in an out-of-school learning environment. Out-of-school learning environments are where STEM-oriented activities with specific contexts can be implemented, and their positive effects on students are among the results of many studies (Baran, Canbazoğlu Bilici, Mesutoğlu, & Ocak, 2016; Bicer, Beodeker, Capraro, & Capraro, 2015; Bozkurt Altan, Üçüncüoğlu, & Öztürk, 2019; Sullivan, 2008; Şahin, Ayar, & Adıgüzel, 2014). The literature will benefit both from the direct use of the activity carried out to this end for the researchers planning to carry out STEM activities in out-of-school learning environments and also from its use to develop new activities.

ACTIVITY IMPLEMENTATION

This study aims to present in detail the activity named *A Transportation Problem for Moving Companies*, which was planned based on the engineering design process, as an example activity compatible with the concept of STEM education. The activity is one of the activities developed within the scope of the project called "Preparing the STEM Education Program for Secondary School Students and Investigating Its Effects", which is supported by the Scientific Research Projects Unit of a university in the Black Sea Region of Turkey. The project was planned as an out-of-school learning environment. Detailed findings regarding the outcomes of the project are included in the research conducted by Bozkurt Altan et al. (2019). The activity presented in this study was implemented in 12 periods of 40 minutes.

Within the scope of the project, the Ethics Committee Report was obtained and with this report, permission was received from the Directorate of National Education for the participation of students. Information letters, posters and application forms and parental consent forms were then distributed to the schools in the central district. Twenty-four students (13 females, 11 males) in the sixth, seventh, or eighth grade, who applied voluntarily, were selected by simple random sampling.

In this activity, students are presented with a scenario in which moving companies must carry out transport operations in high-rise buildings without using building lifts. Then they are requested to make a design at a scale of 1/20 that can be used to carry goods to the fourth floor of a building. In this activity that was planned within the frame of the engineering design process, students were requested to use technology (the Arduino program) for developing a solution for the given problem. This activity enabled integration of the disciplines of technology, engineering, science, and mathematics. In order to achieve technology integration, students need to have an entry level of knowledge and skills in coding with Arduino. Within the scope of this project, some activities were carried out before this activity in order to develop the skills of students to use Arduino. Another prerequisite is that the students have experience in how to create a mathematical model.

Tools and Equipment

The tools and equipment to be used for the activity is listed below. During the implementation of the activity, it was ensured that students are free to use simple/waste materials in addition to the given tools and equipment. The tools and equipment included

- ❖ Ardunio Uno board,
- ❖ computer connection cable,
- ❖ jumper cable,
- ❖ stepper motor,
- ❖ lego set*,
- ❖ rope,
- ❖ pulley,
- ❖ cardboard,
- ❖ scissors,
- ❖ band,
- ❖ computer,
- ❖ activity sheet (Appendix 1),
- ❖ design evaluation rubric (Appendix 2), and
- ❖ students' diary (Appendix 3).

**A lego set was used because it was available in the laboratory. It is not necessary to have legos for the implementation of the activity. It can also be carried out using simple materials.*

The activity was carried out with groups of four students. The implementation process of the activity will be presented on the basis of the steps of the engineering design process.

Stage I: Defining the Problem

At this stage, first a problem is presented to students. In the current study, the following problem was asked:

> *Mr. Ahmet, the manager of a moving company, came to your company with some complaints. He stated that the personnel working in door-to-door moving works exert a lot of effort when unloading or*

carrying goods upstairs and that they have difficulty in carrying large and heavy goods. He said that they mostly experienced this problem in buildings as high as 8-10 floors. Moreover, in some apartment buildings, management does not allow the use of the lift even for the transport of small items. As a general problem, he said that they suffer great difficulty when they come up or down the stairs from the stairwells of apartment buildings with goods because stairwells are narrow in some apartment buildings and low in some others, and that they occasionally cause material damage, even if very little, to the transported goods. As a result of increasing customer complaints and demands, he asked you and your team to find a solution that will not only reduce the burden on the employees but also enable carrying the goods safely to the desired point.

In this part of the lesson, the students are asked what is expected of them in the problem. Then the following questions are asked:

- ❖ How do you think we can find a solution to this situation?
- ❖ Can we find a solution using simple machines? How?
- ❖ Can a system be installed outside the apartment?
- ❖ How do you think we can minimize manpower?

Some of the student answers to these questions were as follows:

S16: It would be hard to pull a load using a movable pulley and I think manpower would also be less.

S9: We can build a system with a lever and pulley from simple machines.

S13: I thought of making a crane-like system outside the apartment building. But its details remain to be planned.

At this stage, students began to form models in their minds but they needed to think about the details. It was observed in general that they were able to answer the questions.

After discussing the above questions, the students were told that they were required to prepare a model to solve the problem presented in order to best explain this system to the customer. The model will be built by reducing it to a scale of 1/20 based on a 4-storey building. The model to be prepared will have to bear at least a 1 kg load. Simple machines will also need to be used to reduce costs.

After discussing the details of the problem, the students are asked what criteria and constraints are in this problem and this stage is ended. Firstly, at this stage, how the criteria and limitations were to be determined was explained to students through another example. It was observed afterwards that they could determine the criteria and limitations related to this problem. This stage was carried out in 2 periods of 40 minutes

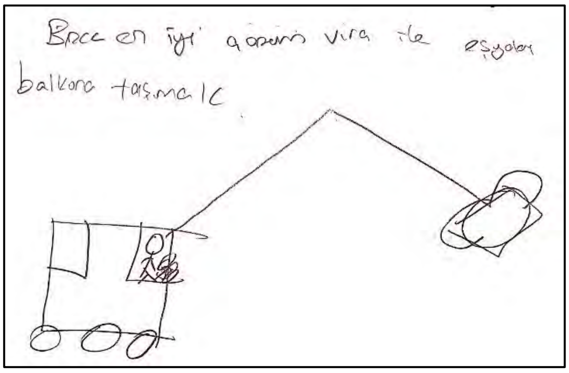
Stage II: Developing of Possible Solutions

At this stage of the activity that is carried out through group work, each student in the group is asked to individually produce more than one solution for the problem. The stage of developing possible solutions in the design process is the stage in which students are expected to reveal their creativity (Brunsell, 2012; Hynes et al., 2011). Although brainstorming improves generating creative ideas, individual solutions are taken first so that one of the students' first solution does not prevent other students from producing different suggestions. In Photos 1 and 2, some of the individual solutions of the students are presented.

Photograph 1. S19's Individual Solution

It was observed that students could make a drawing for a single solution in their individual solutions. Although attention was drawn to the importance of generating multiple solutions, only a few students were able to propose multiple solutions. After generating individual solutions, students brainstorm over the solutions that each individual in their group has produced. They share the details of the solutions with each other and conduct group work in order to provide better solutions. At this stage, instructors listen to possible solutions and ask questions that can help groups to improve their solutions. An example dialogue between instructors and students at this stage is as follows:

> S13: Our solution is to grab something like a crane and carry it up.
> Researcher: How do you plan to do that?
> S14: We're going to make a long arm, we can make a motor-driven reel to the end, but we haven't looked at how to make the connections to run the engines.
> Researcher: So how will the crane grasp the objects, should the objects be shaken? Have you thought about anything to prevent shaking?
> S16: Hmmm, we didn't think that.



Photograph 2. S7's Individual Solution

At this stage, which requires intensive utilization of creativity, it might be suggested that students are asked to elaborate their ideas. This is because students can develop original ideas but they might not be aware of details. At this stage, they should be asked how they will implement their solutions. They may be asked to draw/explain them in detail.

Students may need information about the principles of simple machines, how the stepper motor works, etc. in order to elaborate their solutions. At this stage, therefore, the necessities in such matters as operating stepper and servo motors that are contained in the solutions proposed by students and involving simple machines and Arduino as prerequisites, and small activities were planned. The activities related to simple machines are as follows:

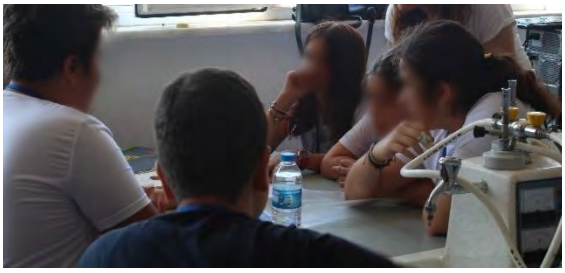
How does the fixed and movable pulley work? In this activity, force was measured after fixed and movable pulley assemblies were prepared using Legos. Also, analyses were made on gains and losses involved in displacement and force and on ease of working.

Let's make a lever. In this activity, students were first introduced to leverage. Using Legos, they were led to build leverage models in which the support point was close to the load and force and to notice force and displacement gain/loss situations through force measurements.

How do stepper and servo motors operate? Prior to this activity, the students already had knowledge and experience about physical programming with Ardunio. In this activity, operation of stepper and servo motors and their places of use in daily life were discussed. Then, stepper and servo motor codes were examined and run. Subsequently, the students were asked to prepare a mechanism to solve a problem in daily life by running a stepper and servo motor. In this activity, some students designed garage shutters, while others designed barriers.

Stage III: Selecting the Best Solution

At this stage, after discussing the individual solutions of the students and developing, as a group, several alternatives based on these solutions, the students were asked to decide on the solution that best meets the criteria and constraints in the problem. Students were asked to make evaluations by considering the criteria and constraints in order to decide the best solution. A picture of the group work in the selection of the best solution is shown in Photograph 3.



Photograph 3. An Image of the Process of Selecting the Best Solution

In one of the groups, there was an intra-group dispute in deciding the most appropriate solution. It was concluded as a result of the dialogues established with the students that the situation was due to the fact that they did not have much experience of group work in formal education. The source of the dispute was that two of the students in the group insisted on the selection of their own solution. At this stage, the importance of choosing the most appropriate solution for the next stage was explained to the students. It was also emphasized that the most appropriate solution should be based on the criteria and limitations in the problem.

The instructors listen to the decisions of the groups and question why that decision is best. This process continues until satisfactory answers are received from the students. An example dialogue was:

> S1: Our decision is to make a rail. In this rail, we will put the items in a box that we think of as a wagon and pull this box with a rope tied to an engine.
> Researcher: Why do you think this is the best solution?
> S3: It meets almost all criteria. We can move things safely. It also costs cheap.

Stage IV: Prototyping and Testing

In this part of the lesson, the students began to model their solutions. At this stage, the students might tend to construct models with trial and error and without considering the 4-storey building and reduction at a ratio of 1/20 stated in the problem. Therefore, the students were asked to make calculations before giving them the necessary materials and to form a mathematical model expressing how the simple machines in the model that they will build can maintain the system, and the power gain in their models. The students who decide to use Arduino are given the opportunity to make small applications about how to make connections.

It is tested whether the prototypes prepared by the students are working, and whether they meet the criteria of carrying at least 1 kg load and using simple machines. In the testing stage, causes of problems are questioned with the groups in which those problems are identified. They are given the opportunity to make improvements. A few images relating to the stage in which the students presented their prototype making process are presented in Photographs 4 and 5.

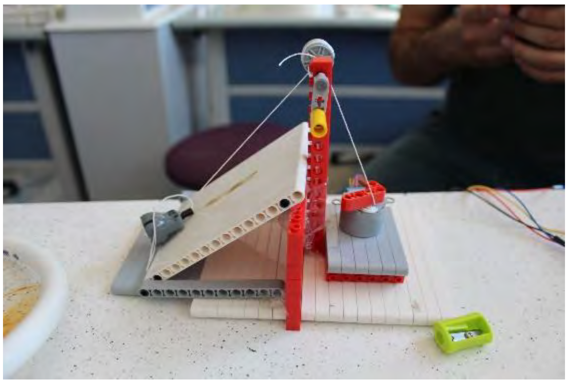
Photograph 4. An Image of the Process of Making Prototype

Photograph 5. Another Image of the Process of Making Prototype

One of the problems observed during the prototyping process was that the students had difficulty in transferring their designed solution to the model. At this stage, it was determined that the students frequently used the following expressions in the dialogues established with them:

> S11: We had done a better drawing. But we were able to transfer it to the model only this much.
> S17: This wasn't exactly what we designed in our minds. We have difficulty transferring it to the model.

One of the students' prototypes is presented in Photograph 6. For example, the mechanism prepared in the prototype of the group given in Photograph 6 is suitable for solving the problem. However, it does not meet the 1 kg load-carrying criterion. It is also not suitable for the 1/20 scale for a 4-storey building. The group stated that they aimed to put their ideas into practice but that they realized only close to the end of the design that they did not pay attention to dimensions. After the testing phase, it was ensured that the group built the same assembly in consideration of these criteria.



Photograph 6. One of the Prototypes

It was found that the students had difficulty in creating a mathematical model for their designs. Often, the simple machines they used in the design were fixed pulleys and levers. They expressed their gain in leverage with the known force gain formula, but they could not plan it by taking into account the variables in their designs.

Stage V: Communication

At this stage, it is ensured that students prepare digital posters to introduce their prototype. They are then asked to name their own projects and create a slogan. Students will need to convince that their solution is the best.

Through the rubric presented in Appendix 2, the designs were evaluated by three researchers in the learning environment and feedback was provided to the students. At this stage, students were also given time to develop ideas on how to improve their design.

EVALUATION OF THE ACTIVITY

As part of the project in which this activity was developed, the opinions of the students for each activity were taken through diaries. The papers listing the name of each activity were distributed to the students at the end of each activity. The following statements were included:

- I liked this activity because...
- I did not like this activity because...
- This activity improved me in terms of...

Evaluations in the student diaries for this activity were examined (Appendix 3). At the end of the implementation, 23 of the students evaluated the activity and 22 of them reported positive opinions. It was determined that, when students expressed their positive opinions, they emphasized the practice of design development processes (f=9), the opportunity of thinking creatively (f=6), the contribution made to developing themselves in coding (f=5), the motivation of dealing with a problem from daily life (f=5), the contribution made to the increase in their interest in engineering (f=2), being fun (f=2), and the contribution made to teamwork (f=2). For example, one student, S5, wrote "We were faced with a real problem again and finding solutions to real problems makes me feel useful." to appreciate the value of working with real life problems. Another student, S8 pointed to a motivation in engineering by expressing "…For the first time, I was interested in engineering." The student coded as S14 wrote about the value of group work: "…We have learned to think fast, make group decisions, and cooperate."

One student who expressed a negative opinion referred to their designs being not successful and expressed their views as follows. "…We made a nice conveying belt but felt bad because it didn't work because we couldn't do the calculations correctly." (S19).

CONCLUSIONS and SUGGESTIONS

In this study, an activity in which students experienced the engineering design process in an out-of-school learning environment was presented in detail. The students worked enthusiastically although it was a long and exhausting activity. *The Moving Companies* problem, which is a problem from daily life, is believed to be appropriate to the context of the students. As a matter of fact, it was observed that the students found the problem realistic and were motivated to find solutions. Furthermore, it was ensured that students gained awareness about how engineers solve problems and about the engineering design process. Therefore, it can be said that the activity can be applied to develop design skills.

It was found that the students made positive evaluations for the activity. They emphasized that in their opinions the activity enabled them to employ design development processes and think creatively, supported them for improving themselves about coding, motivated them to deal with a problem from daily life, helped to increase their interest in engineering, and contributed to teamwork. In this context, it can be said that students approached positively to this activity in which engineering design process was used. There was only one student who presented negative opinions about the activity. It was determined that this student could not make the design as planned and thus felt frustrated. At this stage, practitioners may be advised to give students the opportunity to develop their prototypes after testing and they should pay attention to encouraging them.

It was determined that the students experienced problems about developing possible solutions and selecting the best solution in the implementation process of the activity, and about developing multiple solutions, carrying out group work, transforming their solutions into prototypes and making mathematical models in the stages of prototype building. Possible causes of these problems and recommendations for practitioners are presented below.

It was revealed that, at the stage of developing possible solutions, the students first preferred to express a single solution in their individual solutions. Only a few students have shown the tendency to produce more than one solution. This is thought to be due to the fact that students had not frequently encountered such activities that require them to use their creativity. Efforts were made to prevent creativity from declining by applying the criteria of using Arduino and simple machines only after the presentation of the solutions for the problem case.

It was observed that students in a group experienced intra-group disputes in the decision-making process. As a result of the dialogues established with the students, this situation is thought to be due to the fact that the students do not experience much group work in formal education. Moreover, it was observed that the students had difficulty in transferring the solutions they dreamed and drew to the prototype. For this reason, it may be suggested that the activities which use the engineering design process in formal education should be applied more.

It was observed that the students had difficulty in transferring the models in their drawings or in their imagination to the prototype. Based on the dialogues established with the students, it was determined that this situation stemmed from the fact that the students had not had much experience of similar practices in formal education. It is believed that performing more than one application will enable students to develop themselves in this matter. Practitioners to work with students who will experience this practice for the first time are advised to encourage students to transfer their solutions to the model as much as possible.

It was determined that the mathematical modelling part of the activity needs improvement. In the activity, it was planned for the students to create a mathematical model for efficiency by considering possible data for parameters such as human labor, cost, and power gain related to the loads to be carried. However, it was observed that students had difficulty in making these connections. It may be suggested that practitioners should focus more on ensuring that students develop mathematical models regarding the force gain in their designs.

Considering the objectives of the science curriculum to improve engineering and design skills (MoNE, 2018), it may be suggested to use engineering design activities in science courses as well. It would be useful to make a small explanation for teachers who want to use the engineering design process in their classes. As this activity was planned for an out-of-school learning environment and implemented in the context of a wider project, there was no concern for teaching comprehensively toward the science standards. However, since students in the sixth, seventh, and eighth grade were involved and one of the criteria for the problem was to use at least two simple machines, mini activities were planned in which the inquiry processes related to simple machines were used in the process of developing possible solutions. It is suggested to ensure that students gain the knowledge and skills they need to produce solutions related to design through such techniques as mini research, experiments, brainstorming, etc. in classroom applications at the stage of developing possible solutions for the science standards involved in the design problem.

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Appendix 1

Activity Sheet

A TRANSPORTATION PROBLEM FOR MOVING COMPANIES

THE GROUP MEMBERS

-
-
-
-

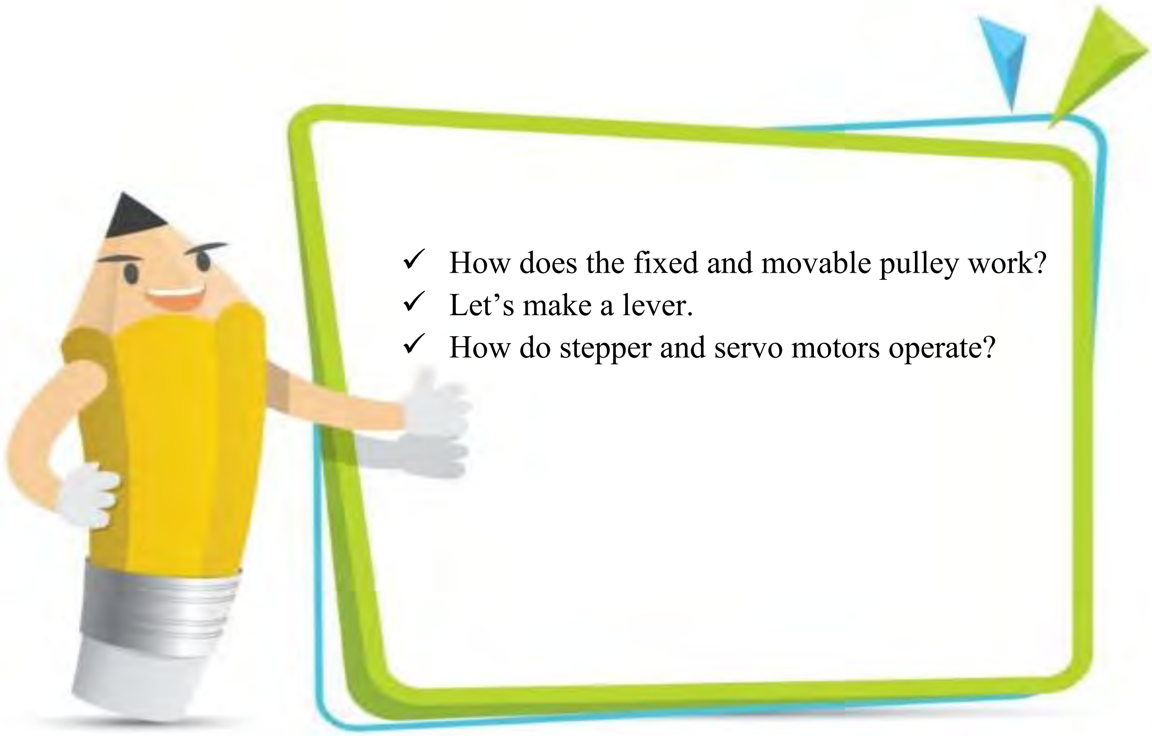
"Mr. Ahmet, the manager of a moving company, came to your company with some complaints. He stated that the personnel working in door-to-door moving works exert a lot of effort when unloading or carrying goods upstairs and that they have difficulty in carrying large and heavy goods. He said that they mostly experienced this problem in buildings as high as 8-10 floors. Moreover, in some apartment buildings, management does not allow the use of the lift even for the transport of small items. As a general problem, he said that they suffer great difficulty when they come up or down the stairs from the stairwells of apartment buildings with goods because stairwells are narrow in some apartment buildings and low in some others, and that they occasionally cause material damage, even if very little, to the transported goods. As a result of increasing customer complaints and demands, he asked you and your team to find a solution that will not only reduce the burden on the employees but also enable carrying the goods safely to the desired point."

What solutions can you suggest for this situation?

Discuss your individual solutions with your teammates. What would be the best solution? Can you explain your solution in detail by writing / drawing in the space below?

WHAT DO WE NEED?

What do you need to know to implement your solutions? How about we complete your shortcomings together?



CALCULATIONS ARE IMPORTANT!

With the new system you have developed, you will use less manpower and reduce the damage to the goods during transportation. But to best explain this system to the company's employees and the boss, you need to make a small working model for the third floor of the 4-storey building. Considering the information and materials given to you, you are asked to create a model of your system together with your teammates by reducing the actual measurements at ratio of 1/20.

INFORMATIONS	
Building Height	20 meters
Total Floors	4 floors
Floor to be transported	3^{rd} floor
Height of each Floor	5 meters

		Meter	**Centimeter**	**Ratio by 1/20 (cm)**
Building Height				
Height of each Floor				
Height of 3rd floor				

Dear friends,

We expect you to offer solutions to optimize your design by taking into account variables such as the amount of load to be carried, the required manpower, cost and force for the design you plan to make. Finally, taking into account the force and cost variable for a certain amount of load to be transported, you are expected to present a model that shows the strength, cost, and load amount your design can carry.

Appendix 2

Design Evaluation Rubric

CRITERIA	YES	SHOULD DEVELOPMENT	NO
Is 1 kg of cargo carried by the prototype?			
Is the prototype a simple machine?			
Is the prototype a 1/20 of the dimensions given for the 3rd floor of a 4-storey building?			
Does it allow employees to consume less energy?			
Does it allow for safe transport of goods?			
Is the prototype cost low?			

Appendix 3

Student Diary

I liked this activity because...

I did not like this activity because...

This activity improved me in terms of...