# THE EFFECT OF ENGINEERING DESIGN-BASED SCIENCE INSTRUCTION ON 6TH-GRADE STUDENTS' ASTRONOMY UNDERSTANDINGS AND ENGINEER CAREER INTERESTS

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# ABSTRACT

## THE EFFECT OF ENGINEERING DESIGN-BASED SCIENCE INSTRUCTION ON 6TH-GRADE STUDENTS' ASTRONOMY UNDERSTANDING AND ENGINEER CAREER INTERESTS

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The aim of this study was to investigate the effects of engineering design-based science education on 6th-grade students' understanding of astronomy concepts and engineer career interests. The study was administered to 6th-grade students (N=37) in a public school which is located in Kilis, Merkez. Using the convenient sampling method, a school was determined among the public schools in the Merkez district of Kilis, which was determined as the sample of the study. The study was operated as a one group pre-test post-test experimental design, and engineering design-based instruction which was prepared regarding 6th grade "Solar System and Eclipses" unit objectives, was administered to all participants. In the study, using the quantitative research method, the students' understanding of astronomy concepts and engineer career interests were operated through the pre-test and post-test application. Statistical analyzes were implemented in order to investigate the effect of engineering design-based astronomy instruction on students' understanding of astronomy concepts and engineer career interests. The results of the present study showed that there is a significant mean difference between the pre-test and post-test mean scores of students taught with engineering design-based instruction (EDBI) with respect to students' understanding of astronomy concepts. Moreover, there is a significant mean difference between gained interest pre-test and post-test scores of students taught with engineering design-based instruction (EDBI) with respect to students’ engineer career interests.

Keywords: Engineering Design-based Science Education, Astronomy Education

# ÖZ

## MÜHENDİSLİK TASARIM TEMELLİ FEN EĞİTİMİNİN 6. SINIF ÖĞRENCİLERİNİN ASTRONOMİ KAVRAMLARINI ANLAMALARINA VE MÜHENDİSLİK MESLEK İLGİLERİNE ETKİSİ

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Bu çalışmanın amacı mühendislik tasarım temelli fen eğitiminin 6. sınıf öğrencilerinin astronomi kavramlarını anlamalarına ve mühendislik meslek ilgilerine yönelik olan etkilerini incelemektir. Çalışma Merkez, Kilis ilçesinde bulunan bir devlet okulunda bulunan 6. sınıf öğrencilerine (N=37) uygulanmıştır. Uygun örnekleme yöntemi kullanılarak, çalışmanın örneklemi olarak belirlenen Kilis ilinin Merkez ilçesinde bulunan devlet okulları içerisinden bir okul belirlenmiştir. Çalışma tek grup ön test son test deneysel çalışma deseni olarak yönetilmiştir ve bütün katılımcılara 6. sınıf "Güneş Sistemi ve Tutulmalar" ünitesindeki kazanımları içeren mühendislik tasarım temelli öğretimi uygulanmıştır. Çalışmada nicel araştırma yöntemi kullanılarak, öntest ve sontest uygulaması ile öğrencilerin astronomi kavramlarını anlamaları ve mühendislik meslek ilgileri belirlenmiştir. Kullanılan mühendislik tasarım temelli astronomi öğretiminin öğrencilerin astronomi kavramlarını anlamalarına ve mühendislik meslek ilgisine olan etkisini incelemek amacı ile istatiksel analizler yapılmıştır. Bu çalışmanın sonucunda, mühendislik tasarımına dayalı fen öğretimi uygulanan öğrencilerin astronomi kavramlarını anlamalarında ön test ve son test puan ortalamaları arasında anlamlı bir fark olduğunu göstermiştir. Ayrıca, mühendislik tasarımına dayalı fen öğretim uygulanan öğrencilerin mühendislik kariyer ilgisi kazanımlarında ön test ve son test puanlarının ortalamalası arasında anlamlı bir fark bulunmuştur.

Anahtar Kelimeler: Mühendislik Tabanlı Fen Eğitimi, Astronomi Eğitimi

To My Dear Father

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**TABLE OF CONTENTS**

**LIST OF TABLES**

TABLES

# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

The developing world brings improvements in the science and technology fields. When we look at the last century, it is seen that the science and technology area has developed more. This situation requires more people who can support from the basic to advanced level of science. The 21st century needs more creative and innovative employees. The countries should educate individuals, especially young children, regarding 21st century needs in order to cope with developing science and technology. The countries should give special importance to science education in order to train people who can handle 21st century needs such as producing information, technology literacy, and innovation (Marrero, Gunning & Williams, 2014). Science education is important for both individual and national aspects. When looking at the individual aspect, science education provides people with a chance to develop themselves. This situation affects national goals such as producing technology, quality of education, and catching the need of the last century. Developing science and technology directly affected countries' points of view on science education. Nearly the whole world needed to revise their current national science education curriculum accordingly, developing technology, science, and their needs (Percy, 1998). Current curricula commonly do not give attention to 21st-century needs such as being science literate, critical thinking, or collaboration. However, for instance, if the country wants to be able to produce technology, it should aim individuals to be scientifically literate. In this line, science education reforms were key points of gaining those innovative skills from a little age of children. In other words, both developments and changes in science and technology have revealed the importance of revision of education policies of countries; therefore, most of the countries have revised their science education curricula (Tabaru, 2017).

Turkish science curriculum also has been revised accordingly to the needs of present situations. Science curriculum had new goals which were parallel to 21st century needs, such as being scientifically literate, technology literate, and entrepreneurship. The remarkable point of the 2018 science education curriculum was integrating engineering education into the curriculum with objectives (MONE, 2018). When looking at the objectives, the science curriculum not only focused on 21st century needs but also aimed to gain students' engineering practices with the help of engineering design process activities which were integrated into the curriculum. This education curriculum emphasized the importance of interdisciplinary teaching of Science and Engineering fields. However, giving the engineering field only within objectives is missing part of the 2018 science curriculum because this is not sufficient for integrating engineering into science education (Hacıoğlu, Yamak & Kavak, 2016).

The engineering design-based science education has been proposed as a sufficient integrated method of the engineering field into the science curriculum (Barnett, Connolly, Jarvin, Marulcu & Rogers, 2008). This approach has taken place in STEM-based instruction, which includes science, technology, engineering, and mathematics disciplines. The approach aims to provide science classes with products that will solve the situations they may encounter in real life. In addition, engineering desing-based science education aims to provide students with a process that enables them to think like engineers when finding solutions to real-life problems. The engineering design process organizes this process and provides working like an engineer while finding a solution to a problem (Daugherty, 2012). On the other hand, engineering design-based science education improves students' 21st century skills because to be able to complete the engineering design process successfully, students should make brainstorming, think critically, and communicate (Ercan & Bozkurt, 2013). The engineering design-based science education is an effective method to increase students' success in science lessons and to motivate them to science and engineering disciplines (Hacıoğlu, Yamak & Kavak, 2016).

The engineering design process (EDP) is helpful for integrating engineering discipline into K-12 education (Hynes, Portsmore, Dare, Milto, Rogers, & Hammer, 2011). EDP activities help the student think like an engineer, design a product and then develop products in order to make the product more useful. The aspect of design is one of the basic aspects of the engineering field. In other words, engineering cannot be completed without the design process (Cunningham & Hester, 2007). The EDP enables children to apply their theoretical science knowledge to daily life context (Altan & Karahan, 2019).

EDP follows its own steps, which organize the design process. The steps of EDP may vary from engineer to engineer (NRC, 2012). In other words, these steps are not fixed with only one structure; on the contrary, they are flexible and reversible. The organization of EDP steps has multiple forms that have both common and different frames. The model of Tayal (2013) has eight steps which cover defining the problem, background research, specifying possible solutions, choosing the best solutions, developing solutions, building, and testing, and redesigning the prototype. The other model of EDP is the model of Valuano, and Yerraballi (2014) has five steps followed: analyzing the problem, designing, developing, and testing the solution, and lastly, the deployment step. The last step of the model, which is different from most of the other models, enables the solution to adapt to new requirements. According to Mosborg et al. (2005), the model of EDP includes the following six steps: defining the problem, data collection, finding possible solutions, analyzing and evaluating the solution, choosing the solution, and building and communicating steps. Li, Huang, Jiang, and Chang (2016) adapted EDP steps to elementary education. The model has five following steps: defining the problem, developing possible solutions, choosing the best solution, building a prototype, and testing. The researchers stated that this model is useful for elementary classes.

Consequently, the researchers commonly framed these steps in the following; "the definition of the problem", "finding the possible solutions", "analyzing and choosing the best solution", "building and testing the best solution or prototype", and if necessary, returning any previous step. The description of each step was presented in Table 1.1.

*Table 1.1 The Steps of the Engineering Design Process*

| Engineering Design Process Step | Description |
|---|---|
| The definition of the problem | Students understand and define what the main problem is and also analyze the problem. |
| Finding the possible solutions | Students develop the solutions for the defined problem by using engineering skills such as brainstorming and synthesizing. |
| Analyzing and choosing the best solution | Students analyze each possible solution according to problem needs and then choose one solution that matches best with those needs. |
| Building and testing the prototype | Students work to build a design that meets the problem requirements. After building, students test their solutions accordingly criteria of the process. (Jiang & Chang, 2016) |

These steps guide students through the process; also, they lead students to analyze what the problem is and synthesize the information about the possible solutions for the problem (Hynes, 2018).

### 1.1.1 Significance of Study

Although STEM education has been started to use all around the world, the component of science (S) and technology (T) has been more popular than its other components in many nations. STEM education is the basis of training citizens who have greater technical, personal, and 21st-century skills, and engineering, which is represented with the "E" letter in the STEM acronym, is the key point for growing people who have 21st-century skills, critical thinking and innovative thinking (Bybee, 2010; NRC, 2012). Many nations disregard the component of engineering (E) by not taking place in engineering experiences in schools (English, Hudson, & Dawes, 2013). However, according to National Research Council (2009b), nations should train students as future engineers for elementary and middle schools. When looking at Turkish Science Education, the component of "E" was first defined in the Turkish science curriculum in 2017. The engineering field was integrated into the Turkish science curriculum as "Science and Engineering Application" (MONE, 2017). In 2018, the curriculum was revised, and the unit of "Science and Engineering Application" was removed from the curriculum. The application of engineering was only given into objectives which were called "Science, Engineering and Entrepreneurship" applications (MONE, 2018). It is seen that engineering activities were integrated into the science curriculum; however, the objectives of these applications are not well-defined. The present study aimed to investigate how to integrate engineering design-based activities into science classes successfully. On the other hand, despite high interest in integrating STEM disciplines into lessons, there is not much research that covers how to integrate components of engineering (E) into formal lessons in the best way (National Research Council [NRC], 2014). The present study aimed to contribute to this gap in the literature by developing engineering design-based activities which were covered dimensions of the engineering design process.

The students do not choose engineering as a career choice because they have inadequate perceptions and even inaccurate knowledge about the engineering profession (Fralick, Keam, Thompson, & Lyons, 2009). Fralick et al. (2009) also state that engineering-based instruction changes students' perceptions in a positive way. It is seen that engineering design-based instructions should be integrated into the lessons in order to strengthen students' perceptions about what engineering is; therefore, their negative views about engineer career choices can be changed. To be able to grow into well-trained engineers, students should meet with engineering from a young age (NRC, 2009b). Although young ages have more potential for developing engineering concepts, the studies which have the administration of engineering design activities are generally carried out with older learners (English & King, 2015). Therefore, the present study was carried out with young learners who were in 6th grade and investigated the change in 6th-grade students' engineer career interest after the implementation of engineering design-based instruction which covers two engineering design process activities.

The present study integrated engineering design-based instruction into astronomy topics. When astronomy education was reviewed, the countries have started to give importance to astronomy education after developing space technologies, and therefore they have tried to integrate astronomy education into their education curricula (Percy, 1998). Many national science programs in countries do not have separate astronomy lessons; in other words, the field of astronomy is either integrated into the science curriculum as a unit or given as an elective course. In the same way, the Turkish science education curriculum does not cover astronomy as a separate mandatory or elective course, and the astronomy field is included in the science curriculum as a unit. In the 2017 science curriculum, the units containing astronomy subjects were put at the beginning of the curriculum in all grades (MONE, 2017). The replacement of astronomy units from the end to the beginning of the curriculum is one of the necessary aspects of the 2017 science curriculum (Özcan, Oran & Arık, 2018). This situation shows that the importance given to astronomy issues by the Turkish education system has increased. The nations have begun to pay attention to astronomy education; however, students still have trouble grasping the topics that cover astronomy and have many misconceptions (Adams & Slater, 2000). The present study selected astronomy topics to improve students' understanding and see how they would increase their understanding of astronomy topics.

In addition, Arslan and Koparan (2018) stated that astronomy education is a useful topic for the implementation of STEM education at the elementary level. Acut and Latonio (2021) claimed that engineering design-based science instruction increases students' interests and academic performance in the space sciences. Thus, it is seen that engineering design-based science instruction is important for both growing prepared students for 21st century needs and supporting the academic performance of students in the astronomy field. Engineering-based astronomy activities not only help students gain skills in the engineering design process (analyzing, critical thinking, brainstorming), but these activities also help the student improve their understanding of objectives covering astronomy concepts (Voss & Dailey, 2012). Although engineering design-based science instruction helps to improve understanding levels of astronomy concepts, there are limited studies in this field. It is seen that the studies on the development of engineering-based instruction generally cover environment, electricity, and simple machines topics (Cunningham, 2009). Although it is known that engineering design-based education is suitable for astronomy subjects and increases the understanding of astronomy concepts, the fact that there are not many studies on this subject shows why the present study chose the subject of engineering design-based astronomy education. The present study was carried out to investigate the change in 6th-grade students understanding levels of astronomy concepts after the implementation of engineering design-based instruction.

Lastly, the studies covering examining students' understanding of the solar system were not much, and these studies state that learners find the solar system topic difficult to understand. They not only have difficulties, but also the learners have many misconceptions about solar system components (Adams & Slater, 2000). The present study aims to contribute to facilitating the understanding of the solar system by applying engineering design-based science education because the previous research showed that engineering design-based science education improves students' understanding of astronomy concepts. The present study focused on the solar system topic to investigate the change in 6th-grade students understanding levels after the implementation of engineering design-based instruction.

### 1.1.2 Research Questions of Study

1) What is the effect of engineering design-based instruction (EDBI) on 6th-grade students understanding of astronomy concepts?

*a)* Is there a significant mean difference between the pre-test and post-test mean scores of students taught with engineering design-based instruction (EDBI) with respect to students' understanding of astronomy concepts?

2) What is the effect of engineering design-based instruction (EDBI) on 6th-grade students' engineer career interests?

*a)* Is there a significant mean difference between gained interest pre-test and post-test scores of students taught with engineering design-based instruction (EDBI) with respect to students' engineer career interests?

### 1.1.3 Purpose of the Study

The purpose of the present study is to investigate the effect of engineering design-based instruction on 6th-grade students' understanding of astronomy concepts and students' engineer career interests. Students' understandings of astronomy concepts and their engineer career interests were determined before and after the implementation of EDBI. The obtained quantitative data were analyzed by conducting statistical analysis in order to examine the effect of engineering design-based instruction on 6th-grade students' understanding of astronomy concepts and engineer career interests. In addition, direct quotations of students' responses were used in order to support the quantitative data of the present study.

The first null hypothesis of the present study:

- There is no significant mean difference between the pre-test and post-test mean scores of students taught by engineering design-based instruction (EDBI) with respect to students' understanding of astronomy concepts.

The first hypothesis of the present study:

- There is a significant mean difference between the pre-test and post-test mean scores of students taught by engineering design-based instruction (EDBI) with respect to students' understanding of astronomy concepts.

STEM-based activities improve students' academic performance in terms of explaining and describing complex concepts about space science (Acut & Latonio, 2021). Therefore, it was expected to increase students' understanding of astronomy concepts after the implementation of engineering design-based instruction.

The second null hypothesis of the present study:

- There is no significant mean difference between gained interest pre-test and post-test scores of students taught by engineering design-based instruction (EDBI) concerning students' engineer career interests.

The second hypothesis of the present study was:

- There is a significant mean difference between gained interest pre-test and post-test scores of students taught by engineering design-based instruction (EDBI) concerning students' engineer career interests.

### 1.1.4 Definitions of Important Terms

STEM Education: The STEM term consists of four disciplines which are Science, Technology, Engineering, and Mathematics fields and the approach appears in many fields all around the world, such as industry, education, and innovation (Marrero, Gunning & Williams, 2014). STEM Education aims to collaborate these four fields with each other, not separately; therefore, the education approach mentioned an interdisciplinary method. According to Bybee (2010), STEM education is the basis of training citizens who have greater technical, personal, and 21st-century skills.

Engineering Design-based Science Education: Engineering design-based science education represents the "E" letters of STEM Education. The approach aims to find solutions to engineering problems which consist of daily life problems (Marulcu, & Sungur, 2012). Skills and abilities such as 21st-century skills, critical thinking, and innovative thinking can be developed thanks to the design process (Bybee, 2010).

Engineering Design Process: The design process has the necessary steps to find a promising solution among many ideas that are about an engineering problem. The steps include comparing alternative ideas, brainstorming, concluding, designing, and revising the process if necessary (NRC, 2012). Additionally, the engineering design process forces individuals' systematical thinking and creativity because there are different solutions to find a solution to engineering problems (Guzey, Moore & Morse 2016). The literature has many different definitions of the engineering design process; however, the definitions generally have common approaches for each step. Therefore, the design process includes the steps of the definition of the problem, finding the possible solutions, analyzing possible solutions, and testing and revising the selected solution (if necessary) (Aydin-Gunbatar, Tarkin-Celikkiran, Kutucu, & Ekiz-Kiran, 2018).

Engineering Career Interest: It is expected to grow the job market of engineering in the next decade. Despite of need for engineers in the market, there is a problem with enrollment in engineering jobs (Dohm & Shniper, 2007). STEM activities are mentioned as the best option for increasing students' interest in engineering professions because these hands-on activities, which are designed for the engineering process, enable students to practice the engineering profession (Yılmaz, Ren, Custer & Coleman, 2009).

# CHAPTER 2

# LITERATURE REVIEW

The literature review chapter reviews the literature regarding STEM education, STEM education in Turkey, integration of engineering into the science curriculum in Turkey, engineering design process, engineering design-based science education, STEM-based astronomy education, and engineer career interest of middle students are presented.

## 2.1. STEM Education

As technology evolves, the problems facing individuals today has become more complex and sophisticated. The skills required to solve these problems in daily life were also differentiating in this direction. It is said that every individual should have 21st century skills such as critical thinking, problem solving, creativity, cooperation and communication in the context of universal literacy. (Akgündüz et al., 2015; Bybee, 2010; Wagner, 2008; Windschitl, 2009). Raising individuals with the specified skills is possible with a modern and qualified curriculum and education process (Küçükahmet, 1995; Varış, 1996). Science courses are also extremely important in terms of acquiring the above-mentioned competencies that students should have.

It becomes necessary to approach the events from different and multiple perspectives and to use the knowledge in one field by transferring it to other fields in order to overcome the problems that are difficult to produce solutions with the existing information. Interdisciplinary integration is necessary in order to approach problems from multiple perspectives. In this context, it is necessary to create curriculums by integrating the right disciplines in order to fulfill the requirements of the age. Since the nature of the integration of Science, Technology, Mathematics, and Engineering (STEM), which has become widespread in the field of integration in recent years, eliminates the boundaries between disciplines, it can be stated that this integration is compatible with the nature of teaching (Wang, 2012). STEM education aims to enable students to find solutions to problems they will face in daily life, do background research. (Beane, 1995; Childress, 1996). And also, STEM education helps studens to transfer the acquired knowledge to different disciplines and find possible solutions to problems (Capraro & Slough, 2008; Jacobs, 1989).

In the literature, STEM education is generally examined in terms of its applications, development, and effectiveness, and it can be said that these studies are mainly conducted on primary and middle school students (Brown, 2012; Johnson, 2012; Locke, 2009; Stohlmann, Moore, McClelland, & Roehrig, 2011).

STEM education is seen more prominently in the science curriculum prepared by the Ministry of National Education of Turkey in 2018. In the new curriculum of the Ministry, which begins in 4th grade, is designed to help students make the connection between engineering and science and understand interdisciplinary interaction. In this curriculum, the engineering field of STEM education, represented as the letter (E), was also integrated into the curriculum. The curriculum aims for students to experience science and engineering practices in order to increase the scientific research and technological development capacity, socio-economic development, and competitiveness of Turkey. Within the applications of science, engineering, and entrepreneurship in the curriculum, students are expected to define a daily problem related to the topics covered in the units. It is desired that the problem is aimed at improving the tools or designing objects, or systems in encountered in daily life. In addition, the problems should be worked within the framework of criteria such as material, time, and cost. (MONE, 2018).

### 2.2. Engineering Design-Based Science Education

In our modern world, innovations and new technologies emerge every day. With the developing technology, it has become easier to access information. In the current period, education systems have been revised in order to raise individuals who can use knowledge and produce solutions to problems as well as having knowledge. Engineering is the process of creating products that produce solutions to problems by using the findings of science, mathematics, and technology (Bozkurt, 2014). Engineers create products to apply their knowledge, and while creating products, they take advantage of the engineering design process. The engineering design process is also defined as the thinking process in which mathematics and science can be integrated into the engineering and technology disciplines of real-world problems (Purzer, Moore, & Dringenberg, 2015).

Engineering design-based science education is a teaching approach that aims to integrate the engineering design process into the science course. This method includes designing products that may be the solutions to daily life problems. However, the emphasized point is not only the product but also the stages such as finding alternative solutions, deciding on the best solution, and testing the product are also important (Wendell, 2008). Engineering design-based science education represents the letter (E) of STEM education; therefore, it is also aimed to establish interdisciplinary connections with other fields when designing the product. In particular, the integration of science and engineering is the focus of this approach because it does not aim to provide direct engineering education but to use the field of engineering to gain scientific knowledge (Gencer, 2017; NRC, 2012). In other words, engineering design-based science education expects students to find solutions by applying their science knowledge to the design process (Cardella, Atman, Turns, & Adams, 2008). EDBI enables students to work like an engineer by following the engineering design steps; thus, students can see how an engineer goes through while producing solutions to problems they may encounter in daily life (Bybee, 2010). In addition, engineering design-based education helps students to improve their 21st century skills such as critical thinking, brainstorming, communication. For instance, during the finding possible solution and choosing the best solution steps, students do brainstorm by using higher-order thinking skills such as analysis and synthesis

(Wendell, 2008). Thus, it is suggested that engineering applications should be integrated into curricula from pre-school (NRC, 2012; English & King, 2015).

### 2.2.1. Engineering Design Process

The Engineering Design Process includes the process with a start and end interval followed for the solution of the problem that plays a role in the emergence of a need. This process provides environments where problem solvers gain 21st-century skills such as scientific concepts, insights into the field of engineering, communication, generating new ideas, producing solutions to problems, critical thinking, and disaggregating information (Schnittka, Bell & Richards, 2010). It enables individuals who do not accept information as it is and question it to produce different solutions in the face of events. The engineering design process has an important place in solving problems because, with this process, individuals will have the opportunity to realize their daily life problems and use the knowledge they have in order to find solutions to these problems. The engineering design process is a way of integrating engineering education into science classes (NAE, 2009).

According to Mentzer (2011), the engineering design process is divided into five steps. These are; identifying the problem, creating solutions, analyzing and visualizing data, testing/trying, concluding, and collaborating. In the literature, it is seen that the engineering design process consists of different stages according to the teaching levels. The engineering design process for primary school students is identifying the problem, searching for possible solutions, choosing the most appropriate solution, making the prototype, and testing the prototype (Bozkurt, 2014; Ercan, 2014; Wendell et al., 2010; Yasak, 2017). The engineering design process for high school students is defining the problem, researching the problem, developing solutions, choosing the best solution, creating a prototype, testing and evaluating solutions, presenting solutions, redesigning, and completing the decision (Hynes et al., 2011). It is seen that the stages of the engineering design process increase as the education level progresses. While the engineering design process consists of 5 stages at the primary school level, it consists of 9 stages at the high school level. Although the engineering design process consists of different stages according to the education levels, the problem situation, solution generation, and prototyping are handled at all stages. In this direction, the steps of the engineering design process; identifying the problem situation and proposing solutions, drawing the draft design, reviewing possible solutions and choosing the best solution, and making and testing the prototype. Engineering design steps are examined in detail in the following sections according to Wendell's engineering design process (Wendell et al., 2010).

*Step 1: Status of the Problem*

The Engineering Design Process begins with the determination of the problem or need situation. When the problem situation is the problems encountered in daily life, it can draw the attention of the students to the subject and create a basis for meaningful learning. As well as regional problems, global problems can also be addressed in problem determination. In addition, possible situations can be considered while determining the problem situation. In other words, when the problems/needs that students do not encounter in daily life but may encounter in the future are identified, students may be more willing to work on these problems. After the problem is determined, a scenario can be prepared for the problem, and students can be made a part of the problem in the fantasy world and explore the problems. By presenting the problem situation by the teacher, students can be brainstormed about the subject, and the development of their imagination and creativity can be supported. In addition, the problem situation can also be used as scientific process steps for students to explore. Exploring the problem situation by asking students to make observations, research, and trips on the determined topic can enable students to find easier solutions.

*Step 2:  Finding the Possible Solutions*

Students may be asked to do research on solving similar problems before. Necessary information is collected by making trips, observations, experiments, or resource searches for the solution of the problem situation. Each possible solution is noted for consideration.

*Step 3: Choosing the Best Solution*

The information obtained as a result of the research can be analyzed by the students, and the most suitable solution can be selected among the possible solutions. They can do research about the solution they have determined and give the final form. At this stage, factors such as cost, success, time, and functionality (fulfilling the task) should be considered when choosing the most appropriate solution proposal because the concept of most has no end. An increase in success is desirable, but an increase in cost and time (production time) is not desirable in the engineering design process. Also, it is necessary to pay attention to the criteria and limitations for success. In studies where only one problem scenario is given, problem solving is easily accessible (Soysal & Laçin-Şimşek, 2021). However, in the case of criteria and limitations, individuals can produce creative solutions to problems by thinking more carefully. One of the important steps of the engineering design process is the drafting of the design. Because in this process, students have the opportunity to work interdisciplinary and have the opportunity to look at life from a wider perspective. For example, they create their designs by incorporating mathematics course calculation and measurement gains into the process. It also facilitates the creation of drawings before the prototype is made, providing the desired criteria and limitations.

*Step 4: Making the Prototype*

At this stage, a prototype is created to show the most appropriate solution. Thus, it is observed whether the solution gives the desired results or not. In this direction, it can be foreseen what needs to be changed and improved.

*Step 5: Testing the Prototype*

The prototype is tested and re-evaluated to observe whether the prototype gives the desired results. The necessary corrections are made, and the prototype is examined to determine whether it fulfills its task. If it does not fulfill its duty, necessary corrections are made. After the desired results are obtained, the prototype is made ready.

### 2.2.2. Research on Engineering Design-Based Science Education

Engineering design-based science education improves students' 21st century skills and also high-order thinking skills such as analyzing, synthesis and evaluation. In addition, students' academic achievements, conceptual understandings, and interests in science lessons increase when the engineering field is integrated into science education (Wendell, 2008; Gencer, 2017; Guzey et al., 2016).

Ercan (2014) examined the use of engineering applications in science education. The research was conducted to determine how engineering design-based science activities affected the academic achievement, decision-making skills, opinions, and competencies of seventh-grade students regarding "Force and Motion". There were 30 students in the study group. Three design-based science education modules were implemented. Using mixed methods, the academic achievement test on force and simple machines, the decision-making skill test, and the engineering discipline information form developed within the scope of the research were used as quantitative data. The qualitative data were collected using engineering design guide documents, free student diaries, interview forms, field notes, and engineering thoughts questionnaires. In the force and motion unit of the study, design-based science education increased students' academic achievement, decision-making skills, and engineering knowledge. Moreover, the study determined that students' ideas about the feature of engineers should have developed after applications reflected their engineering-specific qualities. After the applications, some students who hadn't thought about engineering as a career began to consider it.

This article discusses the role STEM education plays in science education because of its contribution to transferring theoretical concepts to students in practice, as noted by Yıldırım and Altun (2014). The activities and lesson plans are presented on "Energy Conversion and Renewable Energy". Students will organize the knowledge and experiences they have gained through these and similar engineering design process activities and lesson plans in a meaningful way in their daily lives. They will do this by organizing them in a meaningful way with these and similar engineering design process activities. It is stated that the students who receive engineering design-based education also reach the targeted level of knowledge and understanding level, without falling into misconceptions.

According to Marulcu and Sungur (2012), the study examined perceptions of pre-service science teachers' about engineers and engineering design as a method. Both the open-ended and multiple-choice questions, as well as a freehand drawing about engineering, are included on this scale. The study asked 44 pre-service teachers to draw freehands about the importance of engineering and its features in order to evaluate their cognitive structures. As a result of evaluating the preservice teachers' answers, it was determined that they had a basic understanding of engineering. However, this understanding was not enough to integrate the engineering process into the teaching of science and technology concepts.

After giving general information about STEM education in their study, Yamak, Bulut, and Dündar (2014) emphasized the scarcity of academic studies on this subject in Turkey, and they wanted to investigate whether STEM education affected students' science-related skills and attitudes toward science in fifth grade. The importance of this study is emphasized. Twenty-five students attending an applied science school opened within the scope of a project in Ankara participated in this study, which used a single-group pre-test-post-test experimental design. A total of three engineering design-based activities were used in the study. This study found that STEM education improved the science process skills of fifth-grade students and their attitudes toward science, similar to other studies. Those activities allow students to create original products by creating mini designs. By obtaining a visible and useful product, students realize that the information they learned is useful in real life, and as a result, they desire to learn more.

Martinez-Ortis (2008) investigated the effects of applications including engineering and mathematics activities on primary school students' understanding of engineering and mathematics concepts and effects on technology awareness. Activities involving the engineering design process had been applied to the students for 10 weeks. Before and after the application, the conceptual understanding instrument was applied to the students. The posttest result showed that students had more positive perceptions toward engineering career and technology after participating in engineering education.

Wendell and Rogers (2013) investigated the effects of engineering design-based science education on primary school students' conceptual understanding of science, their attitudes toward field of science, and other STEM disciplines. The model of pre-test post-test was used to obtain data, and it took two years in total. In the first year, curriculum-based education was taught to the students, and in the second year, engineering-based science education was applied. It was concluded that there was an increase in the conceptual understanding of the students who received engineering-based education And, there was no significant difference between attitudes of the students to the science lesson.

Purzer et al. (2015) investigated the effect of engineering design-based science education on conceptual understanding of high school students. Projects that produced buildings on energy efficiency were carried out with high school students (N=63). The notes and drawings that the students took during the design process were collected with the software program. The study revealed that engineering design-based science education has a positive effect on students' conceptual understanding. Also, students who received engineering-based education made more scientific explanations of the concepts.

Another study examined the effects of engineering applications including engineering design processes on students' academic achievement in simple machines topic. Students (N=26) firstly, made sketches and planned the construction steps. While planning the construction process, they used visuals such as presentations and tables. They made three-dimensional models (prototypes) and then tested these models. As the last step, they presented their designs. The analysis of pre-test and post-test results showed that engineering applications, including engineering design processes, help increase the academic achievement of students (Rhot, 2001).

In a study conducted with 7th-grade students, the researchers searched the effects of engineering design-based science education on conceptual understandings and attitudes of students The content of engineering design-based education was prepared by three science teachers. The prepared program consists of engineering activities that enable the use of analysis and synthesis capabilities such as problem situation, prototype design, design planning, and application. The conceptual understanding and attitude scales were implemented to 7th-grade students (N=257) as the pre-test and post-test. It has been shown that there was a significant increase in academic achievements of students, their understandings on science concepts and their attitudes toward STEM, after participating engineering-based science education (Guzey, Moore, Harwell & Moreno, 2016).

### 2.2.3. Integration of Engineering Education in Turkish Science Education

While STEM studies are gaining momentum all around the World, it has been stated that an arrangement should be made in the Turkish Science curriculum. The vision of science and technology literacy, which started with the 2004 science and technology curriculum and continued in the 2013 science curriculum, was aimed to develop skills such as research-inquiry, problem-solving, critical thinking, entrepreneurship, cooperation, and responsibility in students (MONE, 2013; 2015).

Ministry of National Education renewed the science curriculum in mid-2017 before the start of the academic year. This program can be expressed as the 2017 Science Curriculum (draft). While this curriculum was at the stage of being implemented as a pilot in the 5th grade for the 2017-2018 academic year, the Board of Education and Discipline revised the curriculum again at the end of 2017 in line with the opinions of different institutions and individuals and published the 2018 science Course Curriculum, which was updated in 2018. The Science process skills, Engineering, and Design Skills are expressed in the same way within the scope of "skill" learning area under the Basic Skills Title in both the 2017 and 2018 curricula. Unlike the 2017 curriculum, it is seen that the title of the 2018 science curriculum differs in the context of engineering integration, and the expression of practices of science, engineering, and entrepreneurship in the curriculum is emphasized, and the explanations given under this heading clearly differ. For example, by adding the concept of "entrepreneurship" directly to the title, the expectations from the students were clarified within the framework of Science, Engineering, and Entrepreneurship Applications in the curriculum, unlike the 2013 science curriculum. In the 2018 science curriculum, the title of these applications was differentiated, and the last unit, "Applied Sciences", was removed and replaced with “Engineering and Entrepreneurship Applications” covering all grade levels and all units. While students are expected to practice throughout the year, the practices became more concrete with the end-of-year Science Festival. The “Engineering and Entrepreneurship Applications” expected students to follow the engineering design steps and design products with appropriate solutions to the problems. The engineering design process consists of 7 steps as creating a question, designing a product/invention, testing the product/invention, drawing conclusions, evaluating, sharing, and rethinking the product according to the 2018 Science curriculum (MONE, 2018). With the engineering design process, students create products with the knowledge they have by being involved in the interdisciplinary thinking process.

## 2.3. Astronomy Education

Astronomy is a science that deals with the study of everything that lies beyond the limits of the Earth's atmosphere (Mitton, 2008). The term astronomy is derived from the ancient Greek words astron and nomos and means stellar law (Shu, 1982). The origins of astronomy are based on the human desire to understand and control natural phenomena. For prehistoric people, forecasting weather and celestial events is a necessity for the continuation of life on the basis of needs such as agriculture and trade (Kırbıyık, 2001). In this context, the main use of astronomy has been the measurement of time. Movements, positions, and shapes of celestial bodies on the celestial sphere are based on certain cycles. For example, if the sky is observed from the northern hemisphere for several months, new constellations can be observed rising from the east of the sky.

Similarly, the formation of the moon concept is based on the change of the phases of the Moon (Arny, 1998). In the 17th and 18th centuries, the main occupation of astronomy was to produce practical solutions for position determination due to the rapid development of navigation. Because sea voyages aimed at the development of trade and the discovery of new regions have extended to the open seas and determining which direction they are going has become the biggest problem for seafarers. The effort to solve this problem enabled scientists such as Copernicus, Tycho Brahe, Kepler, Galilei, and Newton to put forward the principles, theories, and laws of planetary motions, and thus astronomy led to the formation of one of the breaking points of science (Karttunen et al., 2017). Until this period, the focus of astronomical observations was limited to the stars that could be observed on the celestial sphere, and these stars were only found in the Milky Way galaxy. The first important observations beyond this limit were made by Edwin Hubble in 1922-1923. These observations of Hubble have radically changed our understanding of science and the universe (Siegel, 2015).

It is necessary to evaluate astronomy researches, which dates back to almost as old as the beginning of humanity, from a different perspective. Astronomy researchers have taken the human's view of the universe from an Earth and human-centered understanding to a heliocentric understanding, and from a heliocentric understanding to the understanding that the universe has no center. The understanding that the universe has no center has revealed how small and mundane a role man and the Earth play in the universe (Karttunen et al., 2017).

The first educational research on astronomy took place many years ago, and the topics of those studies were about how students or people understand astronomical phenomena. The scholarly research was started by Piaget in early 1920 (Piaget, 1929). Jean Piaget wrote two books about young children’s ideas about astronomy which are flat-Earth, the Sun- Earth relationship, and day-night events (Piaget, 1929, 1930). These books influenced future research in this field. The following studies were examined with either local population or global (Wall, 1976, Lubben, 2009; Adams & Slater, 2000). Those researchers reviewed astronomy education. Thanks to reviews, it is shown that young children have many erroneous thoughts about basic astronomy. Lanciano (2009) revealed that not only culture but also mass media affects children's lack or wrong astronomical thoughts.

The researches and reviews showed that astronomy must be included in educational curricula. Before integrating astronomy into the national curriculum, the researchers asked this question "Why is astronomy not included in the curriculum?" (Percy, 2003). This research answered the question with seven reasons;

a) Astronomy is seen as irrelevant with popular concerns such as health, environment,

b) Teachers have little or no knowledge about basic astronomy content,

c) Astronomical observations are generally at midnight, and also, tools are expensive,

d) Astronomy is seen as only "Western" cultural concern and belongs to Western societies,

e) There are differences between facts about astronomy and personal-cultural beliefs about astronomy,

f) Undeveloped and poor countries cannot reach available resources because of a lack of translation of resources,

g) Astronomy needs high technology.

Astronomy has played many important roles in the historical process, such as facilitating human life, meeting human needs, and changing our understanding of the universe. Percy (2006) stated that astronomy is about our cosmic origin and our place in time and space. The origin and evolution of the Sun and Earth can be understood by studying the origin and evolution of other stars and planets outside the solar system. Most of the elements in the human body come from other stars. The sun is just one of billions of stars in the Milky Way galaxy, and likewise, the Milky Way galaxy is just one of billions of galaxies in the universe. It reveals a vast and very beautiful universe, such as the beauty of the dark sky, the appearance of a comet or solar eclipse, and the color image of a nebula or galaxy. All of these have an aesthetic appeal Also, astronomy fosters curiosity, imagination, and exploration. The sky and the universe enable young individuals to develop their imaginations (Percy, 2006). Engaging in inspiring astronomy issues helps young people expand their world of thought and accordingly develop a holistic worldview (International Astronomical Union (IAU, 2012). On the other hand, astronomy is a dynamic science in itself that supports the development of science, mathematics, and technology. The most exciting science news today is mostly about astronomy. It is a tremendous tool for encouraging students to take an interest in science and technology. Space travel and life outside Earth are fascinating topics in their own right. These subjects can be integrated with science and mathematics teaching and linked to engineering and technology studies. Likewise, according to Percy (2006), astronomy offers an integrative approach across disciplines. In this way, it supports the connections and learning between different curricula. For example, many mathematical concepts are used in the study of astronomy. Studying basic motions on the celestial sphere allows students to use math-based positioning systems and timing tools. The history of mathematics and astronomy are inextricably linked (Percy, 2006; Shu, 1982). This integration allows students to become acquainted with exciting scientific research (IAU, 2012). In addition, astronomy can contribute significantly to the creation of qualified manpower within the framework of 21st-century requirements (National Research Council [NRC], 2001). In addition, astronomy provides application possibilities for scientific methods, especially for observation (NRC, 2001; Percy, 2006). It also provides many examples of the use of simulation and modeling in science. Astronomers try to understand the universe by comparing their observations with the predictions of theories or models (Percy, 2006). For young people, astronomy topics are an excellent and exciting start for the rational and logical exploration of nature (IAU, 2012). Such basic and practical applications of astronomy not only facilitate learning by questioning but also make learning permanent (Göğüş, 2010).

In this context, astronomy has the features of having a dynamic structure that supports the development of science, technology, engineering, and mathematics, supporting feelings of curiosity, imagination, and discovery, including topics related to our cosmic origin and our place in time and space. Also, it encourages interest in science, technology, engineering, and mathematics, and enabling the use of scientific methods and researching nature with rational and logical methods, and offering an integrative approach between disciplines. Therefore, astronomy is an effective tool for STEM education. In summary, by the nature of the subjects involved in astronomy, it can be used as an effective tool for both STEM and engineering education processes as it has the characteristics of arousing interest in STEM fields, enabling applications that include the integration of science, technology, and engineering on the basis of the history of science, the nature of science and scientific methods, and supporting young individuals' career choices in STEM fields.

### 2.3.1 Research on Astronomy Education

The study explored how young learners construct solar and lunar models from their drawings and how age and prior knowledge affect modeling and drawing. The study was conducted with 247 young learners who visited the science museum over 4 weekends. The students were asked to model the solar and lunar eclipse events through the drawing software. Two separate scales measuring knowledge content and motivation were administered to the participants as pre-test and post-test. As a result, it has been observed that prior knowledge increases with age, that is, older children score higher and express what they know in the models they draw. It was concluded that regardless of age, young learners reasonably drew desired natural phenomena and created working models. When the results of the motivation scale were analyzed, it was stated that the drawing software positively affected the motivation of the children (Van Joolingen, Aukes, Gijlers, & Bollen, 2015).

Johns (2017) investigated the effect of students' participation in astronomy-focused exploration and kinesthetic activities in an after-school program on their science self-efficacy and interest in STEM. This study was carried out with 51 primary school students. The process consisted of structured hands-on activities consisting of a total of five sessions, each lasting one week. The contents of these activities consisted of activities that led students to observe, create models, predict results, and develop explanations. The analysis of pre and post-test showed an increase in interests and knowledge of students about STEM and space-related topics after they participated the program.

Another study examined the impact of teaching practices in natural settings on improving students' understanding of astronomy concepts related to celestial motion. The participants were interviewed before and after the astronomy training given in the first year of the study, which was conducted along the two paths. In the second year, the participants were interviewed before taking them to a planetarium. In the interviews, the participants were asked to describe the movements of the earth, moon, and sun using models. The sizes, definitions, and sequences of the models used by the students were examined. The analysis of the study concluded that visual simulations and psychomotor models improved students' conceptual understanding of celestial motion. Also, after the planetarium visit, students tended to explain the motion of the Earth, Moon, and Sun more scientifically (Plummer, Kocareli & Slagle 2014).

### 2.4. Engineer Career Interest

Today, especially developed countries such as the USA, China, and Germany attempt to integrate engineering into their education policies to meet the STEM workforce needs. In addition to their efforts for the development of engineer career interests, educational policymakers also attach importance to the acquisition of critical thinking, problem-solving, cooperation, creativity, and communication skills that the 21st-century workforce requires (Partnership for 21st Century Skills, 2004). Including engineering education in primary, secondary, and high school curricula and gaining 21st-century skills are seen as indispensable goals (NRC, 2010; Rynearson, Douglas, & Diefes-Dux, 2014). In this context, the recent changes in the science curriculum in Turkey are noteworthy in order to develop interest of students in STEM content and their professions. The science curriculum updated in 2018 aims to develop students’ career awareness and entrepreneurship skills related to science and engineering (MONE, 2017; MONE, 2018b).

Engineering, as one of the components of STEM, is a profession that has the ability and potential to change the quality of life of people in a positive or negative way. Although our daily life is covered with all kinds of engineering products, it is stated in the studies that students basically have problems to understand what engineers do (Frehill, 1997). It is also important to determine the students' perceptions of engineers and their views on the work they do. Because the tendency of students to have a career related to the engineering profession is formed in line with these views (Knight & Cunningham, 2004). In the studies conducted so far, it has been determined that most students think of engineers as mechanics or they are busy with the installation of something or mostly physical effort, and they see engineering as a boring field that only attracts the attention of hard-working students (Powell, Dainty & Bagilhole, 2012; Gibbons, Hirsch, Kimmel, Rockland & Bloom, 2004; Oware, Capobianco & Diefes-Dux, 2007; Oware, 2008; Cunningham, Lachapelle & Lindgren-Streicher, 2005). The study carried out by Ünlü and Dökme (2017) found that middle school students mostly drew male civil engineers. This can be interpreted as students having incomplete and wrong information on this subject. In the research, it is also found that students imagine engineer as a male profession because they usually work in jobs that require more power (Cunningham, Lachapelle & Lindgren-Streicher, 2005). It can be said that students’ perceptions of the engineering profession affect their interest in engineer careers. The engineering design-based science education improves students’ perceptions of the engineering field (Thompson & Lyons, 2008). The study was carried out with middle school students who received engineering education in order to determine 6th grade students’ perceptions about engineering field. In the study conducted with a total of 88 (44 of them control group; 44 of them experimental group) students and the design pre-test-post-test model was conducted. The drawing and semi-structured interviews were used to obtain data from the students. After the engineer design-based education, the experimental group made definitions about the nature of engineering, while the control group students made lack ones about the engineering profession. The research showed that engineering-based education improves students' perceptions of the engineering profession (Thompson & Lyons, 2008). Another study, an out-of-school STEM study with 6882 university students, examined the impact of activities on students' career choices in the STEM field. The result of the study showed that students had positive effects on their career choices in these fields (Dabney et al., 2012). In addition, the fact that engineering is a challenging profession outside the home, that is, not an ideal profession for women, is one of the biggest obstacles for women to not be interested in an engineer career (Nichols, Gilmer, Thompson & Davis, 1998). This situation affects the interest of female students in the engineering profession. When looking at research on engineer career interests of middle school students, it is seen that engineer career interest is generally examined within STEM career studies. These studies show that students' interest in STEM fields is an important factor that determines their future career choices. Alsup (2015) concluded that directing students to careers in STEM fields is essential for creativity, advancement of discoveries, and economic growth. The aim of this research is to develop Gottfredson's (1981) “Circumscription and Compromise Theory”. In this theory, the role of gender in choosing a profession has been examined as one of the factors that guide career preferences. Six STEM professionals were interviewed about their profession, education, abilities, and the positive and negative aspects of their careers. To help middle school students better understand STEM careers, the interviews were turned into a 25-minute video. It was investigated whether the video increased students' interest in STEM careers and whether gender was a factor. The study involved six schools. Four of them have separate science lessons for seventh and eighth graders, while two have a joint science lesson for seventh and eighth graders. Schools with separate science lessons were classified as both control and experimental groups, while schools with joint classes were classified only as experimental. Both groups underwent a pre- and post-test. After the pre-test was administered to the experimental group, a 25-minute video was viewed. Following the video, both groups took a post-test approximately seven days later. The video was also shown to the control group after the post-test. ANCOVA was used to analyze the obtained data. This process was completed in each school within the first few weeks of the 2014-2015 school year, and the pre-test-intervention (video watching)-post-test process took about four weeks. According to the findings of this study, viewing the recorded video did not increase the view of STEM subjects or interest in STEM careers. According to Wyss, Heulskamp, and Seibert (2012), watching a video of STEM professionals increased students' interest in STEM careers. Also, choosing a profession in the STEM field and continuing their university education in this direction depends on STEM career interests (Astin & Astin, 1992; Maltese & Tai, 2011). It is stated that students' interests, expectations, and goals in STEM fields in their middle school years play an important role both in their academic performance and in choosing a career in the future (Young, Young & Ford, 2017; Tai, Liu, Maltese & Fan, 2006). Therefore, it is important for students to determine their interest in science and engineering during their middle school years.

As a result, it has been determined that the students have classical thoughts about engineers and engineering. In order to change this and improve students' engineer career interests, it would be useful to make applications related to engineering in elementary school classrooms. And also, the engineering profession and diversity can be shown to students by collaborating with schools, engineering faculties of universities, or various institutions. By organizing science festivals or conferences in schools, students can be introduced to engineers from middle school ages and shared with them in the same environment.

# CHAPTER 3

# METHODOLOGY

In the methodology chapter, the research design, research group, and instruments which are administrated during data collection; and administration parts are presented.

## 3.1 Design of the Study

The purpose of the study was to examine the effects of engineering design-based science education on 6th-grade students' understanding of astronomy concepts and career interests in engineering. The one group experimental research design was conducted. The quantitative research method was operated to obtain data for the study. One group pre-test-post-test design was used because there was a lack of participants for both the control and comparison groups. The independent variable of the study is engineering design-based instruction, and the dependent variables of the study are 6th-grade students' understanding of astronomy concepts and students' engineer career interests.

In the present study, the quantitative research method was operated to examine participants' understanding of astronomy concepts and career interest toward engineering. The open-ended scale, which is "The Scale of 6th-grade Students Understanding Level of Astronomy Concepts" (Akbaş & Ekiz, 2005) (Appendix- B) was analyzed for students' understanding of astronomy concepts and "Science, Technology, Engineering, and Mathematics Career Interest Survey (STEM-CIS)" (Koyunlu Unlu, Dokme & Unlu, 2016) (Appendix-C) was analyzed for students' engineer career interests. Before instrumentation, the necessary permissions were received from the developers of the instruments (Appendix- K and Appendix- L).

Students' responses on the open-ended scale were also used in order to support the collected quantitative data of the study.

In this study, engineering design-based science instruction activities about "The Solar System and Eclipses" unit were implemented in 6th-grade science classroom. These activities were suitably prepared with the 2018 science curriculum which was published by the Ministry of National Education of Turkey. In the present study, activities were prepared depending on engineering design-based science education. Those engineering design-based activities are integrated into the "Solar System and Eclipses" unit of the 6th-grade science curriculum (MONE, 2018) and were implemented in 6th-grade science classrooms. There were three activities prepared, which are "Meeting with Engineers", "Design New World" and "Design Spacecraft". The quantitative part of the study evaluates the effects of three activities on the participants.

The one-group pre-test-post-test design was used in the present study. The one group pre-test-post-test design is not available for the randomization of the participant. This technique is usable when non-large samples are present (Campbell & Stanley, 1963). All participants were operated engineering design-based instruction. The effects of engineering design-based instruction were evaluated by two different instruments.

## 3.2 Sample of the Study

In the present study, the target population was identified as all 6th-grade students in public schools of Kilis while all 6th- grade students in a public school of Kilis, Merkez district was an accessible population. The convenience sampling method was chosen by the researcher. This technique was preferred because of the accessibility aspect. Thanks to this technique, money, time, and effort were not considered. A public middle school in Merkez, Kilis was selected accordingly convenience sampling by the researcher in the 2021-2022 school year. The availability of the school was suitable for the aim of both the researcher and the research. The administration of the school was informed about the research process. After consultations with the school administration, necessary permissions were received from the Governor’s Office of Kilis and the Provincial Directorate of National Education (Appendix-A).

The convenience sampling method was used for the presented study. The selected school had two different 6th-grade sections (6/A and 6/B) and 37 students (16 of male and 19 of female) in total. According to the school administration, the students were randomly registered to sections depending on their registration time. The present study used one group pre-test-post-test design; therefore, both two sections were formed as one group, which is the experimental group. There was no comparison group because of the limited number of students in the school.

It was expected that the students have learned the curriculum-based “Solar System and Eclipses” unit before the treatment. All participants were administered “Meeting with Engineers”, “Design New World” and “Design Spacecraft” activities which were developed parallel with the 2018 Turkish science curriculum objectives. Three activities that were developed by the researcher were implemented in the experimental group.

## 3.3 Data Collection

In this part, instruments which were used during the data collection and administration procedure are presented.

### 3.3.1. Description of Instruments

The quantitative data collection technique was operated for the present study. Two different instruments which are prepared for quantitative data collection research were used.

#### 3.3.1.1. The Scale of 6th-grade Students Understanding Level of Astronomy Concepts

The Scale of 6th-grade Students' Understanding Level of Astronomy Concepts was developed by Akbaş and Ekiz (2005) (Appendix-B). The instrument was piloted with 13 students before the first implementation by developers. The answer of participants was evaluated by researchers. Thanks to the pilot study, the items which make incoherency or are not understood by students were detected. Those questions are changed with clearer and more understandable ones. The questionnaire covers 10 open-ended items, which are remember, understand and apply the levels of Bloom's taxonomy. The main aim of the scale is to detect the level of students' understanding of astronomy concepts. To be able to detect the level of understanding, the developers asked students, for instance, "What do you think about the universe?" or "What is the solar system?". The items are divided into four main sections according to which topic the question aims to detect. The sections cover the universe, solar system, stars and planets, and orbit parts. Question numbers and related sections are given in Table 3.1.

*Table 3.1 Questions and Related Sections*

| **Question Number** | Core |
|---|---|
| **1** | Universe |
| **2** | Universe |
| **3** | Solar System |
| **4** | Solar System |
| **5** | Solar System |
| **6** | Stars and Planets |
| **7** | Stars and Planets |
| **8** | Stars and Planets |
| **9** | Orbit |
| **10** | Orbit |

All of the open-ended questions are related to objectives of the 2018 Turkish Science Curriculum for sixth grade; therefore, participants are familiar with the terms within the questions, such as Sun, orbit, and the universe.

#### 3.3.1.2. Science, Technology, Engineering, and Mathematics (STEM) Career Interest Survey (STEM-CIS)

The Science, Technology, Engineering, and Mathematics Career Interest Survey (STEM-CIS) scale was implemented to evaluate students' engineer career interests for the present study. The STEM-CIS scale was originally developed by Kier, Blanchard, Osborne, and Albert (2013) and implemented to 1,061 middle school students with a range of grades from six to eight by online ways. The whole scale covers 44 items which are divided into 4 sub-dimensions which are; science, technology, engineering, and mathematics. Each sub-dimension includes 11 items which are in the type of a 5-point Likert scale. The answer options of the scale cover "5= Totally Agree", "4= Agree", "3= Undecided", "2= Disagree", and "1= Totally Disagree". Cronbach's alpha values of science, technology, mathematics, and engineering sub-dimensions were found to be 0.77, 0.89, 0.85, and 0.86, respectively (Kier, Blanchard, Osborne, & Albert, 2013).

Koyunlu Unlu, Dokme and Unlu (2016) adapted STEM-CIS survey into Turkish as "Fen, Teknoloji, Matematik ve Mühendislik Mesleklerine Yönelik İlgi Ölçeği" (Appendix- C). The scale was translated into Turkish by three language experts by using the retranslation technique. After translation, 12 native English experts from the education field examined and gave feedback about the translation consensus. Considering their (12 native English experts) feedback, three Turkish language experts made important modifications. The pilot study of study firstly was administered to 30 participants. After that, STEM-CIS survey was administered to 1,033 middle school students. The value of Cronbach's alpha of the adapted version of STEM-CIS in Turkish was calculated as 0.93 for the scale. When looking at four sub-dimensions of the scale, 0.86 for science, 0.88 for technology, 0.94 for engineering, and 0.90 for mathematics subdimensions were found. The Cronbach's alpha values for the original form of study and the adapted one are shown in Table 3.2 below.

*Table 3.2 Cronbach Alpha Values of STEM-CIS*

| | *Number of Items* | *Original Form of Scale (Kier et al., 2013)* | *Adapted into Turkish Form of Scale (Koyunlu Ünlü et al., 2016)* | *The present study* |
|---|---|---|---|---|
| Overall Scale | 44 | - | 0.93 | 0.79 |
| Science | 11 | 0.77 | 0.86 | 0.76 |
| Technology | 11 | 0.89 | 0.88 | 0.79 |
| Engineering | 11 | 0.86 | 0.94 | 0.82 |
| Mathematics | 11 | 0.85 | 0.90 | 0.80 |

According to Cronbach's alpha value of the adapted version and present study of STEM-CIS, it is seen that overall and sub-dimension values are more than 0.70, and the scale has a high level of reliability (Nunally, 1978).

### 3.3.2 Treatment

In the presented study, one group experimental pre-test-post-test design was conducted. Also, quantitative research method was operated to examine participants' understanding of astronomy concepts and career interest toward engineering.

The experimental research design process was operated with one group. All participants were exposed to engineering design-based astronomy instruction. The treatment process lasted 8 weeks and a total of 26 lesson hours. The instruction process was carried out by the researcher; in other words, the engineering design-based instruction (EDBI) was given by the researcher. The researcher had prior knowledge about engineering design-based science education and prepared lesson plans for each class instruction according to this method. The EDBI covered the "Solar System and Eclipses" unit for 6th-grade students. The two instruments, which are The Scale of 6th-grade Students Understanding Level of Astronomy Concept and Science, Technology, Engineering, and Mathematics Career Interest Survey, were used as pre-test and post-test. These scales were administered to all participants both before the instruction (as a pre-test) and at the end of the instruction (as a post-test).

The engineering design-based instruction was administered to participants for six weeks. In the first week and the last week (eighth week of treatment), pre and post-test were administered to the students by the researcher. There were two 6th-grade sections which were 6/A and 6/B, and to be able to eliminate instruction differences, these sections were put together while engineering design-based instruction was implemented. Three lesson plans were prepared by the researcher before the instruction; "Meeting with Engineers", "Design the New World" and "Design a Spacecraft". While the first lesson plan aims to meet students with engineer careers, engineers, and the engineering design process, the last two lesson plans were related with "Solar System and Eclipses" unit concepts with the engineering design process. These lesson plans were prepared regarding the objectives of the 2018 Science Curriculum. On the other hand, all lesson plans aim to make students participate actively by doing discussion, brainstorming, and questioning; in addition to active participation, these lesson plans were prepared in order to increase students' curiosity about the topic.

"Design the New World" and "Design a Spacecraft" class instructions were based on "engineering design-based" activities which included steps of the engineering design process. These activities were prepared using the model of Wendell et al. engineering design process including steps which are the definition of the problem, finding the possible solutions, choosing the best solution, building the prototype, testing the prototype, and, if necessary, returning any previous step. For the present study, to be able to make a physical product, prototypes had to be used. These activities made students build a prototype and then test this prototype. Activity sheets which were following the engineering design process were prepared by the researcher in order to organize the flow of instruction. In other words, "Design the New World" and "Design a Spacecraft" instructions had activity sheets that were prepared according to engineering design process steps and based on their own topics. The activity sheets, which were distributed to students, also aimed to make students follow the steps easily and if they needed to go back to any previous step, help them more quickly.

#### 3.2.2.1. Verification of Independent Variable

The engineering design-based activities were prepared originally by the researcher; however, while preparing of activities, the researcher took into consideration of "STEM Analysis Criteria" which was developed by Aydın (2019). This rubric analyzes the activities with regard to the basic structures of a STEM approach. The researcher evaluated the activities of the present study according to "STEM Analysis Criteria" with three options: Yes, Partially, No (Appendix-D). This rubric analysis that the main problem of activity is whether suitable for daily life or not and is a clear and interesting problem for students also asked. When looking at the two activities of the present study, which are "Design the New World" and "Design a Spacecraft", both of them had scenarios about possible astronomical problems. These scenarios were reviewed by a science educator to check them in terms of understandability for middle school students and appropriateness for STEM problems. The following criterion mentioned in the rubric evaluates how the activity includes four different disciplines of the STEM approach. In this present study, the instructions were prepared depending on the "Engineering Design Process" and, as mentioned previously, the lesson plans were arranged in engineering design steps which started with defining a problem and then the definition of the problem, finding the possible solutions, analyzing and choosing the best solution, lastly, building and testing the best solution. The main structures of activities were prepared regarding the Engineering discipline of STEM. The next, third criterion of the rubric evaluates being student-centered activity. In the present study, the researcher did not lead students' choices. Students did their own research about problems in order to find possible solutions, and then they chose their best solution with their group members. In the building a prototype step, students were free to design their constructions and choose materials according to their plans; therefore, both the activities "Design the New World" and "Design a Spacecraft" were prepared as student-centered. The next criterion mentioned on the rubric is how the activities reflect the characteristics of three science instruction methods which are project or problem and inquiry-based learning approaches. The present lesson plans started with defining a problem. After defining and researching about the problem, student groups designed their constructions according to their best solution. While making prototypes, choosing materials, or deciding about design, they cooperated with each group member. During the EDP instruction, these activities encouraged students to communicate with their group members, do brainstorming with groups and decide along with friends. Lastly, students presented their prototypes verbally to the whole participants. Therefore, the activities included elements of project-based learning. The last criterion of the rubric checks the students' opportunity for redesign. The activity sheets provided students to return any steps of the engineering design process if they had any deficiencies in their physical designs. In addition, those asked students why they needed to redesign and which step helped them to solve their faults on prototypes. The evaluation criteria of the prototype include the criteria and constraints placed at the end of both of the activity sheets; therefore, students had opportunities to see what the evaluation criteria and constraints are. During the preparation process for each step of the activity sheet, the researcher got feedback from the advisor, who is a professor of science education.

#### 3.3.2.2. Engineering Design-based Instruction (EDBI)

The present study administered "Engineering Design-based Instruction" to one group. The two classes of the selected school were gathered as one group in order to eliminate any instruction differences. Three engineering activities and two different EDBI lesson plans were prepared by the researcher for the "Solar System and

Eclipses" unit and then, had administered for 16 lesson hours. The first activity was "Meeting with Engineers", the second one was "Design the New World", and the last activity was "Design a Spacecraft". In this part, the implementation of these activities was explained in detail and sample photos of treatment were given in Appendix-M . Also, the detailed schedule of instruction is shown in the Table 3.3 below.

*(a) Meeting with Engineers*: Before the instructions started, the two scales, which are The Scale of 6th Grade Students Understanding Level of Astronomy Concepts and Science, Technology, Engineering, and Mathematics Career Interest Survey, were implemented to the group as a pre-test. In the second week of treatment, students met with two different engineers who were computer engineers. The guest engineers were selected; one of them was a woman, and the other one was a man in order to eliminate the general opinion that "the profession of engineering should be selected by man". The researcher arranged an online meeting with these two computer engineers during the first lesson of the second week. The researcher managed the meeting according to the characteristics of the engineering profession, the experiences of engineers, and the engineering design process. The students not only met with engineers; they also realized how the engineers use the engineering design process in their projects, thanks to examples of guests. After the online meeting with guest engineers, the next lesson hour, the researcher started the class discussion about the previous lesson. The second lesson started with the question of "Do you want to be an engineer for your future career?" and then continued "Which type of engineering have you heard?" to catch the students' attention. The presentation about "Nature of Engineering" and "Engineering Design Process" were presented by the researcher on the smartboard of the classroom. This presentation was prepared with notable visuals and fonts which were understandable for middle school students. The researcher presented the engineering profession, types, and basic characteristics of engineers. During the introduction of these topics, the researcher asked students, "What does an engineer do?", "Do you have any opinion about civil engineering?" and "What are the features of the engineering profession?". The second aspect of the

presentation was the “Engineering Design Process,” which was presented as a diagram to be able to visualize and realize the circle of process. After each step of EDP was examined in detail with students, the researcher asked students to make the connection with the guest engineers' mentioned experiences. The next aspect was the explanation of characteristics of EDP such as “returnable steps”, “providing less cost” and “saving time”. While explaining these features, the researcher first got the opinions of students and then explained the feature. To be able to extend students’ understanding of EDP, the researcher presented a problem to the students, which was about spacecraft. This activity was mentioned “Think Like an Engineer” in the presentation. Thanks to “Think Like an Engineer” activity, students applied EDP steps to an astronomy-based problem. The presentation ended with a question of “If there were not any engineers, what would happen to the World?”. Therefore, class discussion about the engineering profession and EDP was made during lesson hour with the support of the presentation.

*(b) Design the New World*: For the next two lesson hours, engineering design-based science instruction of “Solar System” had administered to participants according to the “Design the New World Lesson Plan” (Appendix-E), which was prepared by the researcher. The lesson started with obtaining students' prior knowledge, which they learned in previous grades, about the solar system. The researcher used the questioning method to gather students’ prior knowledge and; asked “What is the name of our planet?”, “Does the Earth have any satellites?” and “Do you know the name of any planets in our solar system?”. After obtaining prior knowledge, students were informed about the topic of the lesson with the help of a video presentation. In addition, the researcher introduced students to the concepts of the solar system, such as the Sun, the planets, orbits, and asteroids. The questioning method was implemented to train students for the next lesson by asking the following questions; “Does the Earth revolve around the Sun freely or a path?”, “What is this “path” called by?”.

The third week of the instruction started with the engineering design process activity, which was mentioned as “Design a New World”. The presented activity was prepared by the researcher according to the application of engineering design process steps. In addition, “The Handbook of Engineers Team Activity Sheet” (Appendix-F) was prepared in order that both students were able to follow the activity easily, and the researcher managed the lesson more coordinated. At the beginning of the lesson, students were divided into small groups (3-4 people each), which were determined previously by the researcher. The activity sheets were distributed as one to each group, and then it was stated that students were expected to act like engineers during the activity. The activity started with the reading scenario loudly by the researcher. While reading, the smartboard was used for projecting scenario on the screen. After the scenario, the lesson continued with the steps of; 1) Describe a problem, 2) Finding possible solutions, and 3) Choosing the best solution of EDP. Students were expected to follow EDP steps while doing the activity; therefore, before starting the activity, the researcher revised the steps of the engineering design process by projecting them on the smartboard.

The engineering design process activity which was “Design a New World” started with identifying the problem of a given scenario by groups. Students were expected to find possible solutions by analyzing the same problems’ solutions or brainstorming for possible new solutions after they identified the problem. During finding possible solutions, students decided where humans could live in the solar system to build a living space. The students integrated their knowledge about the solar system’s planets, stars, asteroids, and satellites to find a living space. They decided the properties of these celestial bodies, such as temperature (hot or cold), terrestrial or Jovian planets, and physical features (having mountains, caves), accordingly suitability for human needs. The materials for modeling were introduced to the students; therefore, they took into consideration of which materials were given to make the prototype while choosing the best solution. The student groups analyzed their possible solutions, and then they researched the solutions’ advantages and disadvantages by using computers and scientific magazines. In the light of research, brainstorming, and group discussion, the groups chose the best solution which met the needs of the problem of the scenario. After completing the first three steps, which are identifying the problem, finding possible solutions, and choosing the best solution, students proceeded to the next step of EDP, which was building and testing prototypes in the following two lesson hours of the third week. According to the "Design a New World Lesson Plan", it was expected to build a prototype regarding the best solution, which was decided in the previous lesson of the third week. The drafts of models were drawn by student groups with details such as mentioning of used material and introducing the systems or parts of living spaces with a few words; therefore, it was decided which materials to be used in accordance with the drawings made. Then, each group built a prototype of the best solution they chose from the previous step. In the first two lessons of the fourth week, the students tested their models according to the criteria of activity, and in the next two lessons, they made evaluations about both the process and product. The evaluation criteria rubric in the activity sheet was used for evaluating each group's prototype. After testing of model process, the students were expected to answer conceptual questions, which were mentioned "Project Evaluation" and "Self-Evaluation" parts.  These parts included questions which were about the design process, possible redesign ideas, and engineering design process steps.

*(c) Design a Spacecraft:* In the fifth week of the treatment, "Design a Spacecraft Lesson Plan"  (Appendix- G), which was prepared based on engineering design-based instruction, started to administer to the group by the researcher. As a previous lesson plan, "Design a Spacecraft" activity also followed the engineering design process steps, which were the definition of the problem, finding the possible solutions, analyzing and choosing the best solution, and lastly, building and testing the best solution.  Two lesson hours, engineering design-based science instruction of "Solar System" started to administrate participants accordingly "Design the Spacecraft Lesson Plan" which was prepared by the researcher. Firstly, the prior knowledge of students was obtained to prepare them for the Solar System topic. The researcher used the questioning method to gather students' prior knowledge and then

asked questions about the solar system, such as "What is the order of the planets in order of their distance from the sun?", "What are the names of terrestrial planets?" and "What are the names of Jovian planets?". After getting the answers from the students, the researcher explained each question in detail. The simulation was used to support the explanation of questions and to visualize solar system concepts. Lastly, the researcher explained what the distance from the Sun affects planets' properties.

When the engagement part was over, the "The Handbook of Engineer for Space Mission" (Appendix-H) activity sheets were distributed to student groups which were the same as the previous activity. The activity sheet was used to increase cooperation between the researcher and students because it helped students follow the EDP easily. In the sixth week of the treatment, the EDP activity, which was based on designing a spacecraft, had administered by starting with three steps of EDP, which were identifying a problem, finding possible solutions, and choosing the best solution. Students were expected to act like an engineer during the activity and complete each step with their groups which were the same as the previous activity. The scenario which covered the solar system was introduced by the researcher loudly in the classroom. When looking at the scenario, it is seen that it mentioned that a failed space mission was done by an engineer team. Although the procedure of the previous and this activity was the same, "Design a Spacecraft" activity led students to choose which EDP step to start with according to their solution. After reading the scenario, students connected their knowledge about the solar system with it in order to find out the main problem in the scenario. The researcher emphasized the steps of the engineering design process with the given figure on the activity sheet. Firstly, the student groups described the problem of the given scenario by doing a group discussion. After describing the problem, the activity led them to choose which step of EDP was more suitable for their solution; therefore, the groups discussed with their members to decide which step to start. During group discussion, the researcher moved around the groups and did not give any opinion about the situation. Each group presented why they chose "X" step of EDP to start with their reasons. The group which decided to start at "finding possible solutions"; researched new solutions to the problem by using the Internet and scientific magazines and also, analyzed existing solutions to connect with their problem needs. The group which decided to start with "choosing the best solution"; analyzed the given possible solutions in the scenario and then replaced the best solution with another one from within the possible ones. In the next two lesson hours, all the groups continued the activity by building a prototype step of EDP. The drafts of models were drawn by student groups in detail, such as mentioning of used material and introducing parts and components of spacecraft briefly; therefore, which materials to be used were decided regarding their drawings. Lastly, the groups built their prototypes according to their best solutions from the previous step. In the first two lessons of the seventh week, the students tested their models depending on the criteria of the activity. The evaluation criteria rubric which was presented in the activity sheet was used for evaluating each group's prototype. Also, one of the group members from each group presented their models to the classroom briefly. In the next two lessons, the students made evaluations about both the process and the product. It was expected to answer conceptual questions which were mentioned "Project Evaluation" and "Self-Evaluation" parts. The evaluation parts included questions which were about the process of activity, possible redesign ideas, and engineering design process steps.

*Table 3.3 Administration Schedule for "Solar System and Eclipses" Unit*

| ***Week*** | ***Date*** | ***Topic/Objective*** | ***Administration/Duration*** | ***Tool*** |
|---|---|---|---|---|
| **1st week** | 26.01.2022 | Pre-test | Two different instruments were administered as a pre-test to evaluate students' understanding about astronomy concepts and engineer career interests<br><br>2 lesson hours | • The Scale of 6th Grade Students Understanding Level of Astronomy Concepts<br>• Science, Technology, Engineering, and Mathematics Career Interest Survey (STEM-CIS) |

| | | | | |
|---|---|---|---|---|
| **2nd week** | 02.02.2022 | Engineering Application* | “The Meeting with Two Engineers” activity and presentation, which explain “Engineering Profession” and “Engineering Design Process” were administered<br><br>2 lesson hours | |
| **2nd week** | 03.02.2022 | F.6.1.1. Solar System | EDBI based on objectives of “ F.6.1.1 Solar System concepts” was administered to the class<br><br>2 lesson hours | Design the New World Lesson Plan |
| **3rd week** | 09.02.2022 | F.6.1.1. Solar System | 1) Describe a problem, 2) Finding possible solutions, and 3) Choosing the best solution of EDP steps on the activity sheet were administered<br><br>2 lesson hours | Design the New World Lesson Plan |
| **3rd week** | 10.02.2022 | F.6.1.1. Solar System | 4) Building the prototype; planning prototype activity, planning design activity step of EDP was administered<br><br>2 lesson hours | Design the New World Lesson Plan |

| | | | | |
|---|---|---|---|---|
| **4th week** | 16.02.2022 | F.6.1.1. Solar System | 5) Test the prototype step; evaluation and presentation of each group of EDP steps were administered.<br><br>2 lesson hours | Design the New World Lesson Plan |
| **4th week** | 17.02.2022 | F.6.1.1. Solar System | The project evaluation and self-evaluation sections were administered, and the homework about EDP was given<br><br>2 lesson hours | Design the New World Lesson Plan |
| **5th week** | 23.02.2022 | F.6.1.1. Solar System | EDBI based on the topic of "F.6.1.1 Solar System" was administered to the class<br><br>2 lesson hours | Design the Spacecraft Lesson Plan |
| **6th week** | 02.03.2022 | F.6.1.1. Solar System | 1) Describe a problem, 2) Finding possible solutions, and 3) Choosing the best solution of EDP steps on the activity sheet were administered<br><br>2 lesson hours | Design the Spacecraft Lesson Plan |
| **6th week** | 03.03.2022 | F.6.1.1. Solar System | 4) Building the prototype; planning prototype activity, planning design activity step of EDP was administered<br><br>2 lesson hours | Design the Spacecraft Lesson Plan |

| | | | | |
|---|---|---|---|---|
| **7th week** | 09.03.2022 | F.6.1.1. Solar System | 5) Test the prototype step; evaluation and presentation of each group of EDP steps were administered.<br><br>2 lesson hours | Design the Spacecraft Lesson Plan |
| **7th week** | 10.03.2022 | F.6.1.1. Solar System | The assessment and self-evaluation (1 and 2) sections were administered<br><br>2 lesson hours | Design the Spacecraft Lesson Plan |
| **8th week** | 15.03.2022 | Post-test | Two different instruments were administered as a post-test to evaluate students' understanding about astronomy concepts and engineer career interests<br><br>2 lesson hours | • The Scale of 6th Grade Students Understanding Level of Astronomy Concepts<br>• Science, Technology, Engineering, and Mathematics Career Interest Survey (STEM-CIS) |

*Engineering application is the term of the 2018 Science Education Curriculum, which includes applications of any engineering design process activity in science class.

### 3.4 Data Analysis

"The Scale of 6th- Grade Students Understanding Level of Astronomy Concepts" and "Science, Technology, Engineering, and Mathematics Career Interest Survey (STEM-CIS)" were used to collect quantitative data for the present study.

### 3.4.1 Data Analysis of The Scale of 6th-Grade Students' Understanding Level of Astronomy Concepts

The "The Scale of 6th-Grade Students Understanding Level of Astronomy Concepts" scale was an open-ended questionnaire; therefore, the collected data were grouped and analyzed by using a rubric that was developed by Akbaş and Ekiz (2005). According to developers, the understanding levels of students are categorized into 5 levels which were; sound understanding, partial understanding, no understanding, specific misconceptions, and no response. The rubric is presented in Table 3.4 with explanations.

*Table 3.4 Categorization of Understanding Levels of Students in the Scale*

| ***Understanding Level*** | ***Meaning*** |
|---|---|
| No response | Blank and "I do not know", "I do not remember" responses |
| Specific Misconceptions | Illogical, conflicting with scientific facts, and alternative for scientific facts responses |
| No Understanding | Repeating questions, irrelevant and no clear responses |
| Partial Understanding | Including at least one of the components of the scientific response, but not all of the components |
| Sound Understanding | Including all of the components of the scientific response |

The interrater agreement method was used for the categorization of students' responses according to the given scale. The researcher compared with own analysis with another researcher who is both a master's student in science education and an active science teacher.

In order to convert students' responses on the given scale into quantitative data, the researcher grouped understanding levels and assigned these groups a point scale.

*Table 3.5 Scale for Quantitative Analysis of Given Scale*

| ***Point*** | ***Understanding Level*** |
|---|---|
| **0** | No response |
| | Specific Misconceptions |
| | No Understanding |
| **1** | Partial Understanding |
| **2** | Sound Understanding |

The Table 3.5. presented that “No Response”, “Specific Misconceptions,” and “No Understanding” Levels were grouped and assigned as “0 (zero)” point. “Partial Understanding” was assigned as “1 (one)” point. Lastly, the understanding level of “Sound Understanding” was assigned as “2 (two) points” on the scale.

*Table 3.6. Normal Distribution of Data Gathered with Astronomy Understanding Scale*

| Group | ***Sharpio Wilks Statistic*** | ***df*** | ***p*** |
|---|---|---|---|
| Experimental (E) | .966 | 37 | .302 |

$p > .05*$

According to the result of Table 3.6., the p value of gathered data (*p*= .302) was bigger than the alpha value (.05). The sample size of the study was less than 50; therefore, “Shapiro-Wilks” values were checked to see if there was a violation of normal distribution. According to “Shapiro-Wilkstest, if the test value is bigger than the alpha value (.05), the gathered data have a normal distribution. On the contrary, if the test value is less than the alpha value (.05), the gathered data do not have a normal distribution (Mertler & Vannatta, 2005). “The Scale of 6th-Grade Students Understanding Level of Astronomy Concepts” was appropriate for using parametric test since the gathered data is normally distributed. The paired sample t-test was used for analyzing the given scale.

### 3.4.2 Data Analysis of "Science, Technology, Engineering, and Mathematics Career Interest Survey (STEM-CIS)"

The data which was collected from the STEM-CIS instrument were analyzed according to the given procedure by developers of scale. The instrument was 5- point Likert-type scale; therefore, descriptive statistics were collected by scoring all subscales of it. The points of answer options of the scale assigned as "5 points = Totally Agree", "4 points = Agree", "3 points = Undecided", "2 points = Disagree", and "1 point = Totally Disagree".

*Table 3.7. Normal Distribution of STEM-CIS*

| Type | ***Sharpio Wilks*** ***Statistic*** | ***df*** | ***p*** |
|---|---|---|---|
| Data Gathered | .964 | 37 | .303 |
| Gained Score | .960 | 37 | .168 |

$p > .05*$

In order to determine whether to use parametric or non-parametric analysis test for "Science, Technology, Engineering, and Mathematics Career Interest Survey (STEM-CIS)" the normal distribution of the obtained data was tested. The result of the test showed that obtained data were normally distributed; it was appropriate to use a parametric test (Table 3.8). The paired sample t-test was used for analyzing data from STEM-CIS. In addition to paired sample t-test, non-parametric Wilcoxon Signed Rank test was used for analyzing gained interest in STEM-CIS scales because it recommended that if the sample size is less than 50, non-parametric test results should also be considered (Boone & Boone, 2012).

Consequently, the presented study was conducted with one group experimental pre-test-post-test design; therefore, "Paired Sample t-test" was preferred to analyze obtained data from "The Scale of 6th-Grade Students Understanding Level of

Astronomy Concepts" and Science, Technology, Engineering, and Mathematics ginWilcoxon Signed Rank was used for analysis STEM-CIS.

### 3.5 Validity and Reliability

The validity and reliability of the instrument are the necessary points of the studies. The consistency of data that were collected with instruments of study at all locations, conditions, and time represents the reliability of the study. Additionally, validity is the accurate inferences of the researcher according to the results of instruments, instrumentation process, and group characteristics (Baldwin, 2018; Fraenkel, Wallen, & Hyun, 2012). The validity and reliability of STEM-CIS were developed before the presented study was conducted by the developers of instruments; therefore, this instrument was considered as reliable for the measurement of variables of research. For "The Scale of 6th-Grade Students Understanding Level of Astronomy Concepts", the researcher conducted an interrater agreement method with another researcher on science education. Cohen's Kappa statistics were performed to find the degree of agreement between researchers. The value of Kappa is interpreted ranges from zero to one, and the closer the value is to one, the higher the agreement is interpreted (Landis & Koch, 1977). For the presented study, the interrater reliability for the researchers was found to be Kappa = 0.64; therefore, the agreement of the interrater was found as a "substantial agreement" degree. Thus, both of the instruments were considered as reliable for the measurement of variables of research.

#### 3.5.1 Internal Validity

Internal validity is the degree of differences which are observed between the dependent variable and the independent variable, not the other variables which are uncontrolled (Fraenkel, Wallen, & Hyun, 2012). The present study was conducted in one group pre-test-post-test experimental design; therefore, the internal validity threats which have the possibility to affect the study are listed below.

According to Frankel et al. (2012), researchers should pay attention to internal validity in order to minimize these nine internal validity threats;

Subject characteristics: Participants' differences from each other such as age, gender, and socioeconomic statutes. *(1)*

Mortality: Dropping out subject during the study progress because of some reasons such as family relocation or diseases. *(2)*

Location: The different data collection locations may affect the results. (3)

Instrumentation: The threat is examined in three categories; data collector bias, data collector characteristics, and instrument decay. *(4)*

Testing: Administered pre-tests may cause clues for participants and increase their efforts for materials. *(5)*

History: The unexpected events may affect the responses of participants during the study. *(6)*

Maturation: The responses and perceptions of participants may change because of the passing of time. This change may affect the result of the study. *(7)*

Statistical Regression: The extreme high or low scores on the pre-test may come close to the mean score of the post-test depending on the change in performance of participants, chance or measurement errors. *(8)*

Implementation: The experimental (or implementation group) group may be treated in an advantageous way. The different behaviors, attentions, and additional practices of the researcher may cause implementation threat. *(9)*

The present study was administered as one group experimental model; therefore, there were not two different groups which were experimental and control groups.

The one group of the study consisted of two classes of school, which were selected by a convenient sampling model. Therefore, subject characteristics did not pose a threat. The second one is mortality threat which is because of the loss of subjects during progress. To minimize this threat, the researcher informed the participants about the importance of participation in both pre- and post-tests; therefore, mortality was not a significant threat for the present study. The participants of the present study consisted of two different classes, which were 6/A and 6/B. These classes were put together during the study in order to create the same environment. Therefore, the location threat was minimized by the researcher. The fourth threat is instrumentation which has three aspects; data collector bias, data collector characteristics, and instrument decay. The instruments were administered by the same researcher without any leading or directing during the instrumentation; therefore, data collector bias and characteristics were not considered as a necessary threat. The responses of students on an open-ended scale were evaluated by using an evaluation rubric to minimize instrumentation decay. Additionally, the scores of each subject were evaluated at different times for all instruments. Testing is another fifth threat for internal validity. The time gap between pre- and post-test was eight weeks. Therefore, the time gap minimized the threat of the administration of pre-test for the present study. The sixth internal validity threat is history which affects participants' responses because of unplanned events, and maturation is the seventh threat which affects participants' responses because of passing time. The gap between pre- and post-tests has been planned by trying not to be long in order to avoid much more unexpected events and maturation. The eighth internal validity is statistical regression. Statistical correction, which excludes outliers from the analysis, was used to overcome this threat. The last one is implementation. The implementer and researcher were the same person in the present study because introducing EDBI to a traditional teacher in order to train another implementer would spend much time. The researcher took care to act objectively and took ethical rules into consideration during the implementation process. However, since this situation may threaten internal validity, it is stated in the limitation part. Also, the present study was conducted with only one group;

therefore, there was only one implementation group. In order to minimize this threat, the researcher tried to standardize conditions during the study and avoid helpful threats which may cause any advantage to participants.

### 3.5.2 External Validity

External validity is the degree of generalizability of the results of the study to other samples (Baldwin, 2018). In the presented study, the convenient sampling method was used to select the sample. Therefore, the results of the research can be generalized to the groups which have the same characteristics.

### 3.5.3 Reliability

The consistency of the data of the study, which were collected with instruments at all locations, conditions, and time represents the reliability of the study (Baldwin, 2018). Interrater agreement reliability for "The Scale of 6th-Grade Students Understanding Level of Astronomy Concepts" (Kappa = 0.64, substantial agreement degree) and Cronbach Alpha value for STEM-CIS ($\alpha$=0.79) were calculated for the reliability of all instruments.

## 3.6 Limitations

1) The results of the research can be generalized only to the groups which have the same characteristics because a convenient sampling method was used to select the sample.

2) The present study design was one group experimental design because of the limited sample size of the study.

3) There was no qualitative data, such as drawings or interviews with participants, in order to extend and support the quantitative data of the study.

4) Limited sample size of the study may limit the generalization of the results.

5) The implementer and the researcher were the same person, therefore, it may be a threat to internal validity.

### 3.7 Assumptions

1) The same standard conditions were arranged for the implementation of instruments.

2)The participants were randomly distributed into small groups.

3) All participants responded to the instruments seriously and honestly.

# CHAPTER 4

# RESULT

In this chapter, the result of the data analysis of the study is presented. The first section is descriptive results of "The Scale of 6th-grade Students Understanding Level of Astronomy Concepts" questionnaire, and the second section is descriptive results of the "Science, Technology, Engineering, and Mathematics Career Interest Survey (STEM-CIS)" scale.

## 4.1 Descriptive Results for "The Scale of 6th-grade Students Understanding Level of Astronomy Concepts" Questionnaire

The main problem about students' understanding level of astronomy concepts, null hypothesis, alternate hypothesis, and the result are presented below sections.

### 4.1.1 Effect of Engineering Design-Based Astronomy Instruction on Students' Understanding of Astronomy Concepts

The sub-problem was generated to research the main problem of the presented study, which is about the understanding of astronomy concepts. The sub-problem is;

- Is there a significant mean difference between the pre-test and post-test mean scores of students taught with engineering design-based instruction (EDBI) with respect to students' understanding of astronomy concepts?

The null hypothesis for the sub-problem is;

- There is no significant mean difference between the pre-test and post-test mean scores of students taught with engineering design-based instruction (EDBI) with respect to students' understanding of astronomy concepts.

The alternate hypothesis for the sub-problem is;

- There is a significant mean difference between the pre-test and post-test mean scores of students taught with engineering design-based instruction (EDBI) with respect to students' understanding of astronomy concepts.

The descriptive statistics table of the experimental group of the presented study is shown in Table 4.1.

*Table 4.1. Descriptive Statistics of Experimental Group*

| Group | N | $\bar{x}_{pre}$ | $\bar{x}_{post}$ |
|---|---|---|---|
| Experimental (E) | 37 | 4.63 | 8.67 |

When Table 4.1. was analyzed, the mean score of the pre-test was $\bar{x}$= 4.63, while the mean score of post-test was $\bar{x}$= 8.67. There is a mean difference between the pre-test and post-test of the experimental group. It is seen that the mean scores of the experimental group increased after the instruction.

The paired sample t-test was applied to check whether there was a significant difference between the pre-test and post-test mean values. The analysis of the average scores of the experimental group students' understanding of astronomy concepts before and after the implementation of engineering design-based instruction was compared with the paired sample t-test. The paired sample statistics of understanding of astronomy concepts of students were presented in Table 4.2.

*Table 4.2 Paired Sample Statistics of Astronomy Understanding*

| Scale | Test | *N* | $\bar{x}$ | *SS* |
|---|---|---|---|---|
| Astronomy | Pre-test | 37 | 4.63 | 2.643 |
| Understanding | Post-test | 37 | 8,67 | 3.333 |

The result of paired sample t-test analysis is shown in Table 4.3.

*Table 4.3 Paired Samples Test of Astronomy Understanding*

| Scale | Test | *N* | *t* | *p* |
|---|---|---|---|---|
| Astronomy Understanding | Pre-test | 37 | +8.550 | ,000 |
| | Post-test | 37 | | |

According to Table 4.3. , it was seen that p value of the test is less than the test value ($p<.05$). There was a significant mean difference between the experimental group students' pre-test and post-test scores. Therefore, the null hypothesis was rejected. The engineering design-based instruction increased the experimental group scores on the scale. According to the results, it was observed that there was an increase in the astronomy understanding scores of the students after the implementation of engineering design-based science instruction.

All five concepts of the given scale (universe, solar system, stars and planets, orbit) were analyzed in detail, and frequency distribution tables of both pre-test and post-test values with the percentages were presented in the following tables. Previously, "no understanding", "specific misconception" and "no response" understanding levels were gathered in one group; therefore, in the presented tables, the name of this group is labeled as “no understanding level”. In addition to frequency distribution, example responses given by students on pre-test and post-test were directly shown in tables.

#### 4.1.1.1 Universe Concept

The first and second question of “The Scale of 6th Grade Students Understanding Level of Astronomy Concepts” questionnaire focused on the “ universe” concept of the astronomy field. The statistical analysis of the students' understanding levels before and after the implementation of engineering design-based instruction within the scope of the universe concept was compared. The statistic of understanding of the universe concept of students was presented in Table 4.4.

*Table 4.4. Frequency and Percentage Values for Universe Concept (Q1)*

| Question | *No understanding* | | *Partial Understanding* | | *Sound Understanding* | |
|---|---|---|---|---|---|---|
| 1 | *f* | % | *f* | % | *f* | % |
| pre | 36 | 97.3 | 1 | 2.7 | 0 | 0 |
| post | 25 | 67.5 | 12 | 32.4 | 0 | 0 |

When looking at the "Q1" results in the table, it was seen that the majority of the students (97.3%) held no understanding level, while the minority of students (2.7 %) held a partial understanding level according to the pre-test results of the questionnaire. In other words, most of the students gave no answer, illogical or irrelevant answers to the question. Only one student responded with at least one correct component of the response before the implementation. According to the results, none of the students answered "sound understanding" level, which includes all correct components of the response, to the question. Regarding the students' understanding of the concept of the universe in the first question after the post-test, 67,5 % of the students held no understanding level, while 32,4 % of students held a partial understanding level. According to the post-test results of the questionnaire, most of the students still had misconceptions or misunderstandings about the universe concept after implementation. However, a couple of students developed at least one component of the universe concept. Likewise, in the pre-test results, there was no student who answered the 1st question on "sound understanding" level. The example responses of students pre and post-implementation of the scale were presented in Table 4.5. Thus, the statistical result of the first question presented that there was an increase in the frequency of a partial understanding level of the student, while the frequency of no understanding level of the student decreased after engineering design-based instruction.

*Table 4.5. Example Responses of Students to Universe Concept (Q1)*

| *Test type* | *No understanding* | *Partial Understanding* | *Sound Understanding* |
|---|---|---|---|
| Pre | "The universe is our environment. The trees and animals make up the Universe." (A6E) | "The Earth, the Sun, and the Moon are parts of the Universe." (B3K) | - |
| Post | "The Earth where humans are living on is the Universe." (A8E) | "The Solar System is part of the Universe." (A17K) | - |

The frequency distribution and percentage of understanding levels of students on the 2nd question were presented in Table 4.6.

*Table 4.6. Frequency and Percentage Values for Universe Concept (Q2)*

| Question 2 | *No understanding* | | *Partial Understanding* | | *Sound Understanding* | |
|---|---|---|---|---|---|---|
| | *f* | % | *f* | % | *f* | % |
| pre | 28 | 75.7 | 9 | 24.3 | 0 | 0 |
| post | 26 | 70.3 | 11 | 29.7 | 0 | 0 |

Table 4.6 shows that 75,7 % of students responded to Question 2 with a no understanding level on the pre-test of the questionnaire. Students who held this level randomly or completely wrongly ordered the sizes of the universe, stars, planets, and satellites. About 24.3 % of the students held partial understanding level answers to the 2nd question. It means these students could not order all components of the question fully correctly; however, they made the correct comparison of at least two of the given celestial bodies. According to pre-test results, most of the students gave

an incorrect answer to the 2nd question while comparing the size of "the planet" and "the star". The post-test results presented the majority of students (70.3%) had no understanding level, while minor of them (29.7 %) held a partial understanding level. None of the students answered the question fully completely, which has the correct order of given components of the question after implementation. The students responded that the stars are celestial bodies that are smaller than satellites, and they ordered the satellites in order to be larger. Thus, the statistical result of the second question presented that there was an increase in the frequency of a partial understanding level of the student while the frequency of no understanding level of the student decreased after engineering design-based instruction.

#### 4.1.1.2 Solar System Concept

The third, fourth, and fifth questions of "The Scale of 6th-grade Students Understanding Level of Astronomy Concepts" questionnaire aim to measure understanding of the Solar System concept. The statistical analysis of the students' understanding levels after the implementation of engineering design-based instruction was compared with before instruction. The statistics for the understanding of the solar system concept of students were presented in Table 4.7.

*Table 4.7. Frequency and Percentage Values for Solar System Concept (Q3)*

| Question 3 | *No understanding* | | *Partial Understanding* | | *Sound Understanding* | |
|---|---|---|---|---|---|---|
| | *f* | % | *f* | % | *f* | % |
| pre | 30 | 81.1 | 6 | 16.2 | 1 | 2.7 |
| post | 14 | 37.8 | 17 | 45.9 | 6 | 16.2 |

According to Table 4.7, before the implementation of EDBI, 81.1% of the students held no understanding level on question three. It means most of the students did not explain the solar system and its components well. Students responded that the solar system includes more than one star, which can be seen at night, or it covers all planets in space. The other 16.2 % of students held a partial understanding level, and only 2.7 % of the total class held a sound understanding level before the implementation of EDBI. Students with a partial understanding level correctly knew the number of stars and planets but left out other celestial objects such as satellites and asteroids. The sound understanding level response had an answer that included all correct components of the answer. This response not only included all the components of the solar system but also covered the orbit concept and motions of the planets. When looking at the results of 3rd question after implementation, 37.8 of the total class held no understanding level, and most of the students (45.9 %) held a partial understanding level. Seventeen of these students developed that there is only one star in the solar system and eight planets are arranged around this star, while 14 students had difficulty in grasping either the number of stars or the number of planets. Nearly 16.2 % of total students held sound understanding after implementation. In their responses, these students stated the movements of the planets in the solar system in a certain orbit around the Sun and all the celestial bodies of the solar system. The example responses of students before and after the implementation of EDBI are presented in Table 4.8. Thus, the statistical result of the third question presented that there was an increase in the frequency of a partial understanding and sound level student while the frequency of no understanding level student decreased after engineering design-based instruction.

*Table 4.8. Example Responses of Students to Solar System Concept (Q3)*

| *Test type* | *No understanding* | *Partial Understanding* | *Sound Understanding* |
|---|---|---|---|
| Pre | "The sky, stars, the Sun, the Moon, the Earth, and universe are made up the Solar System." (A2E) | "The Sun at the center, and 8 planets and Pluto, and maybe meteorite are made up Solar System." (A10E) | "The solar system consists of eight planets moving around the Sun, their satellites, and asteroids." (A12K) |

| | | | |
|---|---|---|---|
| Post | "All stars and all planets in space come together, and they form the solar system" (A4E) | "The solar system has the Sun and eight planets inside of it." (A17K) | "The system in which the Sun is at the center and 8 planets and their satellites revolve around the sun is called the solar system…(cont'd)" (B15K) |

The frequency distribution and percentage of understanding levels of students on the 4th question were presented in Table 4.9.

*Table 4.9. Frequency and Percentage Values for Solar System Concept (Q4)*

| Question 4 | *No understanding* | | *Partial Understanding* | | *Sound Understanding* | |
|---|---|---|---|---|---|---|
| | *f* | % | *f* | % | *f* | % |
| pre | 35 | 94.6 | 2 | 5.4 | 0 | 0 |
| post | 23 | 62.2 | 12 | 32.4 | 2 | 5.4 |

When the result of frequency and percentage values before engineering design-based instruction were analyzed, the majority of the students (94.6%) held no understanding level on the fourth question, while the minority of students held a partial understanding level. Most of the students at no understanding level did not explain why the planets move around the Sun, or they gave blank the question and responded as "I do not know". At the partial understanding level, students defined that the planets have a path; however, they did not define it as an orbit or orbital movement. Before the implementation of EDBI, there were not any students (0%) who held a sound understanding level that included all scientific components of the answer. When looking at the post-test result of the scale, most of the class (62.2%) held on no understanding level. These students generally responded to this question that the Earth revolves around the Sun for the formation of daytime and nighttime and formation of one day. Also, many students gave blank. The partial understanding level students was 32.4 %of the students. Likewise, in the pre-test responses, the students who stated that the Earth has a revolution path around the Sun and it follows this path periodically but did not specify this path as an orbit were at the partial understanding level. The sound understanding students consisted of 5.4 % of the sample. These students responded to all correct components of the question, in other words, they described the revolution path of the Earth around the Sun, and also, they mentioned this path as an orbit. The example responses of students before and after the implementation of EDBI were presented in Table 4.10. Thus, the statistical result of the fourth question presented that there was an increase in the frequency of a partial understanding and sound level student while the frequency of no understanding level student decreased after engineering design-based instruction.

*Table 4.10. Example Responses of Students to Solar System Concept (Q4)*

| *Test type* | *No understanding* | *Partial Understanding* | *Sound Understanding* |
|---|---|---|---|
| Pre | "In order to formation of one day." (B6K) | "The Earth has a path around the Sun, and it has to follow this path." (B1E) | - |
| Post | "When the Earth revolves around the Sun, the night and day occur." (B13K) | "The Earth has a rotational path, and it always follows this path without stopping." (A9K) | "…. The Earth has an orbit around the Sun and follows this orbit periodically." (A1E) |

The frequency distribution and percentage of understanding levels of students on the 5th question were presented in Table 4.11.

*Table 4.11. Frequency and Percentage Values for Solar System Concept (Q5)*

| Question 5 | *No understanding* | | *Partial Understanding* | | *Sound Understanding* | |
|---|---|---|---|---|---|---|
| | *f* | % | *f* | % | *f* | % |
| pre | 8 | 21.6 | 7 | 18.9 | 22 | 59.5 |
| post | 2 | 5.4 | 1 | 2.7 | 34 | 91.6 |

Table 4.11 shows that 21.6 % of students responded to question 5 with a no understanding level on pre-test implementation. Students who held this level randomly and completely wrongly ordered the planets according to their proximity to the Sun (in order from closest to farthest). About 18.9 % of the students held partial understanding level answers to the 5th question. It means these students cannot order all planets fully correctly. However, they made the correct order at least six of them. According to pre-test results, most of the students (59.5 %) held a sound understanding level which has a totally correct order of planets from the Sun. The post-test results presented that the majority of students (91.6%) held a sound understanding level, which means most of the sample responded totally correct order of planets from the Sun. About 5.4 % of students held no understanding level, which has illogical random order of planets. The partial understanding level students consisted of 2.7 % of the total students. Thus, the statistical result of the fifth question presented that there was an increase in the frequency of sound understanding among students. Also, the reason for the decrease in the percentage of both partial and no understanding can be interpreted as that those students developed a totally correct order of planets after engineering design-based instruction.

#### 4.1.1.3 Stars and Planets Concepts

The sixth, seventh and eighth questions of “The Scale of 6th-grade Students Understanding Level of Astronomy Concepts” questionnaire focused on the understanding of stars and planets concepts. The statistical analysis of the students' understanding levels of pre-implementation before engineering design-based instruction was compared with post-implementation of scale. The statistics of understanding of stars and planets concepts of students were presented in Table 4.12.

*Table 4.12. Frequency and Percentage Values for Stars and Planets Concepts (Q6)*

| Question 6 | *No understanding* | | *Partial Understanding* | | *Sound Understanding* | |
|---|---|---|---|---|---|---|
| | *f* | % | *f* | % | *f* | % |
| pre | 21 | 56.8 | 16 | 43.2 | 0 | 0 |
| post | 17 | 45.9 | 17 | 45.9 | 3 | 8.1 |

According to Table 4.12, before the implementation of EDBI, 56.8% of the students held no understanding level on question six. It means most of the students did not explain the difference between stars and planets. These students either gave the answer part blank or irrelevant answers. For instance, they only wrote one of the features of any planets that they knew. The other 43.2 % of students held a partial understanding level which contains at least one correct comparison between planets and stars, while none of the students held a sound understanding level which contains all correct comparisons of these given celestial bodies. It means there were no students who could explain the difference between planets and stars before engineering design-based instruction. When looking at the after implementation results of the 6th question, no understanding level students were equal to partial understanding level with a percentage of 45.9. No understanding level students responded with illogical explanations such as that stars are much smaller than planets and that stars cannot rotate around themselves. On the other hand, partial understanding level students explained at least one correct comparison between planets and stars. Most of the students responded that the most obvious difference between stars and planets is that stars are natural sources of light, but planets are not. About 8.1 % of students held sound understanding after implementation results. In their responses, these students stated all components of the answer, which covers all the comparisons parallel with the curriculum (three components are acceptable). The example responses of students before and after the implementation of EDBI were presented in Table 4.13. Thus, the statistical result of the sixth question presented that there was an increase in the frequency of a partial understanding and sound level of the student while the frequency of no understanding level of students decreased after engineering design-based instruction.

*Table 4.13. Example Responses of Students to Stars and Planets Concepts (Q6)*

| *Test type* | *No understanding* | *Partial Understanding* | *Sound Understanding* |
|---|---|---|---|
| Pre | "Jupiter is the biggest planet." (B11E) | "The stars are natural light source while the planets are not the light source." (B2K) | - |
| Post | "The planet rotates on its own axis, but stars are motionless." (B14E) | "A planet may have a satellite, but a star does not have any satellite." (A5K) | "The stars are light source, but planets are not. They are hotter and bigger than planets." (A1E) |

The frequency distribution and percentage of understanding levels of students on the 7th question were presented in Table 4.14.

*Table 4.14. Frequency and Percentage Values for Stars and Planets Concepts (Q7)*

| Question 7 | *No understanding* | | *Partial Understanding* | | *Sound Understanding* | |
|---|---|---|---|---|---|---|
| | *f* | % | *f* | % | *f* | % |
| pre | 29 | 78.4 | 7 | 18.9 | 1 | 2.7 |
| post | 13 | 35.1 | 21 | 56.7 | 3 | 8.1 |

According to Table 4.14, before the implementation of EDBI, 78.4 % of the students held no understanding level on the seventh question. The student, at no understanding level, did not explain the difference between satellites and planets correctly. Also, some students only thought of the moon when the word satellite was mentioned, and they did not think that other planets could have satellites that have different features. When looking at other statistics of pre-test results, 18.9 % of students held a partial understanding level, and 2.7 % of participants held a sound understanding level before treatment. Students with a partial understanding level stated the movement of only one of the given celestial bodies. For instance, students mentioned that the satellites revolve around the planets. However, they did not give information about which celestial body the planets revolve around. On the other hand, the sound understanding level response had an answer that included all these two movements. These students stated that planets and moons revolve around different celestial bodies and mentioned what these celestial bodies are. After implementation, results of the 7th question show that 35.1 % of the students held no understanding level, and most of the students (56.7 %) held a partial understanding level. According to post-test results, it is seen that students developed their understanding of the differences between planets and satellites. The minority of total students (8.1%) held sound understanding levels. The example responses of students before and after the implementation of EDBI were presented in Table 4.15. Thus, the statistical result of the seventh question presented that there was an increase in the frequency of a partial understanding and sound level of the student while the frequency of no understanding level of the student decreased after engineering design-based instruction.

*Table 4.15. Example Responses of Students to Stars and Planets Concepts (Q7)*

| *Test type* | *No understanding* | *Partial Understanding* | *Sound Understanding* |
|---|---|---|---|
| Pre | "The satellites are white, but planets can be different colors." | "The planets revolve around the stars, for example, the Earth and the Sun." | "The biggest difference between them is that the satellite revolves around the planet, and the planet does around a star. For example, solar system." |

| | (A13K) | (A7K) | (B15K) |
|---|---|---|---|
| Post | “The satellites consist of asteroids, but planets are not.” (A18K) | “A satellite revolves around a planet; that is the difference.” (B17K) | “Planet: revolves around the star (like the Sun) Satellite revolves around the planet (like Earth)” (A15E) |

The frequency distribution and percentage of understanding levels of students on the 8th question were presented in Table 4.16.

*Table 4.16. Frequency and Percentage Values for Stars and Planets Concepts (Q8)*

| Question 8 | *No understanding* | | *Partial Understanding* | | *Sound Understanding* | |
|---|---|---|---|---|---|---|
| | *f* | % | *f* | % | *f* | % |
| pre | 17 | 45.9 | 20 | 54.1 | 0 | 0 |
| post | 8 | 21.6 | 25 | 67.5 | 4 | 10.8 |

Table 4.16 shows that 45.9 % of total students responded to question eight with a no understanding level on pre-test implementation. Most of these students who held this level responded with illogical or irrelevant answers; however, there were some students who responded as “I do not know” or only “No.”. According to the responses of these students, it was seen that they considered that the stars they see at night and the Sun they see during the daytime are different types of celestial bodies. About 54.1 % of the students held a partial understanding level which includes at least one reason why the Sun is a star. Most of these students stated that the Sun shines like other stars; therefore, the Sun is a star. There were not any students (0 %) who held a sound understanding level which has more than one reasonable explanation. According to the presented post-test results, the majority of students (67.5%) held a partial understanding level. Most of the partial understanding students responded that the Sun is a source of heat source or Sun is a light source like other stars; therefore, the Sun is a star. Nearly 21.6 % of students held no

understanding level, which has illogical or one-word (yes or no) responses. After engineering design-based instruction, students developed the explanation of knowledge that the Sun is a star. About 10.8 % of students held a sound understanding level that covered all reasonable explanations of the correct response. The sound understanding level students responded that the Sun is both a source of light and a source of heat. The example responses of students before and after the implementation of EDBI are presented in Table 4.17. Thus, the statistical result of the eighth question presented that there was an increase in the frequency of a partial understanding and sound level of the student while the frequency of no understanding level of the student decreased after engineering design-based instruction.

*Table 4.17. Example Responses of Students to Stars and Planets Concepts (Q8)*

| *Test type* | *No understanding* | *Partial Understanding* | *Sound Understanding* |
|---|---|---|---|
| Pre | "No. Because the stars are only seen at night." (B16E) | "Yes. Because the Sun sends its light to the Earth like other stars." (B12E) | - |
| Post | "No. Because the Sun is bigger than stars." (A11E) | "Yes. The stars and the Sun are shining, and they are natural sources of light." (A7K) | "Yes. All stars give heat and light to their surroundings. The Sun is the heat and light source of our Earth, so the Sun is a star." (A16E) |

#### 4.1.1.4 Orbit Concept

The last two questions, numbers ninth and tenth of "The Scale of 6th-grade Students Understanding Level of Astronomy Concepts" questionnaire, aimed at the understanding of the orbit concept. The statistical analysis of the students' understanding levels before engineering design-based instruction results was compared with post-test results of scale. The statistics of understanding of the orbit concept of students were presented in Table 4.18.

*Table 4.18. Frequency and Percentage Values for Orbit Concept (Q9)*

| Question | *No understanding* | | *Partial Understanding* | | *Sound Understanding* | |
|---|---|---|---|---|---|---|
| 9 | *f* | % | *f* | % | *f* | % |
| pre | 21 | 56.8 | 15 | 40.5 | 1 | 2.7 |
| post | 10 | 27.0 | 23 | 62.1 | 4 | 10.8 |

According to Table 4.18, the majority of the students held no understanding level on question nine before the engineering design-based instruction. These students responded that they had no idea about the concept of orbit because their responses generally covered either “I have no idea.” or they gave blank answers on pre-test implementation. Less of the students wrote statements that expressed their opinions on the ninth question of the scale. Students with a partial understanding level responded to only one component of the definition of the orbit concept, consisting of 40.5 % of the total students. These students tended to think in terms of the Earth and made their definitions through the concept of the Earth before the instruction. In other words, at a partial understanding level, students generally made explanations as if only the Earth had an orbit, and they did not consider other celestial bodies' orbits. The minority of the students held a sound understanding level (2.7 %) that included a correct explanation of the concept of orbit. The sound understanding level response covers all components of the correct scientific explanation. When looking at the post-test result, students with a partial understanding level were the majority of the class with % 40.5. These students were generally the ones who gave correct but incomplete explanations about the concept of orbit.  Students with a partial understanding level had difficulty in grasping that celestial bodies other than planets may also have orbits because these students' answers generally covered that only planets have an orbit. About 27.0 % of the students held no understanding level on question nine. Unlike the pre-test responses, the students made their own explanations about the concept of orbit at this time; however, these explanations did not contain any component of the correct definition of the orbit concept. Nearly 10.8 % of the students held a sound understanding level, and it is seen that there was an increase in this level of students. These students explained the concept of orbit completely correctly in accordance with their grade level. When looking at their answers, they referred to the concept of orbit as the path of a celestial body revolving around another celestial body. The example responses of students both before and after the implementation of EDBI was presented in Table 4.19. Thus, the statistical result of question nine presented that there was an increase in the frequency of a partial understanding and sound level of the student while the frequency of no understanding level of students decreased after engineering design-based instruction.

*Table 4.19. Example Responses of Students to Orbit Concept (Q9)*

| *Test type* | *No understanding* | *Partial Understanding* | *Sound Understanding* |
|---|---|---|---|
| Pre | "It means around of the Earth in the Space." (B7K) | "The path the Earth revolves is called by the orbit." (B4K) | "The path is drawn by the body in space around other celestial body like a star." (B10K) |
| Post | "There is an orbit between the Sun and the Earth." (B6K) | "The path where planets constantly travel through space, for example, the orbit of the Earth". (B18K) | "The Orbit is the path that a celestial body makes around another celestial body while it is revolving." (A12K) |

The frequency distribution and percentage of understanding levels of students on the 10th question were presented in Table 4.20.

*Table 4.20. Frequency and Percentage Values for Orbit Concept (Q10)*

| Question 10 | *No understanding* | | *Partial Understanding* | | *Sound Understanding* | |
|---|---|---|---|---|---|---|
| | *f* | % | *f* | % | *f* | % |
| pre | 17 | 45.9 | 15 | 40.5 | 2 | 5.4 |
| post | 8 | 21.6 | 23 | 62.1 | 6 | 16.2 |

Table 4.20 presents that 45.9 % of the students held no understanding level before the treatment. These students explained the question by giving irrelevant or illogical examples; that's why they were categorized at no understanding level. Also, most of the responses were not supported with explanations even though the direction of the item says "explain" the answer. Students with a partial understanding level gave at least one correct example, and their explanation of the given situation consisted of 40.5 % of the total students. These students usually focused on the scenario of planets colliding with each other according to responses of the pre-test. The least percentage was sound understanding level of the student with a percentage of 5.4. The sound understanding level response included at least two correct examples with their explanations. Considering the students' grade level and the information given in the curriculum (about orbit concept) , it was sufficient for the students to give two examples for the sound understanding level. According to post-test results, the majority of students (62.1%) held a partial understanding level. It is seen that there was an increase in the percentage of this level of students after the engineering design-based instruction. These students gave a logical example with their explanation. No understanding level students consisted of 21.6 % of total students. Likewise, in pre-test responses, these students gave open-ended, generalized, or unreasonable examples to question ten. Despite there was an increase in the percentage of sound understanding level, still a minority of students (16.2%) held sound understanding level. These students tended to exemplify the situation given in

the question over more than one celestial body. The example responses of students both before and after the implementation of EDBI was presented in Table 4.21. Thus, the statistical result of question ten presented that there was an increase in the frequency of a partial understanding and sound level of the student while the frequency of no understanding level of the student decreased after engineering design-based instruction.

*Table 4.21. Example Responses of Students to Orbit Concept (Q10)*

| *Test type* | *No understanding* | *Partial Understanding* | *Sound Understanding* |
|---|---|---|---|
| Pre | "Maybe, all meteorites would fall to the Earth." (B9E) | "I think the planets collide with each other. *(cont'd)*" (B19K) | "The moon hits the Earth first, and then the Earth hits the Sun, it could even burn. I think it would be like this." (A16E) |
| Post | "There would be no planets." (A4E) | "The Earth and its twin Venus would collide because their orbits are close together." (A10E) | "All the asteroids in the asteroid belt would scatter into space. *(cont'd)* The planets collide with those asteroids." (B15K) |

## 4.2 Descriptive Results for "Science, Technology, Engineering, and Mathematics Career Interest Survey (STEM-CIS)" Questionnaire

The main problem about the engineer career interest of students, null hypothesis, alternate hypothesis, and the result are presented below sections.

### 4.2.1 Effect of Engineering Design-Based Astronomy Instruction on Students' Engineer Career Interests

The sub-problem was generated to research the main problem of the presented study, which is about engineer career interests. The sub-problem is;

- Is there a significant mean difference between gained interest pre-test and post-test scores of students taught with engineering design-based instruction (EDBI) with respect to students' engineer career interests?

The null hypothesis for sub-problem is;

- There is no significant mean difference between gained interest pre-test and post-test scores of students taught with engineering design-based instruction (EDBI) with respect to students' engineer career interests.

The alternate hypothesis for sub-problem is;

- There is a significant mean difference between gained interest pre-test and post-test scores of students taught with engineering design-based instruction (EDBI) with respect to students' engineer career interests.

When the analysis of the Likert scale, it is claimed that both parametric and non-parametric tests can be used (Turan, Aslan & Simsek, 2015). Boone and Boone (2012) recommended that if the sample size is less than 50, non-parametric test results should also be considered. The sample size of the present study is N=37 (less than 50); therefore, the Wilcoxon Signed Rank test was conducted in order to statistically analyze of STEM-CIS scale. The statistics table of the experimental group as a result of the Wilcoxon Signed Rank test was presented in Table 4.22.

*Table 4.22. The Statistics of Wilcoxon Signed Rank test for STEM-CIS*

| | Total Rank of Interest |
|---|---|
| Wilcoxon Signed Ranks | 595.00 |
| Z | +5.056 |
| Asymp. Sig. (2-tailed) | .000 |

According to table 4.22, the z value is -5.056 with a significance level (p) of p =.000. The (p) value is less than .05; therefore, the result was significant. The null hypothesis was rejected and there was a significant mean difference between gained interest pre-test and post-test scores of students taught with engineering design-based instruction (EDBI) with respect to students' engineer career interests.

The sample was normally distributed according to the result of the Sharpio-Wilks test. Therefore, parametric tests can be conducted in order to analyze the STEM-CIS scale. In order to compare the means of the pre-test and post-test, paired sample t-test was applied. The analysis of the average scores of the experimental group students' engineer career interests before and after the implementation of engineering design-based instruction was compared with the paired sample t-test. The result of paired sample t-test shows if there was a significant difference between the pre-test and post-test mean values of STEM-CIS. The paired sample statistics of the engineer career interests of the students were presented in Table 4.23.

*Table 4.23 Paired Sample Statistics of STEM-CIS*

| Scale | Test | *N* | $\bar{x}$ | *SS* |
|---|---|---|---|---|
| STEM-CIS | Pre-test | 37 | 33.86 | 4.454 |
| | Post-test | 37 | 41.27 | 4.032 |

The result of paired sample t-test analysis is shown in Table 4.24.

*Table 4.24 Paired Samples Test of STEM-CIS*

| Scale | Test | *N* | *t* | *p* |
|---|---|---|---|---|
| STEM-CIS | Pre-test | 37 | +9.647 | ,000 |
| | Post-test | 37 | | |

When Table 4.24 was analyzed, p value of the test was less than the test value ($p<.05$). It means the difference between the mean values of the pre and post-test was significant. Therefore, the null hypothesis was rejected and there was a significant mean difference between gained interest pre-test and post-test scores of students taught with engineering design-based instruction (EDBI) with respect to students' engineer career interests. According to the result, it was observed that there was an increase in the students' engineer career interests after the implementation of engineering design-based science instruction.

The paired sample effect size statistic was presented in Table 4.25. The effect size of the test was d=-1.586 regarding Cohen's d value of paired sample t-test. It means a large effect size according to Cohen (1988) criteria since the d value was bigger than .8.

*Table 4.25. Paired Samples Effect Sizes of STEM-CIS*

| | *Point Estimate* |
|---|---|
| Cohen's d | +1.586 |
| Hedges' Correction | +1.553 |

The pre and post-test results of the sub-dimension of "Engineering Part" were analyzed in terms of frequency distribution and agreement percentage, that is, the total percentage of "agree" and "totally agree" options for each of the ten items of this part. Also, the mean scores of the pre-test and post-test were also presented. The results for the engineering sub-dimension of STEM-CIS were presented in Table 4.26.

*Table 4.26. Agreement Percentages for Items and Mean Value of Sub-Dimension of Engineering*

| Item | *Frequency* | | *Percentage* | |
|---|---|---|---|---|
| | *pre* | *post* | *pre* | *post* |
| 1. I am able to do well in activities that involve engineering. | 27 | 34 | 72.9 | 91.9 |
| 2. I am able to complete activities that involve engineering. | 22 | 34 | 59.4 | 91.9 |
| 3. I plan to use engineering in my future career. | 17 | 25 | 45.9 | 67.5 |
| 4. I will work hard on activities at school that involve engineering. | 19 | 29 | 51.3 | 78.3 |
| 5. If I learn a lot about engineering, I will be able to do lots of different types of careers. | 25 | 27 | 65.5 | 72.9 |
| 6. My parents would like it if I chose an engineer career. | 20 | 26 | 54.0 | 70.2 |
| 7. I am interested in careers that involve engineering. | 14 | 28 | 37.8 | 75.6 |
| 8. I like activities that involve engineering. | 16 | 31 | 43.2 | 83.7 |
| 9. I have a role model in an engineer career. | 12 | 19 | 32.4 | 51.3 |
| 10. I would feel comfortable talking to people who are engineers. | 12 | 33 | 32.4 | 89.1 |
| Mean Scores | 33.46 | | 41.27 | |

Firstly, according to table 4.26., after engineering design-based instruction, the percentage of agreement value increased for all items. The engineering part was not included any reverse items that contain negative statements such as “I do not…” or “ I cannot…”. Therefore, the rise in percentages of agreement showed that students’ interest and motivation in engineering increased after engineering design-based instruction. Secondly, when the table was analyzed, a slight change was observed in item 5, while a considerable change was observed in item 10. The huge change in item 10 showed that the engineering activity, which enabled students to meet the engineers, increased the students' interest in talking with engineers. Lastly, it was seen an increase in the mean scores from the pre-test ($\bar{x}_{pre}$=33.46) to the post-test ($\bar{x}_{post}$=41.27) of students.

**4.3 Summary of the Result**

Firstly, according to the results, there was an increase in the astronomy understanding scores of the students after the implementation of the engineering design-based science instruction. When the universe, the solar system, the stars and planets, and the orbit concepts were analyzed in detail;

*a) The Universe Concept:* The statistical result presented that there was an increase in the frequency of a partial understanding level of the student while the frequency of no understanding level of the student decreased after the engineering design-based instruction. Inadequate and illogical conceptions about the universe concept of students also decreased after EDBI.

*b) The Solar System Concept:* The statistical result presented that there was an increase in the frequency of a partial understanding and sound level of students; therefore, students developed an understanding of components of the solar system after engineering design-based instruction. Also, the frequency of no understanding level of students decreased after the engineering design-based instruction.

*c) The Stars and Planets Concepts:* The statistical result presented that there was an increase in the frequency of a partial understanding and sound level of students after engineering design-based instruction. The students differentiated planets from other celestial bodies (stars and satellites) in a more reasonable manner. The frequency of no understanding level of students decreased after engineering design-based instruction.

*d) The Orbit Concept:* The statistical result presented that there was an increase in the frequency of a partial understanding level of the student while the frequency of no understanding level of the student decreased after the engineering design-based instruction. The students developed an understanding of the components of the orbit concept after the implementation of EDBI.

Secondly, There was a significant mean difference between gained interest pre-test and post-test scores of students taught with engineering design-based instruction with respect to students' engineer career interests. In other words, it was observed that there was an increase in the students' engineer career interests after the implementation of engineering design-based science instruction. When the engineering sub-dimension was analyzed in detail, the percentage of agreement value increased for all items after engineering design-based instruction. Therefore, students' interest and motivation in engineering increased after EDBI.

# CHAPTER 5

# DISCUSSIONS, CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

In this chapter, the main results of the presented study are concluded. In addition, the results are discussed in light of the literature. Implications and recommendations are also given at the end of the chapter.

## 5.1. Discussions

The purpose of the present study is to investigate the effect of engineering design-based instruction on 6th-grade students' understanding of astronomy concepts and students' engineer career interests. Students' understandings of astronomy concepts and their engineer career interests were identified before and after the implementation of EDBI. "The Scale of 6th-Grade Students Understanding Level of Astronomy Concepts" and "Science, Technology, Engineering, and Mathematics Career Interest Survey" were applied to the experimental group before and after the application. The obtained data were analyzed by conducting statistical analysis in order to examine the effect of engineering design-based instruction on 6th-grade students' understanding of astronomy concepts and engineer career interests. In the discussion part, the results of the present study were discussed.

### 5.1.1. The Understanding of Astronomy Concepts

In this part, the effects of engineering design-based instruction on the understanding of astronomy concepts of students were discussed according to the findings of the present study.

The main research question of the present study was:

1) What is the effect of engineering design-based instruction (EDBI) on 6th-grade students understanding of astronomy concepts?

The open-ended scale, which is “The Scale of 6th-grade Students Understanding Level of Astronomy Concepts” (Akbaş & Ekiz, 2005) was conducted to investigate the effects of engineering design-based science instruction on students’ understanding of astronomy concepts. According to the result of the present study, the mean scores of students after receiving engineering design-based instruction were higher than before treatment. Also, the mean difference between the experimental group students' pre-test and post-test scores was significant. The pre-test results of the students may represent the knowledge they learned from the traditional curriculum-based astronomy education. The findings of the present study showed that students have many misconceptions in the pretest. In addition, they made irrelevant answers and explanations to the open-ended questions given in the scale. The findings of the post-test showed that the responses given by the students became more meaningful after the EDBI. Not only logical explanations but also students' understanding of concepts had improved. This may show that engineering design-based science education may be more effective than traditional teaching methods in students’ understanding of astronomy concepts. However, since the control group was not used in the study, this comparison can only be made by evaluating the difference between the pre-test and post-test results. When looking at the present study, students were taught by instruction covering the engineering design process activities based on astronomy topics. These students designed prototypes in order to find a solution given astronomy problems using the engineering design process steps. This experience might enhance students’ understanding of astronomy after treatment. In this line, the study conducted by Wendell and Rougers (2013) showed similar results with the present study, and it was concluded that engineering education increased the average scores of the students in the science course. Likewise, the use of activities involving engineering design process steps in the science class was effective in increasing the success of the students in the science lesson (Yıldırım & Altun, 2015). Another study taught middle school students a series of activities that followed the engineering design steps for 3 weeks. It has been revealed that there was an increase in the understanding of students who were exposed to engineering design-based science education (Guzey, Moore, Harwell & Moreno, 2016). A study integrating engineering education with the aerospace and space field has shown that this field was a suitable subject for engineering design-based education, and also, students developed appropriate solutions to the problem by using the engineering design process (English, Hudson & Dawes, 2013). Similarly, in the present study, students were given problems related to astronomy and asked to design solutions to the problem. While the students were searching for solutions to the given problems, they followed the engineering design steps by working like an engineer. As a result of the study, it was seen that the students improved their understanding of concepts such as orbit, planet, and satellite. Based on this, it can be concluded that engineering-based science education can be used as an appropriate method for teaching astronomy subjects. On the contrary to the present study, it was stated that engineering education made a significant difference in the success of only students with a high level of achievement (Doppelt, Mehalik, Schunn, Silk & Krysinski, 2008). The reason why these studies do not support each other may be due to the different types of measurement tools. Unlike the present study, the standardized knowledge test was used in this study for data collection. The researchers of mentioned study stated that knowledge tests might not accurately measure the success of students because when the designs of the students were examined qualitatively, it was seen that although the students with a low level of achievement test scores were lower than high level, their designed products can be suitable for the problem as the other high level of achievement students.

The results of the present study indicated that the students supported their answers with more scientific explanations after the implementation of engineering design-based education. For instance,  on the item of "Is the sun a star? Why?",  in the pre-test, students explained that the sun is a star because it is bright, while in the post-test they explained that the sun is a source of heat, and light. While explaining the difference between the planet and the satellite, the pre-test results generally only included examples of "the Earth" and "the Moon", while the students explained the difference between the planet and the satellite through the movements they made, after receiving engineering design-based instruction. The "finding possible solutions" step of the engineering design process steps may have led the students to investigate most concepts more deeply because, in the pre-test, the students explained the concept of satellites through “the Moon", while they mentioned the satellites of other planets in the post-test. In the same way, the study conducted by Purzer, Goldstein, Adams, Xie, and Nourian (2015) stated that engineering design-based education positively affects students' understanding of science lessons and, at the same time, helps to develop more meaningful science learning. The study also mentioned that the students have made more scientific explanations thanks to design-based activities. In addition, it is revealed that engineering design-based education developed conceptual understandings of students in science topics as it improved skills of students such as decision-making, critical thinking (Fan & Yu, 2015). In another study, Guzey et al. (2019) aimed to measure how much participation time in an engineering design-based science education affects the development of knowledge. It was concluded that students who attended engineering education continuously for three years gained larger knowledge than students who attended only one year. The results indicated that the engineering activities were important in developing the knowledge of the students. Another study conducted with high school students covered three units with lesson plans that included engineering design steps (Fortus, Dershimer, Krajcik, Marx & Mamlok-Naoman, 2004). The research indicated that design-based activities were effective in structuring scientific knowledge and that these designs form “a bridge” for science learning. Likewise mentioned study, the result of the present study after receiving engineering design process activities, students made more scientific explanations and gave more scientific answers in their responses. Similarly, with these studies, the present study consisted of activities that followed engineering design process steps, and it was found that students' understanding of astronomy improved after the implementation of these activities. The engineering design process activities may have directed students to make analyzes to identify problems. As a result of the analysis, the students did research about the concepts that they thought they did not fully understand so that the students could have developed the scientific background of the concepts. In addition, students compared many concepts with each other in the step of finding a possible solution. For example, while investigating which celestial body they can build living space, they compared stars, satellites, and planets in terms of features such as atmosphere, landforms, and temperature. Thus, students may have developed a scientific understanding of many astronomy concepts thanks to the engineering design process. Moreover, English and King (2015) emphasized that each step of the engineering design process, especially the redesign step, played an important role in the development of disciplinary knowledge. Likewise, the presented study also focused on the redesign step of EDP and asked all the working groups “what they would change if they wanted to make changes in their models” and made them to explain. Therefore, the students may have a chance to think about the mistakes they made, and the opportunity for correcting them. To sum up, in light of these studies, it can be said that the engineering design steps had positive effects on both the success and understanding of the students in the science course.

When looking at astronomy topics, in particular, Adams and Slatter (2000) showed that students had difficulties in understanding the solar system and its components, and also they have many misconceptions. Although the result of the pre-test of the present study showed similar findings, post-test results showed that the frequency of students explaining all correct components of responses increased while the number of students having misconceptions and illogical responses decreased, in the solar system concept. Students stated that before EDBI, there are many stars in the solar system and the biggest of them is the sun. When looking at the post-test responses, the students stated that there is only one star in the solar system and its name is the Sun. These findings may show that the use of engineering design-based education will be efficient when teaching the solar system topic. The other studies conducted with 6th-grade students and measuring the level of students' understanding of astronomy concepts indicated that students had difficulties in understanding the concepts of orbit and universe concepts in particular and that they had misconceptions about these concepts (Akbaş & Ekiz, 2005; Keçeci, 2012). The pre-test results of the present study were in the same line in terms of the results showing that students had misconceptions, especially about orbits. However, when looking at the post-test results of the study, it is seen that the student's understanding of the orbit concept has improved because the frequency of students holding the no understanding level has decreased after EDBI. The reason why students developed an understanding of the orbit concept and overcame misconceptions may be due to the engineering design-based instruction they received because one of the problems given to the students was related to the concept of "orbit". The students did a lot of research, group discussions, and brainstorming about the concept of orbit while trying to define a given problem and finding possible solutions. In this way, students may have developed their conceptual understanding of the concept of orbit. To sum up, the study showed that the understanding of the students in astronomy topics increased after engineering design-based instruction. The students developed an understanding of astronomy concepts such as the universe, solar system, planets, stars, and orbit and made more logical and scientific explanations. This may be due to the fact that engineering design-based education was suitable for teaching astronomy subjects; it made students think at a higher level, such as decision-making and critical thinking and therefore caused more meaningful learning (Fan & Yu, 2015; Purzer et al., 2015; Arslan & Koparan, 2018). Therefore, the present study may be concluded that the astronomy-based activities with the engineering design process had a positive effect on the development of students' understanding of astronomy topics.

### 5.1.2. The Engineer Career Interest

In this part, the effect of engineering design-based instruction on students' engineer career interests was discussed according to the findings of the present study.

The main research question of the research was:

2) What is the effect of engineering design-based instruction (EDBI) on 6th-grade students’ engineer career interests?

The 5-Likert type scale, which is the Science, Technology, Engineering, and Mathematics Career Interest Survey (adapted Turkish version) (Kier et al., 2013; Koyunlu-Unlu et al., 2016) was implemented to evaluate the effects of engineering design-based science instruction on students’ engineer career interests for the present study. The findings showed that there was a mean difference between students' pre-test and post-test scores, and also, the mean difference in scores was significant. The results showed that there was an increase in the students’ engineer career interests after the implementation of engineering design-based science instruction.

In the same vein, a study conducted with elementary level students stated that the number of students who want to be an engineer in their future careers increased after receiving engineering education because engineering education developed an awareness of the profession in these students (Katehi, 2009). The engineering design-based instruction changes students’ perceptions of engineering in a positive way because students do not know exactly what the engineering profession is, before receiving EDBI (Fralick et al., 2009; NAE & NRC, 2014). The students' interest in engineer careers increased after receiving EDBI. The engineering design process may help the students see what steps an engineer follows while working, and therefore makes them experience working like an engineer therefore, the students could be more interested in the engineer career after working like a real engineer. Another study showed that middle and high school students interested in engineering activities and other STEM fields would like to choose professions in these fields as future career options (Popa & Ciascai, 2017). Likewise, in the research in which the field of engineering was integrated into the science course, 4th grade students indicated that they could choose engineering as a profession in the future in their views on the process (Acar, 2018). Similar results were obtained in the present study, and students' interest in choosing the engineer career increased after the engineering design process activities. According to the post-test results, the number of students who agreed that they took engineers as role models and liked to work like an engineer increased. Thus, it can be said that the introduction of the engineering profession and the opportunity to work like an engineer during EDBI may have supported students and increased their interest in the engineer career.  However, another study stated that even though students stated that they were interested in the engineering profession, they did not know exactly what engineers do (Barger & Boyette, 2015). The present study aimed to reduce the encounter with the mentioned situation, and therefore students were met with two real-life engineers. They had a chance to direct communication opportunities with these engineers and observed what they did and what steps they followed when finding solutions to problems as engineers. Also, in the post-test administered after this meeting, an increase was seen in the number of students who agreed to enjoy talking with engineers. In addition, at the end of engineering design-based instruction, when the responses of students given to the “Would you prefer to be an engineer in the future career?" question were examined, it was seen that the students generally answered "yes" and that there was aerospace engineering in the fields they wanted to choose. For this reason, it can be concluded that engineering-based science education including astronomy subjects may be effective in increasing students' interest in engineer careers.

### 5.2 Conclusions

Engineering has an important place in the developing world, therefore, engineering education should be integrated into science lessons from primary school in order to raise more skilled individuals (Banks-Hunt et al., 2016; Casey, 2012). Engineering design-based science education that includes engineering design process activities is the way the engineering field is added to the science curriculum. These engineering design process activities increase students' achievements in science lessons (Fortus et al., 2004), and students develop more scientific understandings and overcome misconceptions about science concepts (Purzer et al., 2015; English & King, 2015). In the same vein, the result of the present study showed that students’ understanding of astronomy concepts improved positively after receiving engineering design-based instruction based on astronomy topics because the mean of students' scores on the post-test was higher than pre-test mean scores. Also, the difference between the mean score of the pre and post-test was significant. In addition to gained scores, students developed a more scientific understanding of the concepts of the universe, solar system, stars, planets, and orbits after EDBI. According to the results of the present study, while the frequency of students who responded to logical and scientific answers increased, the frequency of students who could not explain their answers and responded to illogical answers decreased in the post-test. In order for students to overcome misconceptions and develop concepts, engineering design process activities should be given to them as much as possible (Guzey et al., 2019). Thus, it may be concluded that engineering design-based science education improved students' understanding of astronomy concepts.

The engineering job market is expected to grow over the next decade; although there is a need for engineers all around the World, there are problems in enrollment in engineering jobs (Dohm & Shniper, 2007). Students do not prefer choosing engineering as a career choice because they generally have inadequate perceptions and even wrong information about the engineering profession (Fralick et al., 2009). Engineering design-based instruction is a way of increasing students' interest in engineer careers by experiencing the engineering design process because, in order to grow well-trained engineers, it is necessary to meet students to engineering from the elementary school level (NRC, 2009b). In the same way, the present study showed that there was an increase in the students' engineer career interests after the implementation of engineering design-based science instruction. According to the results, there was a significant mean difference between gained interest pre-test and post-test scores of students taught with engineering design-based instruction with respect to students' engineer career interests. The students talked with two engineers who were actively working; therefore, students could observe what the engineers do in work life. This communication may have caused the students to observe the engineering profession more concretely and also may have increased students' engineer career interests. Lastly, engineering education affected students' engineer career interests; therefore, if it is aimed to increase the engineering profession interest of middle school students, engineering-based education should be integrated into the science curriculum (Jagacinski, Lebol, Linden, & Shell, 1985; Banks-Hunt, Adams, Ganter, & Bohorquez, 2016).

## 5.3. Implications and Recommendations for Further Studies

The first significant difference of the present study was an increase in the astronomy understanding of students after receiving engineering design-based instruction. Therefore, it was seen that EDBI positively affected students' development of understanding in terms of astronomy concepts. The second significant difference was found in students' engineer career interests after receiving engineering design-based instruction.

The implications determined by considering the findings, and results of the research process are presented below:

- Engineering design-based instruction may be integrated into the science curriculum with more explicit objectives, and even activities involving the engineering design process may be included in the textbooks.
- Activities such as inviting engineers to the class as speakers or creating a collaborative working environment with students and engineers can be encouraged.
- Engineering design-based education is one of the new approaches in science education. With in-service training, hands-on engineering design-based training may be given to experienced teachers, and sample lesson plans may be shared with them.
- Handbooks covering sample engineering design process activities, visuals, and engineering design-based education lesson plans can be prepared and distributed to in-service teachers by the Ministry of Education.

The recommendations for future researches determined by considering the limitations, findings, and results of the research process are presented below:

- The two engineering-based education lesson plans were used in the present study. The number of engineering design activities may be increased for further research.
- In this study, quantitative data analysis was performed. Qualitative data tools such as drawing pictures or interviews may be conducted with students in order to see students' opinions for future research.
- The level of understanding of astronomy subjects may also be measured at the 5th and 7th-grade levels; therefore, the effect of engineering design-based education on the understanding of more astronomy concepts can be measured. The lesson plans should be prepared depending on the objectives in the curriculum.
- In order to generalize the results better, a larger sample size is more suitable for quantitative studies. It may be more appropriate to increase the sample size of the study so that future studies make better generalizations of the results.

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## APPENDIECES

## APPENDIX-A

## PERMISSION FROM GOVERNOR'S OFFICE OF KİLİS AND PROVINCIAL DIRECTORATE OF NATIONAL EDUCATION

T.C.
KİLİS VALİLİĞİ
İl Milli Eğitim Müdürlüğü

Sayı : E-21722023-605.01-42323596 31.01.2022
Konu : Araştırma İzni

ORTA DOĞU TEKNİK ÜNİVERSİTESİ REKTÖRLÜĞÜNE
(Öğrenci İşleri Daire Başkanlığı)

İlgi : 22.12.2021 tarih ve 263 sayılı yazınız.

İlgi yazınız gereği; Üniversiteniz Matematik ve Fen Bilimleri Eğitimi Anabilim Dalı yüksek lisans öğrencisi Pınar BAŞPINAR tarafından hazırlanan "Mühendislik Tasarım Temelli Fen Eğitiminin 6.Sınıf Öğrencilerinin Astronomi Kavramlarının Anlamalarına ve Mühendislik Mesleği İlgilerine Etkisi " konulu çalışmanın uygulanmasının uygun görüldüğüne dair Araştırma İzin Formu ekte gönderilmiştir.

Gereğini arz ederim.

Mehmet Emin AKKURT
İl Milli Eğitim Müdürü

Bu belge güvenli elektronik imza ile imzalanmıştır.
Adres : Akpınar Cad.İl Milli Eğitim Müd. Kat:1 79100-KİLİS
Belge Doğrulama Adresi : https://www.turkiye.gov.tr/meb-ebys
Bilgi için: Şef :A.SARAÇOĞLU
Unvan : Memur
Telefon No : 0 (348) 813 28 28
E-Posta: istatistik79@gmail.com
İnternet Adresi: http://kilis.meb.gov.tr
Faks:3488131264
Kep Adresi : meb@hs01.kep.tr

Bu evrak güvenli elektronik imza ile imzalanmıştır. https://evraksorgu.meb.gov.tr adresinden 20ad-c79f-30fc-9747-0680 kodu ile teyit edilebilir.

## APPENDIX-B

## 6. SINIF ÖĞRENCİLERİNİN ASTRONOMİ KAVRAMLARINI KAVRAMA ÖLÇEĞİ

**Soru-1: Evren denince aklınıza ne geliyor? Açıklayınız.**

**Soru-2: a-Evren b- Yıldız c-Gezegen d-Uydu**

**Yukarıda verilenleri büyükten küçüğe doğru sıralayınız.**

**1……….. 2………… 3…………….. 4……………**

**Soru-3: Güneş Sistemi ne demektir? Açıklayınız**

**Soru-4: Güneş Sistemi içindeki gezegenler niçin güneşin çevresinde dönerler? Açıklayınız.**

**Soru-5: Güneş Sistemimizde kaç gezegen vardır? Sırasıyla yazınız.**

**Soru-6: Yıldız ile gezegen arasında ne fark vardır?**

**Soru-7: Gezegen ve Uydu arasında ne farklar vardır?**

**Soru-8: Güneş bir yıldız mıdır? Niçin?**

**Soru-9: Yörünge ne demektir? Açıklayınız.**

**Soru-10: Yörüngeler olmazsa ne olurdu? Açıklayınız.**

# APPENDIX-C

## "FEN, TEKNOLOJİ, MATEMATİK VE MÜHENDİSLİK MESLEKLERİNE YÖNELİK İLGİ ÖLÇEĞİ

**FEN BÖLÜMÜ**

| Önermeler | Tamamen Katılıyorum | Katılıyorum | Kararsızım | Katılmıyorum | Hiç Katılmıyorum |
|---|---|---|---|---|---|
| **1.** Fen dersinden iyi not alabilirim. | | | | | |
| **2.** Fen ödevlerimi tamamlayabilirim. | | | | | |
| **3.** Gelecekte fenle ilgili bir mesleğe sahip olmak isterim. | | | | | |
| **4.** Fen dersine diğer derslere göre daha çok çalışırım. | | | | | |
| **5.** Fen derslerindeki başarımın, gelecek meslek hayatımda bana fayda sağlayacağına inanıyorum. | | | | | |
| **6.** Fen alanında bir meslek seçmemi ailem de ister. | | | | | |
| **7.** Fen alanındaki mesleklere ilgi duyuyorum. | | | | | |
| **8.** Fen dersini severim. | | | | | |
| **9.** Fen alanında çalışan birini mesleki açıdan örnek alırım. | | | | | |
| **10.** Fen alanında çalışan insanlarla sohbet etmeyi seviyorum. | | | | | |

*Biyolog, doktor, eczacılık, hemşirelik vb. fen alanındaki mesleklere örnek olarak verilebilir.

**MATEMATİK BÖLÜMÜ**

| Önermeler | Tamamen Katılıyorum | Katılıyorum | Kararsızım | Katılmıyorum | Hiç Katılmıyorum |
|---|---|---|---|---|---|
| **1.** Matematik dersinden iyi not alabilirim. | | | | | |
| **2.** Matematik ödevlerimi tamamlayabilirim. | | | | | |
| **3.** Gelecekte matematikle ilgili bir mesleğe sahip olmak isterim. | | | | | |
| **4.** Matematik dersine diğer derslere göre çok çalışırım. | | | | | |
| **5.** Matematik derslerindeki başarımın gelecek meslek hayatımda bana fayda sağlayacağına inanıyorum. | | | | | |
| **6.** Matematik alanında bir meslek seçmemi ailem de ister. | | | | | |
| **7.** Matematik alanındaki mesleklere ilgi duyuyorum. | | | | | |
| **8.** Matematik dersini severim. | | | | | |
| **9.** Matematik alanında çalışan birini mesleki açıdan örnek alırım. | | | | | |
| **10.** Matematik alanında çalışan insanlarla sohbet etmeyi seviyorum. | | | | | |

* Muhasebeci, bankacı, matematik öğretmenliği vb. matematik alanındaki mesleklere örnek olarak verilebilir.

**TEKNOLOJİ BÖLÜMÜ**

| Önermeler | Tamamen Katılıyorum | Katılıyorum | Kararsızım | Katılmıyorum | Hiç Katılmıyorum |
|---|---|---|---|---|---|
| **1.** Teknoloji kullanımı gerektiren etkinliklerde başarılıyımdır. | | | | | |
| **2.** Teknolojideki yenilikleri kolaylıkla öğrenebilirim. | | | | | |
| **3.** Meslek hayatımda yeni teknolojileri yakından takip etmeyi düşünüyorum. | | | | | |
| **4.** Derslerimde bana faydası olacağına inandığım yeni teknolojileri öğrenmek isterim. | | | | | |
| **5.** Teknolojiyle ilgili çok şey öğrenirsem pek çok iş imkanıyla karşılaşabilirim. | | | | | |
| **6.** Teknoloji alanında bir meslek seçmemi ailem de ister. | | | | | |
| **7.** Sınıf içi çalışmalarımızda teknoloji kullanmayı seviyorum. | | | | | |
| **8.** Teknoloji alanındaki mesleklere ilgi duyuyorum. | | | | | |
| **9.** Teknoloji alanında çalışan biri/birilerini mesleki açıdan örnek alırım. | | | | | |
| **10.** Teknoloji alanında çalışan insanlarla sohbet etmeyi seviyorum. | | | | | |

*Bilgisayar programcılığı, bilgisayar yazılımı ve donanımı ile ilgili meslekler, bilgisayar teknisyenliği, elektrik-elektronik teknisyenliği vb. teknoloji alanındaki mesleklere örnek olarak verilebilir.

**MÜHENDİSLİK BÖLÜMÜ**

| Önermeler | Tamamen Katılıyorum | Katılıyorum | Kararsızım | Katılmıyorum | Hiç Katılmıyorum |
|---|---|---|---|---|---|
| **1.** Mühendislik becerisi gerektiren etkinliklerde başarılıyımdır. | | | | | |
| **2.** Mühendislik becerisi gerektiren etkinlikleri tamamlayabilirim. | | | | | |
| **3.** Meslek hayatımda mühendislik becerilerini kullanmayı düşünüyorum. | | | | | |
| **4.** Derslerimde mühendislik becerisi gerektiren etkinliklere katılma konusunda çok istekliyimdir. | | | | | |
| **5.** Mühendislikle ilgili çok şey öğrenirsem pek çok iş imkanıyla karşılaşabilirim. | | | | | |
| **6.** Mühendislik alanında bir meslek seçmemi ailem de ister. | | | | | |
| **7.** Mühendislik alanındaki mesleklere ilgi duyuyorum. | | | | | |
| **8.** Mühendislik becerisi gerektiren etkinlikleri seviyorum. | | | | | |
| **9.** Mühendisleri mesleki açıdan örnek alırım. | | | | | |
| **10.** Mühendislerle sohbet etmeyi seviyorum. | | | | | |

* Makina mühendisi, inşaat mühendisi, çevre mühendisliği, elektrik mühendisliği, kimya mühendisliği vb.

2

## APPENDIX-D

### STEM ANALYSIS CRITERIA

| The Activity | Yes | Partially | No |
|---|---|---|---|
| 1. Does the activity include a daily life prolem? If yes; | X | | |
| • Is it an interesting problem for the students? | X | | |
| • Is it familiar and understandable for the students? | X | | |
| 2. Does the activity include integration of one or more than one disciplines of STEM? If yes; | X | | |
| • Does it include engineering design homework? | X | | |
| • Does it make connection with mathematics concepts? | | X | |
| • Is it appropriate for technology use? | X | | |
| 3. Is the activity student-centered? If yes; | X | | |
| • Does it give an opportunity to the students about making their own searches? | X | | |
| • Does it enable the students to present scientific questions when the students design? | X | | |
| • Does it avoid direction (choosing materials, design process etc.) when the students design? | X | | |
| 4. Does the activity have the characteristics of project, problem and inquiry-based learning approaches? If yes; | X | | |
| • Does it provide an opportunity to the students to study on a problem or project? | X | | |
| • Does it provide an opportunity to the students to hypothesize and to design a project or process based on their hypothesis? | | X | |
| • Does it allow the students for creativity, thinking and inquiry skill, cooperative learning, designing and innovation? | X | | |
| • Do the students present their designs (a project or process) by verbally or a poster? | X | | |
| 5. Does the activity provide an opportunity to the students to work in small groups and group communication? | X | | |
| 6. Does the activity provide an opportunity to the students to redesign their designs? | X | | |
| • Does it ask the students what and why they change in redesign step? | X | | |

| | |
|---|---|
| 7. Does the activity provide an opportunity to evaluate the design based on criteria (cost, time, availability of materials etc.)? If yes; | X |
| • Does it present a rubric to evaluate the design in intergroup? | X |
| • Did the criteria in the rubric be presented to the students at the beginning of the activity? | X |

## APPENDIX- E

## "YAŞAM ALANI TASARIMI" DERS PLANI

| | |
|---|---|
| **Ders** | Fen Bilimleri |
| **Sınıf Düzeyi** | 6. Sınıf |
| **Ünite/ Konu** | F.6.1. Güneş Sistemi ve Tutulmalar / F.6.1.1. Güneş Sistemi |
| **Süre:** | 8 ders saati |

**Kazanımlar:**

F.6.1.1.1. Güneş sistemindeki gezegenleri birbirleri ile karşılaştırır.

F.6.1.1.2. Dünya'nın, Güneş etrafında belirli bir yörüngede dolandığını belirtir.

F.6.1.1.3 Güneş sistemindeki yıldızın, asteroit, uydu ve gezegenlerin özelliklerini karşılaştırır.

F.6.1.1.4 Mühendislik tasarım basamaklarını takip ederek, güneş sistemi ile ilgili bir probleme yönelik model hazırlar.

**Ön Bilgiler:**

**1)** Dünya'nın Fiziksel Özellikleri (*F.3.1.1. Dünya'nın Şekli ve Yapısı*)
**2)** Dünya'nın Yörüngesi (*F.4.1.2. Dünya'mızın Hareketleri)*
**3)** Güneş Sisteminin Yıldızı'nın Özellikleri (*F.5.1.1. Güneş'in Yapısı ve Özellikleri*)
**4)** Dünya'nın Doğal uydusu olan Ay'ın Özellikleri (*F.5.1.2. Ay'ın Yapısı ve Özellikleri*)

**Materyaller:**

- *“Mühendis Takımı Defteri” Aktivite Kağıdı:* Dağıtılan Aktivite Kağıdının temel amacı öğrencilerin süreci kolay takip etmeleri sağlamak ve tasarımlarını, sorulara verdikleri cevapları yazılı bir şekilde tutmalarını sağlamaktır. Problem senaryosu, mühendislik tasarım basamakları, çizim için noktalı bölüm aktivite kağıdının içinde yer almaktadır. Aynı zamanda problem senaryosu, mühendislik tasarım basamakları, öz değerlendirme ile alakalı soruları da kapsar.
- *Bilimsel Dergiler:* Öğrencilerin “Olası çözümleri araştırma” ve “En iyi çözümü bulma” basamaklarında araştırma yapabilmeleri amacıyla astronomi ile alakalı öğrencilerin seviyelerine ve okul ortamına uygun bilimsel dergiler materyal olarak sunulur.
- *Ürün Tasarımında Kullanılacak Malzemeler:* Mühendislik tasarım basamaklarının son adımı olan “Model Üretme ve Test Etme” basamağında öğrencilerden fiziksel bir ürün oluşturmaları beklenir. Bu ürünü tasarlamak için bir malzeme listesi belirlenmiştir.

**Teknolojik Materyaller:**

- *Akıllı Tahta:* “Mühendis Takımı Defteri” Aktivite Kağıdı’nı ekrana yansıtabilmek amacıyla akıllı tahta kullanılır. Öğrenciler etkinlik sırasında hangi basamakta olduklarını akıllı tahta sayesinde takip edebilirler.
- *Bilgisayar:* Öğrencilerin “Olası çözümleri araştırma” ve “En iyi çözümü bulma” basamaklarında araştırma yapabilmeleri amacıyla internete bağlı bir bilgisayar kullanılır. Bilgisayar kullanımı amaç dışına çıkılmaması için gözetim altında olmalıdır.

- *Video:* Güneş sisteminin ve gezegenlerin genel özelliklerini anlatan bir video kullanılır. (https://www.youtube.com/watch?v=rGGZnh8W7Oo)

**Öğretim Yöntem ve Teknikleri:** Mühendislik Tasarım Temelli Fen Eğitimi

**ÖĞRETİM SÜRECİ**

**Giriş:**

Öğretmen derse girer ve öğrencileri selamlar. Ardından soru-cevap yöntemini kullanarak ön bilgilerini hatırlamalarını sağlar. "Yaşadığımız gezegenin adı nedir?", "Gezegenimizin uydusu var mıdır?" veya "Dünya'nın etrafında dolandığı gök cisminin adı nedir?" gibi sorular sorarak öğrencilerin geçmiş yıllarda öğrendikleri kavramların hatırlanmasını sağlar. Öğretmen bu sorulara ek olarak "Gezegen nedir? Bildiğiniz gezegenler hangileri?" sorusunu sorarak öğrencilerin gezegenler hakkındaki bildiklerini düşünme fırsatı verir. Cevaplar alındıktan sonra, öğretmen öğrencilere Güneş Sisteminin genel özelliklerini anlatan bir video izletir. Video öğrencilerin konuya dikkatlerini çekmek amaçlı kullanılır sadece bilgi vermek amacıyla kullanmak yeterli değildir. Bu nedenle öğretmen sorduğu sorulardan yola çıkarak kısa bilgiler verir. Örneğin; "Güneş Sistemi bir yıldız (Güneş), 8 gezegen, bu gezegenlerin uyduları ve asteroitlerden oluşur", "Uydular, gezegenlerin etrafında belirli bir yörüngede dolanır" "Her gezegenin Güneş etrafında dolandığı belirli bir yörüngesi vardır" benzeri bilgiler verilir **(F.6.1.1.2. ).** Güneş Sistemi gezegenlerinin sıcaklık, Güneş'e yakınlık, uydusu olup olmaması gibi temel özelliklerinin üzerinden geçilir. Eğer gerekli görülürse 6. Sınıf Fen Bilimleri MEB kitabı bu aşamada kullanılır;

**Güneş:** Güneş Sistemi'nin merkezinde yer alan yıldızdır. Güneş sisteminin ısı ve ışık kaynağıdır.

**Karasal Gezegenler:** Güneş Sisteminin ilk dört gezegenine verilen isimdir. Yapıları taş ve kayalardan oluşur.

**Gazsal Gezegenler:** Güneş Sisteminin son dört gezegenine verilen isimdir. Yapıları gazlardan oluşur.

**Merkür**: Güneş'e en yakın ve en küçük gezegendir. Uydusu ve halkası yoktur. En sıcak ikinci gezegendir.

**Venüs:** Güneş'e en yakın ikinci gezegendir. Yüzey sıcaklığı en fazla olan gezegendir. Boyut olarak Dünya'ya çok benzer. Uydusu ve halkası yoktur.

**Dünya:** Güneş'e en yakın üçüncü gezegendir. Güneş sisteminde üzerinde yaşam olduğu bilinen tek gezegendir. Ay adı verilen 1 adet doğal uydusu vardır ancak halkası yoktur.

**Mars:** Kızıl gezegen olarak bilinir, Güneş'e en yakın dördüncü gezegendir. Yüksek dağlar ve kayaları vardır. İki adet doğal uydusu vardır ve halkası yoktur.

**Jüpiter:** Güneş'e en yakın beşinci gezegendir ve gazlardan oluşur. Aynı zamanda Güneş Sisteminin en büyük gezegenidir. 79 adet doğal uydusu ve halkası vardır.

**Satürn:** Güneş'e en yakın altıncı gezegendir ve gazlardan oluşur. Belirgin bir halkası vardır. 82 adet doğal uydusu bulunur.

**Uranüs:** Güneş'e en yakın yedinci gezegendir. Güneş Sisteminin en soğuk gezegenidir. Belirgin olmasa da halkası bulunur. 27 adet doğal uydusu vardır. Dönme yönü diğer gezegenlerin aksine, yuvarlanan bir varil gibidir.

**Neptün:** Güneş'e en yakın sekizinci gezegendir. Güneş sisteminin en sondaki gezegenidir. 14 adet doğal uydusu ve halkası bulunur.

**Asteroit kuşağı:** Büyük kaya ve metal parçaları asteroit kuşağını oluşturur. Mars ile Jüpiter gezegenleri arasında yer alır (MEB Sevgi Yayınları).

Öğrencileri problem senaryosuna hazırlamak için “Dünya’nın, Güneş etrafında belirli bir yörüngede dolandığı” ve “Güneş’e yakın gezegenlerin yüzey sıcaklıklarının arttığını, uzak gezegenlerin ise yüzey sıcaklıklarının azaldığı” bilgilerinin üzerinden geçilmesi ve Güneş Sistemi elemanlarının özelliklerinin birbirileri ile karşılatılması önemlidir **(F.6.1.1.1. ve F.6.1.1.3).** Öğretmen soru- cevap yöntemini kullanarak öğrencilerin anlama düzeylerini değerlendirir. Eğer gerek varsa kavramları tekrar anlatmalıdır. Soru-cevap yöntemi ile değerlendirme yapıldıktan sonra “Giriş” bölümü sonlandırılır.

**Geliştirme:**

Giriş bölümünün ardından, “Mühendislik Tasarım Temelli” ders işlenmeye başlanır. Bu süreçte öğretmen, “Mühendislik Tasarım Basamakları”nı kullanarak bir proje yapmaları gerektiği konusunda öğrencileri bilgilendirir **(F.6.1.1.4 ).** Bu süreç küçük gruplar halinde yapılacağı için öğretmen sınıfı heterojen 3-4 kişilik gruplara ayırır (Gruplandırma planlanan dersten önce de yapılabilir). “Mühendis Takımı Defteri” aktivite kağıdı her gruba bir tane olacak şekilde dağıtılır. Dersin işlenişi ana hatları ile aşağıda verilen “Mühendislik Tasarım Basamakları”nı takip eder:

**1)** Problem tespiti,
**2)** Probleme yönelik olası çözümleri araştırma,
**3)** En iyi çözümü bulma, ve
**4)** Modeli tasarlama ve test etme
**5)** Herhangi bir adıma geri dönme (eğer gerekirse)

Öğretmen aktivite kağıdını dağıtır ve senaryoyu okur;

*“2253 yılında yaşayan bir mühendis olduğunuzu düşünün. Canlılara ev sahipliği yapan ve yaşamımızı sürdürdüğümüz Dünya, biz canlılar için artık yaşanabilecek bir çevreye sahip değil çünkü Dünya’nın yörüngesi son yıllarda Güneş’e yakınlaşmaya başladı. Bu durum sonucunda sıcaklık gittikçe arttı ve kuraklığı da*

*beraberinde getirdi. Su kaynakları gittikçe tükenmeye başladı. Bu nedenle verimli bitkiler yetişemiyor, insanlar ve diğer canlılar yaşamlarını sağlıklı sürdürememekte. Bir takım bilim insanları bu duruma çözümler üretmeye çalışırken, diğer bilim insanları Uzayda Dünyadan başka bir yerde yaşayıp yaşayamayacağımız üzerinde çalışmalar yapıyor. Bilim insanları uzayda başka yerlerde yaşam arıyor çünkü Dünya'nın yörüngesi Güneş'e yaklaşmaya devam edebilecek gibi görünüyor. Uzayda yaşam kurulup kurulmayacağı konusunda çalışmalar yürüten bilim insanları siz mühendisleri de takımlarında çalışmaya davet ediyorlar. Çalışmalara önceliklere doğru bir yer seçip (gezegen- yıldız, uydu vb.) oranın özelliklerinin canlı yaşamını sürdürmeye uygun olup olmadığıyla başlanacak. Ardından seçilen bölgede yaşam kurmak için bir site inşa edilecek. Bu sitenin öncelikli olarak yüz insan ile birlikte bir yıllık deneme süresi gerçekleştirilecek. Eğer çalışmalar olumlu sonuçlar verirse insan kapasitesi yıllar içinde artırılacak. Sizi mühendis olarak takımlarına davet eden bilim insanları, Dünya dışında kurulacak bu yeni düzen için sizlerden fikir alıp, kurulacak yeni yaşam alanı hakkında bir örnek model oluşturmalarına yardımcı olmanızı istiyorlar."*

Senaryo okunduktan sonra öğrenciler öncelikle takım defterlerinde bulunan problem tespitine yönelik soruları grupça tartışıp yanıtlarlar. Öğretmen bu aktivite kağıdının hangi bölümünü yapıyorlarsa, o bölümü akıllı tahtada yansıtarak çıkabilecek karmaşaları önler. Verilen soruların yanıtlandırılmasının ardından öğrenciler problem tespiti yaparak, senaryoda verilen problemi belirlemeye çalışırlar. Öğretmen bu aşamada öğrencilere artık birer mühendis olduklarını ve bundan sonra birer mühendis gibi düşünüp probleme ona göre çözümler üretmeleri gerektiğini vurgular. Problemi tespit ettikten sonra, birer mühendis olarak probleme uygun çözümler araştırırlar. Bu sırada öğrenciler dergilerden ve bilgisayardan yararlanarak araştırma yapabilir. Öğrencilerden "Dünya'dan giden 100 insanın yaşamını devam ettirebileceği sitenin kurulabileceği Güneş Sisteminde bir yer" bulmaları beklenir. Probleme uygun çözümler arasından, öğrenciler grupça tartışarak en uygun çözümü bulurlar. Bu aşamada öğretmen gruplara herhangi bir yardımda bulunmaz. Öğrencilerden aktivite kağıdında bulunan sorulara yanıt vermeleri gerekir.

Gruplardan belirledikleri en iyi çözüme göre tasarım yapmaları beklenir ve bu tasarımları yapmaları için kullanacakları malzemeleri aktivite kağıdından incelerler. Öğrencilerin modelleri aşağıda verilen şartları sağlamalıdır:

1) Modelin kendi başına ayakta durabilmesi gereklidir.
2) Modelin parçalarının düşmemesi, devrilmemesi eğilmemesi gereklidir.
3) En az 3 malzeme kullanılmalıdır.
4) Modeliniz 20 cm x 20 cm boyutlarının altında olmamalıdır.

Malzeme listesinden "temel malzemeler" bütün gruplara dağıtılır ve gruplardan "diğer malzemeler" grubundan 4 adet malzeme seçmeleri beklenir.

- Öğrencilerden yaşam alanı kurulabilecek bir gök cismi seçmeleri ve tasarımları ile de o gök cismine yüz insanın yaşayabileceği bir site kurmaları beklenir. Örneğin; seçtikleri gök cismi Güneş'e yakın sıcak bir gezegense, kuracakları yaşam alanında sıcaklığı insanların yaşayabileceği derecelere indirmeyi planladıkları sistemler bulunmalıdır.

Öğrenciler modellemeye başlamadan önce aktivite kağıdında verilen noktalı alana yapacakları modelin taslağını çizerler ve kullanacakları malzemeleri eşleştirirler. Bütün gruplar taslak çizmeyi bitirince, öğretmen modelleme yapmaları için gruplara belirlenen malzemeleri dağıtır. Modelleme için yaklaşık 50-60 dakika bir süre verilebilir. Bu sürede öğretmen maket bıçağı, sıcak silikon gibi aletleri öğrencilere kullandırmamalı, kendi yardım etmelidir. Ancak modellemenin diğer aşamalarında öğretmen yalnızca rehberlik eder, tasarım konusunda öğrencilere yardımda bulunmaz.

Süre bitince bütün modeller öğretmen masasında toplanır. Numaralandırılmış grupların ilkinden başlanarak modeller öğretmen tarafından test edilir. Gruptan bir kişi tahtaya gelerek modellerini en fazla 4 dakika içinde diğer gruplara sunar, bu esnada hangi mühendislerin görev aldığını da belirtir. Sunumun ardından öğretmen o grubun modelini belirlenen kriterler doğrultusunda test eder ve sonuçlarını aktivite kağıdının belirlenen bölümüne (Görsel 1) not alırlar.

| Puan | Kriter | Bizim puanımız |
|---|---|---|
| Evet : 5 puan<br>Hayır: 0 puan | En az 45 saniye ayakta durabiliyor. | |
| Evet : 5 puan<br>Hayır: 0 puan | Parçalar düşmüyor, eğilmiyor. | |
| Evet : 5 puan<br>Hayır: 0 puan | En az 3 malzeme kullanılmış | |
| Evet : 0puan<br>Hayır: 5 puan | Temel malzemelerden 4'ten fazla kullanılmış. | |
| Evet : 5 puan<br>Hayır: 0 puan | 20 cm x 20 cm boyutlarından küçük değil. | |

Görsel 1

Belirlenen kriterler doğrultusunda modelin kendi başına ölçülen 45 saniye boyunca ayakta durabiliyor olması gerekiyor, devrilen modeller "0" puan üzerinden değerlendirilir. İkinci olarak, modelin her parçasının dik durabilmesi, ters çevrildiğinde düşmeyip eğilmemesi gerekiyor. Bunun sebebi "Yaşam alanı kurulan sitede her sistemin hayati önem taşıdığı bir sistemin çökmesi sonucunda yaşamın durabileceği olarak açıklanır". Parçaları düşen modeller "0" puan üzerinden değerlendirilir. Malzeme kriterine uymayan gruplar "0" puan üzerinden değerlendirilir. En son olarak model boyutu verilen ölçüden küçük ise "0" puan üzerinden değerlendirilir. Bunun nedeni ise "100 kişinin yaşayabileceği bir alan 100 kişiye uygun olmalıdır. Daha küçük alanlar sosyal ve fiziksel sıkıntılar yaratacağı için yeterli bir yaşam alanı oluşturamaz" olarak yapılır. Bütün kriterleri sağlayan bir model "5+5+5+5+5 = 25 Puan" alır.

**Sonuç:**

Mühendislik Tasarım Temelli ders anlatımının ardından, "Sonuç" bölümüne geçilir. Bu bölümde öğrenciler "Değerlendirme ve Öz- Değerlendirme" yaparlar. Değerlendirme bölümleri "Mühendis Tasarım Defteri"nde bulunur ve grupça yanıtlanacak 4 sorudan oluşur. Değerlendirme bölümlerinin amacı öğrencilere öğrendikleri kavramları ve tasarımlarındaki hataları tespit ederek nasıl düzeltebilecekleri sorgulatmaktır. Aynı zamanda öğrencilerin "Mühendislik Tasarım Basamak"larına ne kadar uyum sağladıkları ve önemini ne kadar kavradıkları da öz-değerlendirme bölümünde ölçülmeyi hedefler. Öğretmen bu aşamada gruplar arasında dolaşarak öğrencilerin "evet- hayır" gibi kısa cevaplar vermelerini engeller ve yönergede (soruların yönergesinde) belirtildiği gibi cevaplarının nedenlerini açıklamalarını sağlar.

**DEĞERLENDİRME**

"Mühendislik Tasarım Basamakları"nı ve "Mühendislik Mesleğinin Özellikleri"ni derinleştirmek amacıyla bireysel ödev verilir. Ödev bir sorunu çözmeye yönelik verilen hikaye tamamlama değerlendirmesidir. Öğrencilere ders sonunda dağıtılır ve bir sonraki derste toplanacağı belirtilir.

**APPENDIX- F**

**“YAŞAM ALANI MÜHENDİS TAKIMI AKTİVİTE KAĞIDI”**

# PROBLEM NEDİR?

2253 yılında yaşayan bir mühendis olduğunuzu düşünün. Canlılara ev sahipliği yapan ve yaşamımızı sürdürdüğümüz Dünya, biz canlılar için artık yaşanabilecek bir çevreye sahip değil çünkü Dünya'nın yörüngesi son yıllarda Güneş'e yakınlaşmaya başladı. Bu durum sonucunda sıcaklık gittikçe arttı ve kuraklığı da beraberinde getirdi. Su kaynakları gittikçe tükenmeye başladı. Bu nedenle verimli bitkiler yetişemiyor, insanlar ve diğer canlılar yaşamlarını sağlıklı sürdürememekte. Bir takım bilim insanları bu duruma çözümler üretmeye çalışırken, diğer bilim insanları Uzayda Dünyadan başka bir yerde yaşayıp yaşayamayacağımız üzerinde çalışmalar yapıyor. Bilim insanları uzayda başka yerlerde yaşam arıyor çünkü Dünya'nın yörüngesi Güneş'e yaklaşmaya devam edebilecek gibi görünüyor. Uzayda yaşam kurulup kurulmayacağı konusunda çalışmalar yürüten bilim insanları siz mühendisleri de takımlarında çalışmaya davet ediyorlar. Çalışmalara önceliklere doğru bir yer seçip (gezegen- yıldız, uydu vb.) oranın özelliklerinin canlı yaşamını sürdürmeye uygun olup olmadığıyla başlanacak. Ardından seçilen bölgede yaşam kurmak için bir site inşa edilecek. Bu sitenin öncelikli olarak yüz insan ile birlikte bir yıllık deneme süresi gerçekleştirilecek. Eğer çalışmalar olumlu sonuçlar verirse insan kapasitesi yıllar içinde artırılacak. Sizi mühendis olarak takımlarına davet eden bilim insanları, Dünya dışında kurulacak bu yeni düzen için sizlerden fikir alıp, kurulacak yeni yaşam alanı hakkında bir örnek model oluşturmalarına yardımcı olmanızı istiyorlar.

Yörünge değişimin sonuçları neler olmuştur?

Yörünge değişimden dolayı neden Dünya'da yaşam zorlaşmıştır?

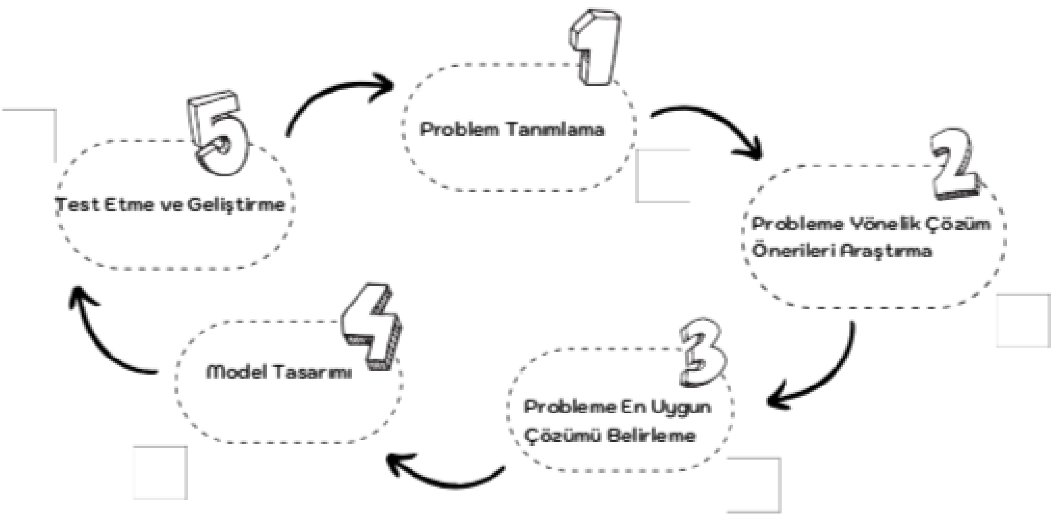
1. Sayfa

# MÜHENDİSLİK TASARIM SÜRECİ

Bir önceki sayfada verilen senaryoya göre sizden beklenen görevi tamamlanız bekleniyor. Bu süreçte bir mühendis olarak çalışacağınız için "Mühendislik Tasarım Süreci" basamaklarını takip etmeniz gerekmektedir.

Aşağıda verilen basamaklar mühendislik tasarım basamaklarını göstermektedir. Her aşamayı tamamladıktan sonra, yanında verilen kutucuklara "x" ile işaretleme yapmanız gerekiyor.

# MÜHENDİSLİK TASARIM BASAMAKLARI




2. Sayfa

# PROBLEM NEDİR?

1. Verilen senaryodaki problemi kendi cümlelerinizle tanımlayınız.

2. Dünya'nın yörüngesinin değişmesinin sonuçları neler olmuştur?

3. Yörünge değişimden dolayı neden Dünya'da yaşam zorlaşmıştır?

3. Sayfa

# ÇÖZÜMLER NELER OLABİLİR?

Grupça bulduğunuz olası çözüm önerilerini aşağıdaki boşluğa yazınız. En az üç çözüm bulmanız bekleniyor. Yeni yaşam alanının neresi olacağını, nasıl bir yaşam alanı kurulacağını mutlaka belirtiniz.

1. **Çözüm Önerisi:**

2. **Çözüm Önerisi:**

3. **Çözüm Önerisi:**

1. **Bulduğunuz çözüm önerilerinden bir tanesini seçip kutucuğa yazınız. Verilen boşluğa neden bu öneriyi seçtiğinizi nedenleri ile birlikte yazınız.**

**4. Sayfa**

2. Tasarıma geçmeden önce bulduğunuz çözüm önerisini değerlendirmeniz bekleniyor. Çözüm öneriniz aşağıda verilen ifadelerden en az üç tanesini içermelidir. Problem çözümünüzde olan ifadelerin yanına "X" işareti koyunuz.

- [ ] Yaşam kurulacak bölge (gezegen, yıldız vb.)
- [ ] Yaşam alanındaki cansız varlıklar (toprak, kum vb.)
- [ ] Yaşam alanının alabileceği insan kapasitesi
- [ ] İnsanlar için oksijen kaynağının ne olduğu
- [ ] Yaşam alanında bulunacak insan dışındaki canlı çeşitleri
- [ ] Yaşam alanının fiziksel özellikleri

3. Eğer seçtiğiniz çözüm yöntemi bir önceki öncüldeki ( 2. ) şartlardan en az üç tanesini sağlamıyorsa, çözümünüzü gözden geçirip yeniden aşağıda verilen boşluğa yazınız. ( Şartları sağlıyorsa bu bölümü boş bırakabilirsiniz.)

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## ÖNEMLİ!

- Seçtiğiniz çözüm yöntemine göre bir sonraki basamaklarda tasarım yapmanız ve o tasarımı modele dönüştürmeniz bekleniyor. Ancak mühendis takımı olarak bazı şartları sağlamanız gerekiyor.
- Modelinizin aşağıdaki şartları sağlaması gerekmektedir. Modeliniz değerlendirilirken bu şartları sağlayıp sağlamaması göz önünde bulundurulacaktır:

1) Modelin kendi başına ayakta durabilmesi gereklidir.

2) Modelin parçalarının düşmemesi, devrilmemesi eğilmemesi gereklidir.

3) En az 3 malzeme kullanılmalıdır.

4) Modeliniz 20 cm x 20 cm boyutlarının altında olmamalıdır.

# MODEL PLANLAMA

Yaşam alanının modellemesi yapmaya başlamanız gerekiyor. Bunun için önce tasarımı planlamanız lazım. Bu aşamada size kullanabileceğiniz malzemelerin listesi aşağıda sıralanmıştır. Mühendislik mesleğinde "ekonomik" olmanın önemini göz önünde bulundurarak, modelleme yapmanız bekleniyor. Bu aşamada bazı kurallar var:

**1) Seçtiğiniz her malzemeyi kullanmanız gerekiyor, bu nedenle seçtiğiniz her malzemenin bir kullanım amacı olması gerekiyor.**

**2) Her malzemeden en fazla bir adet kullanabilirsiniz.**

**3) Temel malzemeler dışında en fazla dört malzeme kullanabilirsiniz.**

**4) Malzeme listesini oluşturup teslim aldıktan sonra sadece bir değişim hakkınız vardır.**

MALZEME LİSTESİ:

**Temel Malzemeler:**

Bant
Sıvı Yapıştırıcı
Küçük Makas
1 Adet Mukavva
2 Adet Fon kartonu
Silikon*
Maket Bıçağı*
Köpük Strafor

**Diğer Malzemeler:**

Elişi Kağıdı ( 2'li set)
Fon kartonu (2'li set)
Poşet (2 tane)
Asetat Kağıdı (2 tane)
Top pamuk ( 5 adet)
Kağıt Peçete ( 3 tane)
İp ( 1 metre)
Şeffaf Dosya ( 2 tane)
A4 kağıt ( 3 tane)
-Kendi malzemem

- **Not:** Yanında ( * ) işareti bulunan malzemeler sadece öğretmen tarafından/yardımıyla kullanılabilir. Bireysel olarak kullanılamaz.

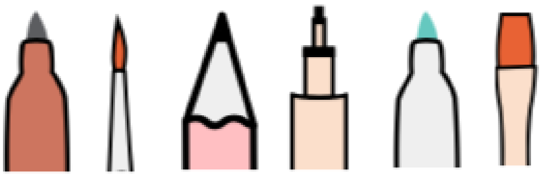
**Seçtiğiniz Malzemeler :**

| **Temel Malzemeler:** | **Diğer Malzemeler:** |
|---|---|
| | 1) |
| | 2) |
| | 3) |
| | 4) |

6. Sayfa

# TASARIMI PLANLAMA

Aşağıda verilen noktalı alana seçtiğiniz bölgede kuracağınız yaşam alanını çizmeniz bekleniyor. Dünya'dan yola çıkacak 100 insanın yaşayabileceği, senaryoda verilen probleme uygun bulduğunuz çözümü çiziniz. Tasarımınızı bir sonraki aşamada modelleyeceğinizi göz önünde bulundurarak bir taslak çizim oluşturmanız gerekmektedir.



- **Not 1:** Çizimlerinizi kurşun kalemle yapmanız, değiştirmek istediğiniz yerleri silmenizi kolaylaştıracaktır.
- **Not 2:** Çiziminiz modelin sağlaması gereken şartlar kısmına uygun olmalıdır. Modelin sağlaması gereken şartları 4. sayfada bulabilirsiniz.

**7. Sayfa**

# MODEL TASARİM- TEST ETME

Şimdi mühendis takımı olarak tasarımınızı model haline getirmeniz gerekiyor. Modelinizi oluşturmak için takım halinde iş birliği yapmanız gerekmektedir çünkü süreniz kısıtlı. Model süreci 40 dakikadır. Ardından modelinizi test etmeniz gerekiyor.

**Test etme: Aşağıda belirtilen kriterlere göre modelinizi test etmeniz gerekiyor, bu aşamayı öğretmeninizle birlikte kaydetmeniz gerekiyor.**

| Puan | Kriter | Bizim puanımız |
|---|---|---|
| Evet : 5 puan<br>Hayır: 0 puan | En az 45 saniye ayakta durabiliyor. | |
| Evet : 5 puan<br>Hayır: 0 puan | Parçalar düşmüyor, eğilmiyor. | |
| Evet : 5 puan<br>Hayır: 0 puan | En az 3 malzeme kullanılmış | |
| Evet : 0puan<br>Hayır: 5 puan | Temel malzemelerden 4'ten fazla kullanılmış. | |
| Evet : 5 puan<br>Hayır: 0 puan | 20 cm x 20 cm boyutlarından küçük değil. | |

TOPLAM PUAN:

- ŞİMDİ SUNUM ZAMANI!

**Bütün gruplar modellerini diğer grupların önünde sunacaklar. Her takımın modellerini anlatarak sunmaları için 4 dakika süreleri var!**

8. Sayfa

# DEĞERLENDİRME

**Aşağıdaki soruları mühendis arkadaşlarınızla birlikte cevaplayınız.**

1) Yaşam yerini seçerken nelere dikkat ettiniz? Uzay ve evren ünitesinde öğrendiğiniz gezegen, asteroit, yıldız, uydu gibi kavramlardan nasıl yararlandınız?

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2) Proje sürecinde "YÖRÜNGE" kavramı hakkında araştırma yaptınız mı? Yaptığınız araştırmalar size nasıl katkıda bulundu? Yörünge hakkında neler öğrendiğinizi yazınız.

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3) Modellemesini bitirdiğiniz çalışmada, daha iyi bir sonuç elde etmek için veya geliştirmek için hangi konular hakkında (gezegen, yıldız, yörünge, evren vb. ) değişiklikler yapmalısınız? Nedenleri ile yazınız.

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4) Seçtiğiniz yaşam yerinin yörüngesi değişirse, yaptığınız model hala işe yarıyor olur mu? Yoksa yeni çözümler mi bulmak gerekir? Nedenini açıklayınız.

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# ÖZ-DEĞERLENDİRME

<u>Aşağıdaki soruları mühendis arkadaşlarınızla birlikte cevaplayınız.</u>

1) Tasarlamış olduğunuz model ile verilen probleme sizce uygun çözümü bulabildiniz mi? Açıklayınız.

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2) Süreç boyunca "Mühendislik Tasarım Basamakları"nı kullandınız mı? Size nasıl yardımı oldu? Mühendislik Tasarım Basamaları olmasaydı modeliniz probleme uygun bir çözüm olabilir miydi? Açıklayınız.

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3) Diğer mühendis takımları ile bire bir benzer modeller mi yaptınız ya da yaptığınız modeller birbirinden farklı mı oldu? Sizce mühendislik tasarımlarında tek tip modeller mi olmalı yoksa çözümler birbirinden farklı olabilir mi?

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4) Problem çözümünde geliştirmeniz gereken parçalar veya değiştirmeniz gereken malzemeler var mı? Nedenleri ile birlikte açıklayınız.

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# ÖDEV

Mühendis Ayşe hanım, eşi Mühendis Mehmet bey ve kedileri Boncuk aynı evde yaşamaktadırlar. Ayşe hanım ve Mehmet bey hafta içi her gün çalışmaktalar. Bazı haftasonları iş seyahatleri için başka şehirlere gidiyorlar. Bu süreçte kedileri Boncuk ise evde yalnız kalmaktadır. Eve geldikleri sırada bazı günler Boncuk'un suyunun-yeminin bittiğini görünce bunun özellikle de haftasonları onlar evde yokken bir problem haline gelebileceğini düşünüyorlar. İki mühendis olarak bu problemi gözlemlemeye başlıyorlar ve kedilerini aç-susuz bırakmamak için ne gibi bir model üretebilecekleri üzerine fikir geliştirmeye çalışıyorlar. .......

- Verilen parçanın devamını "Mühendislik Tasarım Basamakları"nı ve "Bir Mühendis Ne Özelliklere Sahip Olmalı?" konularını düşünerek tamamlayınız. (Unutmayın, hikayenin sonunda kedileri Boncuk'un problemi üzerine bir tasarım fikri oluşturmuş olmalısınız!)

## APPENDIX- G

## "UZAY ARACI TASARIMI" DERS PLANI

| | |
|---|---|
| **Ders** | Fen Bilimleri |
| **Sınıf Düzeyi** | 6. Sınıf |
| **Ünite/ Konu** | F.6.1. Güneş Sistemi ve Tutulmalar / F.6.1.1. Güneş Sistemi |
| **Süre:** | 8 ders saati |

**Kazanımlar:**

F.6.1.1.1. Güneş sistemindeki gezegenleri birbirleri ile karşılaştırır.

F.6.1.1.2. Güneş sistemindeki gezegenleri, Güneş'e yakınlıklarına göre sıralar.

F.6.1.1.3 Güneş sistemindeki gezegenleri özelliklerine göre karasal gezegenler ve gazsal gezegenler olarak sınıflandırır.

F.6.1.1.4 Mühendislik tasarım basamaklarını takip ederek, güneş sistemi ile ilgili bir probleme yönelik model hazırlar.

**Ön Bilgiler:**

**5)** Dünya'nın Fiziksel Özellikleri (*F.3.1.1. Dünya'nın Şekli ve Yapısı*)
**6)** Dünya'nın Yörüngesi (*F.4.1.2. Dünya'mızın Hareketleri)*
**7)** Güneş Sisteminin Yıldızı'nın Özellikleri (*F.5.1.1. Güneş'in Yapısı ve Özellikleri*)
**8)** Dünya'nın Doğal uydusu olan Ay'ın Özellikleri (*F.5.1.2. Ay'ın Yapısı ve Özellikleri*)

**Materyaller:**

- *"Uzay Görevi Mühendis Takımı Defteri" Aktivite Kağıdı:* Dağıtılan Aktivite Kağıdının temel amacı öğrencilerin süreci kolay takip etmeleri sağlamak ve tasarımlarını, sorulara verdikleri cevapları yazılı bir şekilde tutmalarını sağlamaktır. Problem senaryosu, mühendislik tasarım basamakları, çizim için noktalı bölüm aktivite kağıdının içinde yer almaktadır. Aynı zamanda problem senaryosu, mühendislik tasarım basamakları, öz değerlendirme ile alakalı soruları da kapsar.
- *Bilimsel Dergiler:* Öğrencilerin "Olası çözümleri araştırma" ve "En iyi çözümü bulma" basamaklarında araştırma yapabilmeleri amacıyla astronomi ile alakalı öğrencilerin seviyelerine ve okul ortamına uygun bilimsel dergiler materyal olarak sunulur.
- *Ürün Tasarımında Kullanılacak Malzemeler:* Mühendislik tasarım basamaklarının son adımı olan "Model Üretme ve Test Etme" basamağında öğrencilerden fiziksel bir ürün oluşturmaları beklenir. Bu ürünü tasarlamak için bir malzeme listesi belirlenmiştir.

**Teknolojik Materyaller:**

- *Akıllı Tahta:* "Uzay Görevi Mühendis Takımı Defteri" Aktivite Kağıdı'nı ekrana yansıtabilmek amacıyla akıllı tahta kullanılır. Öğrenciler etkinlik sırasında hangi basamakta olduklarını akıllı tahta sayesinde takip edebilirler.
- *Bilgisayar:* Öğrencilerin "Olası çözümleri araştırma" ve "En iyi çözümü bulma" basamaklarında araştırma yapabilmeleri amacıyla internete bağlı bir bilgisayar kullanılır. Bilgisayar kullanımı amaç dışına çıkılmaması için gözetim altında olmalıdır.
- Simülasyon: "Solar System Scope" adlı simülasyon, gezegenlerin Güneş'e olan uzaklıklarını keşfetmeleri için giriş kısmında kullanılır.

**Öğretim Yöntem ve Teknikleri:** Mühendislik Tasarım Temelli Fen Eğitimi

## ÖĞRETİM SÜRECİ

### Giriş:

Öğretmen derse girer ve öğrencileri selamlar. Ardından soru-cevap yöntemini kullanarak "Güneş Sistemi" hakkında öğrencilerin ön bilgilerini hatırlamalarını sağlar. Bunun için hangi gezegende yaşadığımız sorusu ile başlayıp, diğer gezegenlere geçiş yapar. Gezegenlerin hangi sistemin içinde yer aldığını sorarak, "Güneş Sistemi" yanıtına ulaşmayı hedefler. Ön bilgiler hatırlandıktan sonra öğretmen Güneş sistemi hakkında bilgiler verir. Öğretmen "Solar System Scope" adlı simülasyonu kullanarak gezegenlerin birbirlerine göre konumlarını, Güneş sisteminin yapısını (Güneş'in ortada, gezegenlerin çevresinde belirli bir yörüngede olduğu), gezegenlerin Güneş'e yakınlıklarına göre sıralamalarını öğrencilerin incelemesine fırsat verir *(F.6.1.1.1.).* Simülasyon öğrencilerin Güneş Sistemini, üç boyutlu şekilde düşünebilmelerine ve aynı zamanda gezegenlerin birbirlerine göre konumlarını görselleştirebilmesine yardımcı olmayı hedefler *( F.6.1.1.2.).* Simülasyon tek başına kazanımları kavratmak için yeterli değildir, bu nedenle öğretmen sorduğu sorulardan yola çıkarak kısa bilgiler verir. "Karasal gezegenler hangileridir, özellikleri nelerdir?", "Gazsal gezegenlere örnek hangi gezegenleri verebiliriz?", sorularak, alınan cevapların ardından, öğretmen cevapları açıklar *(F.6.1.1.3).* Eğer gerekli görülürse 6. Sınıf Fen Bilimleri MEB kitabı bu aşamada kullanılır. Öğretmen kısaca gezegenlerin özelliklerini açıklar;

> **Karasal Gezegenler:** Güneş Sisteminin ilk dört gezegenine verilen isimdir. Yapıları taş ve kayalardan oluşur.
>
> **Gazsal Gezegenler:** Güneş Sisteminin son dört gezegenine verilen isimdir. Yapıları gazlardan oluşur.
>
> **Merkür**: Güneş'e en yakın ve en küçük gezegendir. Uydusu ve halkası yoktur. En sıcak ikinci gezegendir.

**Venüs:** Güneş'e en yakın ikinci gezegendir. Yüzey sıcaklığı en fazla olan gezegendir. Boyut olarak Dünya'ya çok benzer. Uydusu ve halkası yoktur.

**Dünya:** Güneş'e en yakın üçüncü gezegendir. Güneş sisteminde üzerinde yaşam olduğu bilinen tek gezegendir. Ay adı verilen 1 adet doğal uydusu vardır ancak halkası yoktur.

**Mars:** Kızıl gezegen olarak bilinir, Güneş'e en yakın dördüncü gezegendir. Yüksek dağlar ve kayaları vardır. İki adet doğal uydusu vardır ve halkası yoktur.

**Jüpiter:** Güneş'e en yakın beşinci gezegendir ve gazlardan oluşur. Aynı zamanda Güneş Sisteminin en büyük gezegenidir. 79 adet doğal uydusu ve halkası vardır.

**Satürn:** Güneş'e en yakın altıncı gezegendir ve gazlardan oluşur. Belirgin bir halkası vardır. 82 adet doğal uydusu bulunur.

**Uranüs:** Güneş'e en yakın yedinci gezegendir. Güneş Sisteminin en soğuk gezegenidir. Belirgin olmasa da halkası bulunur. 27 adet doğal uydusu vardır. Dönme yönü diğer gezegenlerin aksine, yuvarlanan bir varil gibidir.

**Neptün:** Güneş'e en yakın sekizinci gezegendir. Güneş sisteminin en sondaki gezegenidir. 14 adet doğal uydusu ve halkası bulunur.

Öğrencileri problem senaryosuna hazırlamak için öğretmen karasal bir gezegenin nasıl fiziki özelliklere sahip olduğunu sorar. Alınan cevapların ardından öğretmen karasal gezegenlerin çoğunlukla katı yapılardan yani; taşlardan, kayalardan ve dağlardan oluştuğunu anlatır. Taşların ve kayaların küçük olabileceği gibi, büyük ve sert de olabileceğini söyler. Ardından aynı soruyu gazsal gezegenler için de tekrarlar ve gazsal bir gezegenin nasıl fiziki özelliklere sahip olduğunu sorar. Öğrencilerin verdiği cevaplardan sonra öğretmen gazsal gezegenlerin yapısının çoğunlukla hidrojen, helyum gibi gaz maddelerden oluştuğunu anlatır. Gezegenlerdeki gazlardan dolayı sert rüzgarların ve fırtınaların ortaya çıkabildiğini söyler. Bütün gazsal gezegenlerin halkalarının olduğunu ancak çıplak gözle görülen en net ve belirgin halkaya sahip olan gezegenin Satürn olduğundan bahseder. Halkaların ise taş, kaya, buz ve toz gibi maddelerin bir araya gelerek oluştuğundan kısaca bahseder. Öğretmen soru- cevap yöntemini kullanarak öğrencilerin anlama düzeylerini değerlendirir. Eğer gerek varsa kavramları tekrar anlatmalıdır. Soru-cevap yöntemi ile değerlendirme yapıldıktan sonra "Giriş" bölümü sonlandırılır.

**Geliştirme:**

Giriş bölümünün ardından, "Mühendislik Tasarım Temelli" ders işlenmeye başlanır. Bu süreçte öğretmen, "Mühendislik Tasarım Basamakları"nı kullanarak bir proje yapmaları gerektiği konusunda öğrencileri bilgilendirir *(F.6.1.1.4 ).* Bu süreç küçük gruplar halinde yapılacağı için öğretmen sınıfı 3-4 kişilik gruplara ayırır (Gruplandırma planlanan dersten önce de yapılabilir). "Uzay Görevi Mühendis Takımı Defteri" aktivite kağıdı her gruba bir tane olacak şekilde dağıtılır. Dersin işlenişi ana hatları ile aşağıda verilen "Mühendislik Tasarım Basamakları"nı takip eder:

**6)** Problem tespiti,
**7)** Probleme yönelik olası çözümleri araştırma,
**8)** En iyi çözümü bulma, ve
**9)** Modeli tasarlama ve test etme
**10)** Herhangi bir adıma geri dönme (eğer gerekirse)

Öğretmen aktivite kağıdını dağıtır ve senaryoyu okur;

*"Uzay araştırmaları yapan bilim insanları hız kesmeden çalışmalarına devam ediyor. Şimdi sıra Güneş Sistemi gezegenlerini keşfetmekte. Bilim insanları Güneş sisteminde bulunan iç gezegenlerden toprak örneği alıp içinde hangi mineraller, elementler olduğunu incelemek ve Dünyamızda bulunan toprak örnekleri ile*

*kıyaslamak istiyor. Toprak örneklerine ek olarak, Güneş Sisteminde bulunan dış gezegenlerden de atmosferinde bulunan gazlardan örnek alıp incelemek ve içeriğinin neler olduğunu keşfetmek istiyorlar. Böylece Dünya atmosferinde bulunan gazlar ile Güneş Sisteminde bulunan başka bir gezegeni oluşturan veya atmosferinde bulunan gazların çeşitlerini kıyaslama şansı bulacaklar. Peki bunun için mühendislerden nasıl yardım istiyorlar? Bilim insanları mühendislerden, bir uzay aracı tasarlamalarını ve bu uzay aracının önce bir iç gezegene giderek toprak örneği almasını ardından da bir dış gezegene giderek gaz örneği almasını ve son olarak Dünya'ya iniş yapmasını bekliyorlar.*

*Bunun için bir mühendis takımı ile çalışmaya başladılar. Bu mühendis takımı "Mühendislik Tasarım Basamakları"nı takip ederek bilim insanlarının problemine çözüm bulup, tasarım yapıp sonrasında da tasarımlarını ürettiler. Denemelerin ardından geçen sene uzay aracını fırlattılar. Ancak uzay aracı bir iç gezegen olan Mars'a iniş yaptıktan sonra toprak örneği alamadı. Çünkü aracın toprak delici aletleri Mars'ın yüzeyini delip örnek alacak kadar güçlü değildi ve kırıldı. Uzay aracı ilk görevini tamamlayamadı ve ikinci görev için bir dış gezegen olan Jüpiter'e doğru yola çıktı. Ancak yine bir sorun vardı. Uzay aracı daha Jüpiter'e varamadan yakıt miktarı azaldığına dair uyarı verdi ve sonucunda Dünya'ya acil iniş yaptı. Yani ilk görev başarısız oldu. Şimdi bilim insanları sizin mühendis takımınızı bu çalışmaya davet ediyorlar. Elinizde eski takımın çalışma raporları ve tasarımları bulunuyor. Çalışmaya "Mühendislik Tasarım Basamakları"ndan doğru bulduğunuz noktadan başlayabilirsiniz.*

*Haydi başlayalım!"*

Senaryo okunduktan sonra, gruplar aktivite kağıdında verilen senaryoyu anlamaya yönelik soruları cevaplayıp ardından, "Mühendis Takımı Raporları"nı inceler ve bir önceki mühendis takımının nerede hataları/eksikleri olduğunu tespit etmeye çalışırlar. Raporlar incelenmeye başlamadan önce öğretmen, önceki mühendis takımının "Mühendislik Tasarım Basamakları"nı takip ederek çalıştıklarını ve bu basamaklardaki çalışmaların raporlandığını vurgular. Aktivite kağıdında verilen mühendislik tasarım basamaklarını öğretmen tekrar eder. Raporlar okunduktan sonra, gruplar önceki mühendis takımının neden başarısız olduğuna dair soruları cevaplandırıp, "Haygi Göreve" etkinliğini yapar. Öğretmen bu esnada aktivite kağıdının hangi sayfası yapılıyorsa kolaylık sağlamak amacıyla o sayfayı akıllı tahtadan yansıtır. Gruplar etkinlik sırasında hangi mühendislik tasarım basamağından başlayacaklarını tartışır ve belirlerler. Öğretmen basamak seçimi sırasında grupları yönlendirmez ve bir fikir belirtmez. Gruplar tartışarak belirledikleri basamaktan ilerlerler. Öğretmenin her grubun hangi basamaktan başladığını not alması, ilerleyen süreçte çıkabilecek karmaşaları önler. Öğretmen bu aşamada öğrencilere artık birer mühendis olduklarını ve bundan sonra birer mühendis gibi düşünüp çözümler üreteceklerini vurgular. Mühendislik Tasarım Basamaklarına göre öğrenciler;

1. Problem tespiti: Bu aşamadan başlayacak gruplar, önceki mühendis takımının problem tespitini hatalı bulmuş ve kendileri yeniden problem tespiti yaparak, senaryoda verilen problemi belirlemeye çalışırlar.
2. Probleme yönelik olası çözümleri araştırma: Bu aşamadan başlayacak gruplar, önceki mühendis takımının ürettikleri olası çözümleri eksik/hatalı bulmuştur bu nedenle kendileri birer mühendis gibi düşünüp probleme ona göre çözümler üretmeye başlar. Bu sırada öğrenciler dergilerden ve bilgisayardan yararlanarak araştırma yapabilir.
3. En iyi çözümü bulma: Bu aşamadan başlayacak gruplar, önceki mühendis takımının olası çözümlerinin bazılarını doğru bulmuş ancak o çözümler arasından seçtikleri en iyi çözümü yanlış bulmuşlardır. Bu nedenle önceki mühendis takımının sunduğu çözüm önerileri tartışarak, başka birini daha uygun bulmuşlardır. Bu sırada öğrenciler dergilerden ve bilgisayardan yararlanarak araştırma yapabilir.

4. Modeli tasarlama ve test etme: Bu aşamadan başlayacak gruplar, önceki mühendis takımının modellerini tasarlarken hatalı/eksik çalıştığını düşünerek; önceki mühendis takımının seçtiği en iyi çözüm üzerinden modeli yeniden tasarlarlar veya revize ederler.

Öğrencilerden "Bir iç gezegene giderek toprak örneği alacak ardından bir dış gezegene giderek gaz örneği alarak Dünya'ya sağlam iniş yapabilecek bir uzay aracı" tasarlamaları bekleniyor. Başlanması gereken doğru bir adım olmadığı, öğrencilerin tartışarak nedenleri ile belirledikleri herhangi bir adımdan başlayabileceklerini öğretmen unutmamalıdır. Öğretmen öğrencilere mühendislik tasarım basaklarının her zaman için kesin başlanması gereken bir ilk basamağının olmadığını, kendilerinin yaptığı gibi belirlenen bir adımdan başlanarak sürecin devam ettirilebileceğini vurgular.

Gruplardan belirledikleri veya önceki mühendis takımının belirlediği en iyi çözüme göre tasarım yapmaları beklenir ve bu tasarımları yapmaları için kullanacakları malzemeleri aktivite kağıdından incelerler. Dersin sonunda bütün grupların probleme göre ürettikleri bir modeli oluşur. Öğrencilerin modelleri aşağıda verilen şartları sağlamalıdır:

5) Modelin kendi başına ayakta durabilmesi gereklidir.
6) Modelin parçalarının düşmemesi, devrilmemesi eğilmemesi gereklidir.
7) En az 3 malzeme kullanılmalıdır.
8) Modelinizin kendine ait bir adı olmalıdır.

Malzeme listesinden "temel malzemeler" bütün gruplara dağıtılır ve gruplardan "diğer malzemeler" grubundan 4 adet malzeme seçmeleri beklenir.

- Öğrencilerden toprak örneği alınabilecek bir iç gezegen ve gaz örneği alınabilecek bir dış gezegen belirlemeleri beklenir. Tasarlayacakları uzay aracının toprak ve gaz örneği için ekipman ve/ya kısımlara sahip olması gerekir. Aynı zamanda Dünya'ya örnekleri geri getirebilecek kadar sürede yakıt kapasitesi olmalıdır.

Öğrenciler modellemeye başlamadan önce aktivite kağıdında verilen noktalı alana yapacakları modelin taslağını çizerler ve kullanacakları malzemeleri eşleştirirler. Bütün gruplar taslak çizmeyi bitirince, öğretmen modelleme yapmaları için gruplara belirlenen malzemeleri dağıtır. Modelleme için yaklaşık 50-60 dakika bir süre verilebilir. Bu sürede öğretmen maket bıçağı, sıcak silikon gibi aletleri öğrencilere kullandırmamalı, kendi yardım etmelidir. Ancak modellemenin diğer aşamalarında öğretmen yalnızca rehberlik eder, tasarım konusunda öğrencilere yardımda bulunmaz.

Süre bitince bütün modeller öğretmen masasında toplanır. Numaralandırılmış grupların ilkinden başlanarak modeller öğretmen tarafından test edilir. Gruptan bir kişi tahtaya gelerek modellerini en fazla 4 dakika içinde diğer gruplara sunar, bu esnada hangi mühendislerin görev aldığını da belirtir. Sunumun ardından öğretmen o grubun modelini belirlenen kriterler doğrultusunda test eder ve sonuçlarını aktivite kağıdının belirlenen bölümüne (Görsel 1) not alırlar.

| Puan | Kriter | Bizim puanımız |
|---|---|---|
| Evet : 5 puan<br>Hayır: 0 puan | Verilen süre içinde proje tamamlandı. | |
| Evet : 5 puan<br>Hayır: 0 puan | Model kendi başına ayakta durabiliyor ve devrilmiyor. | |
| Evet : 5 puan<br>Hayır: 0 puan | Hava tüpleri tamamlandı ve düşmüyor. | |
| Evet : 5 puan<br>Hayır: 0 puan | Delici alet tamamlandı ve düşmüyor. | |
| Evet : 5 puan<br>Hayır: 0 puan | Malzeme sınırları aşılmamış. | |

Görsel 2

Belirlenen kriterler doğrultusunda modelin verilen süre içinde tamamlanmış olması gerekiyor, eksik-bitirilmemiş projeler "0" puan üzerinden değerlendirilir. İkinci olarak model masaya veya sıraya konulduğu zaman kendi başına ayakta durabilmeli ve devrilmemelidir. Bunun nedenini göreve gidecek bir uzay aracının gezegene iniş yaptıktan sonra ayakta duramayıp devrilmesi sonucunda görevin başarısız olacağı olarak söylenir. Kendi başına duramayan modeller "0" puan üzerinden değerlendirilir. Dış gezegenden gaz örneği alacak hava tüplerinin modele bağlı ve düşmüyor olması gerekir. Parçası düşen modeller "0" puan üzerinden değerlendirilir. İç gezegenden toprak örneği alacak delici aletlerin modele bağlı ve düşmüyor olması gerekir. Parçası düşen modeller "0" puan üzerinden değerlendirilir. Bu iki değerlendirme kriterinde de neden olarak uzay aracının temel iki görevi olduğu (toprak ve gaz örneği almak), bu görevleri yerine getirebilmesi için iki parçanın da uzay aracından düşmeden yolculuk edebiliyor olması gerektiği verilir. Son kriter olarak, malzeme sınırlarının aşılmamış olması gerekiyor, aşılan projeler "0" üzerinden değerlendirilir. Bir mühendisin özelliği olarak ekonomik olması gerektiği, verilen bütçe içinde çalışması gerektiği öğrencilere vurgulanır. Bütün kriterleri sağlayan bir model “5+5+5+5+5 = 25 Puan” alır.

**Sonuç:**

Mühendislik Tasarım Temelli ders anlatımının ardından, “Sonuç” bölümüne geçilir. Bu bölümde öğrenciler “Değerlendirme ve Öz- Değerlendirme” yaparlar. Değerlendirme bölümleri “Uzay Görevi Mühendis Tasarım Defteri”nde bulunur ve grupça yanıtlanacak 4 sorudan oluşur.

Bu bölümde öğrencilerden mühendislik tasarım süreci boyunca hangi seçimleri neden yaptıklarını açıklamaları beklenir. Örneğin, devralınan projenin tamamlanabilmesi için seçtikleri mühendislik tasarım basamağına nasıl karar verdiklerini açıklamaları istenir. Aynı zamanda öğrencilerin bir mühendis olarak çalışmayı nasıl buldukları, “Mühendislik Tasarım Basamak”larına ne kadar uyum sağladıkları ve önemini ne kadar kavradıkları da öz-değerlendirme bölümünde ölçülmeyi hedefler. Öğretmen bu aşamada gruplar arasında dolaşarak öğrencilerin “evet- hayır” gibi kısa cevaplar vermelerini engeller ve yönergede (soruların yönergesinde) belirtildiği gibi cevaplarının nedenlerini açıklamalarını sağlar.

**APPENDIX- H**

**“UZAY ARACI TASARLAMA- UZAY GÖREVİ AKTİVİTE KAĞIDI”**

# Problem Nedir?

Uzay araştırmaları yapan bilim insanları hız kesmeden çalışmalarına devam ediyor. Şimdi sıra Güneş Sistemi gezegenlerini keşfetmekte. Bilim insanları Güneş sisteminde bulunan iç gezegenlerden toprak örneği alıp içinde hangi mineraller, elementler olduğunu incelemek ve Dünyamızda bulunan toprak örnekleri ile kıyaslamak istiyor. Toprak örneklerine ek olarak, Güneş Sisteminde bulunan dış gezegenlerden de atmosferinde bulunan gazlardan örnek alıp incelemek ve içeriğinin neler olduğunu keşfetmek istiyorlar. Böylece Dünya atmosferinde bulunan gazlar ile Güneş Sisteminde bulunan başka bir gezegeni oluşturan veya atmosferinde bulunan gazların çeşitlerini kıyaslama şansı bulacaklar. Peki bunun için mühendislerden nasıl yardım istiyorlar? Bilim insanları mühendislerden, bir uzay aracı tasarlamalarını ve bu uzay aracının önce bir iç gezegene giderek toprak örneği almasını ardından da bir dış gezegene giderek gaz örneği almasını ve son olarak Dünya'ya iniş yapmasını bekliyorlar.

Bunun için bir mühendis takımı ile çalışmaya başladılar. Bu mühendis takımı "Mühendislik Tasarım Basamakları"nı takip ederek bilim insanlarının problemine çözüm bulup, tasarım yapıp sonrasında da tasarımlarını ürettiler. Denemelerin ardından geçen sene uzay aracını fırlattılar. Ancak uzay aracı bir iç gezegen olan Mars'a iniş yaptıktan sonra toprak örneği alamadı. Çünkü aracın toprak delici aletleri Mars'ın yüzeyini delip örnek alacak kadar güçlü değildi ve kırıldı. Uzay aracı ilk görevini tamamlayamadı ve ikinci görev için bir dış gezegen olan Jüpiter'e doğru yola çıktı. Ancak yine bir sorun vardı. Uzay aracı daha Jüpiter'e varamadan yakıt miktarı azaldığına dair uyarı verdi ve sonucunda Dünya'ya acil iniş yaptı. Yani ilk görev başarısız oldu. Şimdi bilim insanları sizin mühendis takımınızı bu çalışmaya davet ediyorlar. Elinizde eski takımın çalışma raporları ve tasarımları bulunuyor. Çalışmaya "Mühendislik Tasarım Basamakları"ndan doğru bulduğunuz noktadan başlayabilirsiniz.

Haydi başlayalım!

# Problem Nedir?

1. Çalışmayı yürüten ilk takımda sizce hangi mühendisler görev almıştır? Neden?

2. İlk mühendis takımı neden gezegen olarak Mars ve Jüpiter'i seçmiş olabilir?

3. İlk mühendis takımının çözümündeki/modelindeki hatalar veya eksikler nelerdir?

1-

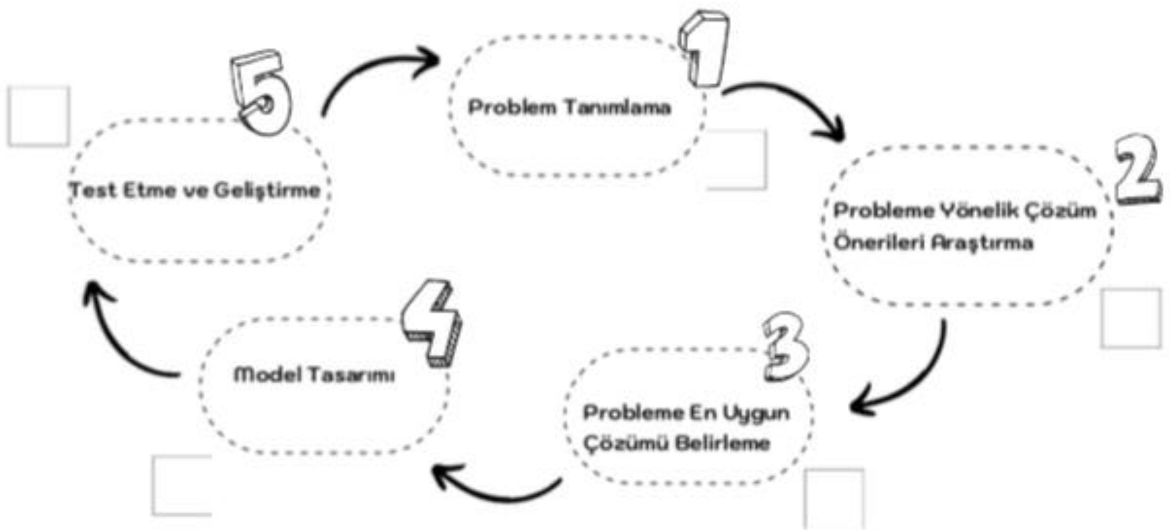
2-

3-

4. Sizce bu çalışmaya en baştan mı başlanıp yeniden mi tasarım yapılmalı? Yoksa aynı tasarım üzerinde geliştirilmeler mi yapılmalı? Neden?

# Mühendislik Tasarım Basamakları

- Bu süreçte bir mühendis olarak çalışacağınız için "Mühendislik Tasarım Süreci" basamaklarını takip etmeniz gerekmektedir.
- Aşağıda verilen basamaklar mühendislik tasarım basamaklarını göstermektedir. Her aşamayı tamamladıktan sonra, yanında verilen kutucuklara "x" ile işaretleme yapmanız gerekiyor.



# Mühendis Takımı Raporları

**Rapor - 1 -**

- Çalışma basamağı 1:

**PROBLEM TANIMLAMA ; Bugün ilk olarak problem tanımı yaptık. Bilim insanlarının bize verdiği bilgiler doğrultusunda problemi bütün takım olarak çözümledik.**

Problem : Güneş sisteminde bir iç gezegene gidip toprak örneği alacak aynı zamanda oradan bir dış gezegene giderek gaz örneği alacak bir uzay aracı tasarlamak. Uzay aracının hem toprak örneği alabilecek ekipmanı olmalı hem de gaz örneği alacak ekipmanı olmalı.

- Çalışma basamağı 2:

**PROBLEME YÖNELİK ÇÖZÜM ÖNERİLERİ ARAŞTIRMA: Bu hafta mühendis takımı olarak olası çözümler üzerine beyin fırtınası yaptık ve iki çözüm önerisi belirledik. Her önerimize öncelikle hangi iç - dış gezegenleri seçeceğimize karar vererek başladık. Ardından da uzay aracının hangi özelliklere sahip olması gerektiğini yazarak tamamladık.**

**Çözüm önerisi 1:** Uzay aracı öncelikle Güneş sistemindeki, 2. gezegen olan Venüs'e gidip oradan bir toprak örneği alacak. Ardından Satürn'e gidip atmosferinden örnek alacak. Bu iki gezegen birbiri ile uzak olabilir. Ancak , Dünya bu iki gezegen arasında yer aldığı için eğer uzay aracı Venüs'te bir sıkıntı yaşarsa, Dünya'ya iniş yapabilir. Böylece Dünya'da problemler çözülüp uzay aracı geri Satürn'e yollanabilir.

Uzay aracının tasarımında sıcaklıktan erimeyecek malzemeler kullanılmalı, aynı zamanda Satürn'ün rüzgarlarına dayanıklı sert malzemeler de olmalı. Toprak örneği almak için büyük matkaplar kullanılmalı. Gaz örneği için de büyük balonlar kullanılmalı.

**Çözüm önerisi 2:** Uzay aracı öncelikle Güneş sistemindeki, 4. gezegen olan Mars'a gidip oradan bir toprak örneği alacak. Ardından Jüpiter'e gidip atmosferinden örnek alacak. Bu iki gezegen birbiri ile art arda olduğu için uzay aracı yakıt açısından daha tasarruflu olacak. Aynı şekilde Jüpiter'de diğer dış gezegenlere kıyasla Dünya'ya daha yakın olduğu için yine yakıt ücreti daha ekonomik olacaktır.

Uzay aracının tasarımında soğuktan donmayacak malzemeler kullanılmalı, aynı zamanda Jüpiter gezegeninin sert rüzgarları olduğu için rüzgarlara dayanıklı sert malzemeler de olmalı. Toprak örneği almak için büyük matkaplar kullanılmalı. Gaz örneği için de büyük balonlar kullanılmalı.

# Mühendis Takımı Raporları

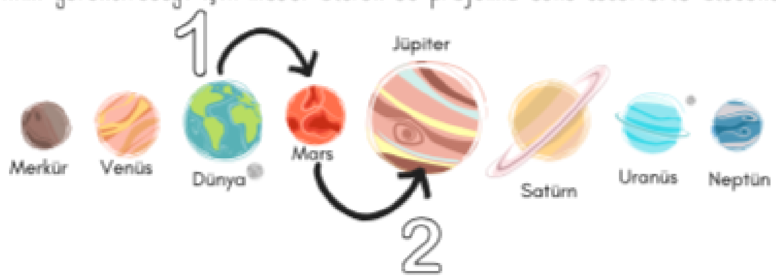
## Rapor - 1 - devamı

- Çalışma basamağı 3 :

<u>PROBLEME EN UYGUN ÇÖZÜMÜ BELİRLEME:</u> Bir önceki hafta belirlediğimiz 2 çözüm önerisinden en uygunu olan 2. çözüm önerisi üzerinde çalışmaya karar verdik. En az bir kaç ay çalışmalarımız sürecektir diye düşünüyoruz.

Seçtiğimiz öneri: Çözüm Önerisi 2

Çözüm önerisi 2 hem zaman açısından hem de maddi (parasal durum) açıdan daha tasarruflu olacaktır. Dünya, Mars ve Jüpiter'in art arda sıralı olması uzay aracının görev süresini uzun tutmayacaktır. Aynı zamanda mesafenin yakın olması daha az yakıt kullanımı gerektireceği için maddi olarak da projemiz daha tasarruflu olacaktır.




Yukarıdaki çizimde görüldüğü gibi uzay aracı Dünya'dan yola çıkıp Mars'a gidecek (1) oradaki görevini tamamladıktan sonra ise Jüpiter'e gidecektir (2). İki görevini de tamamladıktan sonra Dünya'ya dönüş yapacaktır.

**Uzay aracı özellikleri:**

1-Erimeyecek/donmayacak malzemeler: Hem Mars hem de Jüpiter, (-) ° C'ler civarında sıcaklığa sahip olduğu için uzay aracının malzemeleri soğuktan donmayacak özellikte olmalıdır. Delici aletler ise sürtünme sonucunda erimeyecek malzemelerden seçilecektir.

2-Toprak örneği: Toprak örneği almak için büyük bir matkap gibi delici alet tasarlanacaktır.

3- Gaz örneği: Hava balonları uzay aracının içine yerleştirilip, Jüpiter'e varıldığında kapaklar açılıp doldurulacaktır.Balonlar patlamaması, yırtılmaması için metal malzemelerden üretilmelidir.

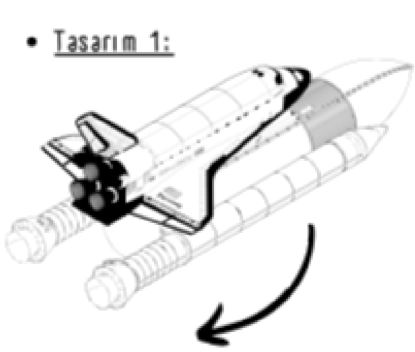
# Mühendis Takımı Raporları

## Rapor 2

- Çalışma basamağı 4 :

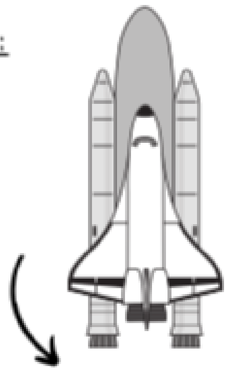
<u>MODEL TASARIMI:</u> İki ay süren çalışmalar sonucunda artık çözümümüz hazır ve yol haritamız belli oldu. Şimdi sıra tasarım yapıp bu tasarımı modelleme aşamasına geldi. Tasarımımız hem doğru malzemeleri içermeli, hem de uygun maliyetli de olmalı. Yapacağımız model aynı zamanda amacımıza da uygun bir tasarım olmalı.

- <u>Tasarım 1:</u>



YAN TARAF TASARIMI

- <u>Tasarım 2:</u>



ÖN TARAF TASARIMI

Yukarıda verilen taslak çizimler uzay aracının dış görüşünüşünü göstermektedir. Toprak örneği için delici alet, gaz örneği için hava balonu uzay aracının içinde yer alacaktır. Zamanı geldiğinde ise araçtan otomatik çıkıp görevlerini gerçekleştireceklerdir. Tasarımları aşağıda verilmiştir.

DELİCİ MATKAP TASARIMI

HAVA TÜPLERİ-BALONLARI

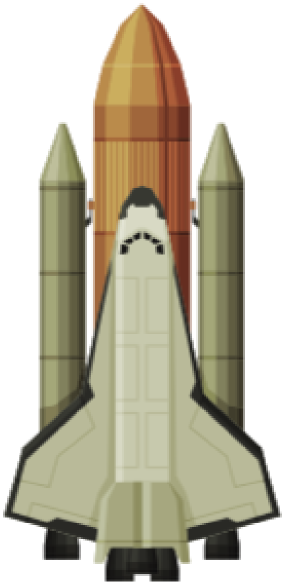
# Mühendis Takımı Raporları

**Rapor 3**

- Çalışma basamağı 5 :

<u>MODEL TASARIMI- devam:</u> Uzun bir tasarım sürecinden sonra artık modellemeye başlayacağız. Bu aşamada tasarladığımız modeli üç boyutlu (3D) hale getireceğiz. Uzun bir süreç yeniden bizi bekliyor. Ancak kağıt üstündeki çalışmamızın üç boyutlu gerçek bir modele dönüşümünü yapacağımız için de heyecanlıyız.

PB-UZY27 ADLI UZAY ARACI



Aylar süren çalışmalarımızın sonucunda modelimiz de tamamlandı. Takımımıza destek olarak başka alanlardan da mühendis arkadaşlarımız model yapma sürecinde bize destek oldular. Uzay aracımıza takım olarak <u>"PB-UZY27"</u> ismini verdik. PB-UZY27 uzay aracını şimdi testlere sokmaya başlayacağız.

# Mühendis Takımı Raporları

## Rapor 4

- Çalışma basamağı 6 : Uzay görevine başlamadan, uzay aracını Dünya'da bazı testlere sokacağız. Bu testlerden başarılı olursa gelecek aylarda, uzay aracımız serüvenine başlayacak.

### TEST 1: Delici alet sağlamlık testi

Uzay aracımızın matkaplarını boş bir arazide denemeye aldık. Bizim gittiğimiz arazideki toprakları delebildi. Bu nedenle yeniden başka bir araziye götürüp deneme yapmadık.

### TEST 2: Hava balonları sağlamlık testi

Uzay aracımızın hava balonlarını doldurmak için rüzgarlı bir günde deneme yaptık. Jüpiter'in rüzgarlı olduğunu biliyoruz. Bu nedenle özellikle rüzgarlı bir gün seçtik ki tüplerimiz yeterince sağlam mı bunu görelim. Balonlarımız da testi geçti, ve herhangi bir yırtılma veya delinme olmadı. Bu nedenle başka bir deneme yapmadık.

### TEST 3: Uzay aracı uçuş testi

Uzay aracımızın yerden doğru bir kalkış yapabildiğini onaylamak için, uçuş testi yaptık. Uzay aracımız doğru bir şekilde havalanıyor ve yere yumuşak iniş yapabiliyor.

**Yaptığımız 3 testin başarılı olduğunu gördük ve onayladık. Bu nedenle artık uzay aracımızı görevine başlamak üzere Güneş Sistemine yollayabileceğiz. Çalışmalarımız bir yılı aşkın süredir devam ediyordu, ancak bugün itibari ile bitirdiğimizi düşünüyoruz.**

# Problem Tespiti

## Görev neden başarısız olmuş olabilir?

İlk mühendis takımının PB-UZY27 adlı uzay aracı Mars'tan örnek alamamış, yakıt bittiği içinde Jüpiter'deki görevine başlayamamıştır. Aşağıda verilen soruları takım arkadaşlarınızla birlikte cevaplayınız.

**1- İlk mühendis takımının problem tespitinde sizce hata var mı? Neden?**

**2- İlk mühendis takımının probleme sundukları çözüm önerileri, problem için uygun mu? Sizce doğru öneriyi mi seçmişler? Açıklayın.**

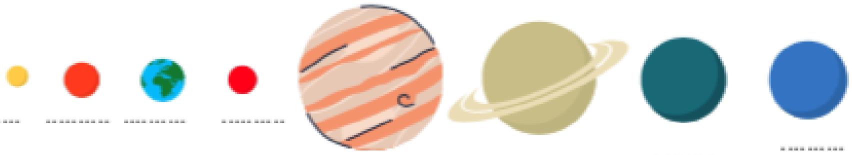
**3- İlk mühendis takımının tasarımı ve modelinde eksikler var mı? Delici alet ve hava balonları çözüme uygun tasarımlar mı? Açıklayın.**

**4- İlk mühendis takımı test aşamasında yeterince test yapmışlar mı? Eğer delici alet testi için daha farklı denemeler yapsalardı, sıkıntılar önceden giderilebilir miydi? Açıklayın.**

# Haydi Göreve!

Bir önceki mühendis takımının neden başarısız olduğunu göz önünde bulundurarak, aşağıdaki soruları takım arkadaşlarınızla cevaplayınız.

**1- Çalışmalarımıza başlamadan önce Güneş Sistemi gezegenlerini hatırlayalım. Hangilerinin iç gezegen, hangilerinin dış gezegen olduklarını ve gezegen isimlerini verilen boşluklara yazın.**



……… GEZEGENLER ……… GEZEGENLER

**2- Takım olarak "Mühendislik Tasarım Basamak"larından, hangisinden başlamaya karar verdiniz? Nedenini açıklayın.**

| |
|---|
| Başlamaya karar verdiğimiz basamak ……………………………………………………………… çünkü; |

**3- Takımınız hangi mühendislerden oluşuyor? Takımınızda çalışabileceğini düşündüğünüz mühendisleri yuvarlak içine alın.**

**Makine Mühendisi**

**İnşaat Mühendisi** **Jeoloji Mühendisi**

**Harita Mühendisi** **Elektrik ve Elektronik Mühendisi**

**Uzay ve Uçak Mühendisi** **Bilgisayar Mühendisi**

# Problem Tanımlama

Bir önceki mühendis takımının problem tanımlama aşamasından itibaren eksik bir yol izlediğini düşündünüz. Bu nedenle çalışmalarınıza "Mühendislik Tasarım Basamak"larının 1. adımı olan "Problem Tanımlama" aşamasından başlamak istediniz. Şimdi problemi yeniden tanımlama zamanı!

**1- İlk sayfada verilen (1. sayfa) problem senaryosunu yeniden okuyun. Ardından problemin ne olduğunu, bilim insanlarının sizden ne yardım istediğini kendi cümlelerinizle tanımlayın.**

# Problem Yönelik Çözümleri Araştırma

Mühendis takımınızla olası çözümleri araştırmalısınız. En az iki tane çözüm önerisini verilen boşluklara yazınız. **Çözüm önerileriniz; gezegen tercihleri ve nedenleri, toprak ve gaz örneklerini nasıl alacağınız bilgilerini içermelidir.**

**1. Öneri:**

**2.Öneri:**

# Probleme En Uygun Çözümü Belirleme

1- Çözüm önerilerinden, problemin çözümüne en uygun olanını nedenleri ile birlikte aşağıda verilen boşluğa yazınız.

2- Tasarıma geçmeden önce bulduğunuz çözüm önerisini değerlendirmeniz bekleniyor. Çözüm öneriniz aşağıda verilen ifadelerden en az dört tanesini içermelidir. Problem çözümünüzde olan ifadelerin yanına "X" işareti koyunuz

- [ ] İç Gezegenin hangisi olduğu
- [ ] Gaz örneği alacak aracın özellikleri
- [ ] Dış Gezegenin hangisi olduğu
- [ ] Yakıttan nasıl tasarruf edileceği
- [ ] Toprak örneği alacak aracın özellikleri
- [ ] Uzay aracının fiziksel özellikleri

3. Eğer seçtiğiniz çözüm yöntemi bir önceki öncüldeki ( 2. ) şartlardan en az dört tanesini sağlamıyorsa, çözümünüzü gözden geçirip yeniden aşağıda verilen boşluğa yazınız. ( Şartları sağlıyorsa bu bölümü boş bırakabilirsiniz.)

# Model Planlama

- Uzay aracınızın modellemesini yapmaya başlamanız gerekiyor. Bunun için önce tasarımı planlamanız lazım. Bu aşamada size kullanabileceğiniz malzemelerin listesi aşağıda sıralanmıştır. Mühendislik mesleğinde "ekonomik" olmanın önemini göz önünde bulundurarak, modelleme yapmanız bekleniyor. Bu aşamada bazı kurallar var:

**1) Seçtiğiniz her malzemeyi kullanmanız gerekiyor, bu nedenle seçtiğiniz her malzemenin bir kullanım amacı olması gerekiyor.**

**2) Her malzemeden en fazla bir adet kullanabilirsiniz.**

**3) Temel malzemeler dışında en fazla dört malzeme kullanabilirsiniz.**

**4) Malzeme listesini oluşturup teslim aldıktan sonra sadece bir değişim hakkınız vardır.**

MALZEME LİSTESİ:

**Temel Malzemeler:**

Bant
Sıvı Yapıştırıcı
Küçük Makas
1 Adet kağıt rulo
1 Adet Fon kartonu
Silikon*
Maket Bıçağı*

**Diğer Malzemeler:**

Renkli A4 kağıt ( 2'li set)
Alüminyum folyo (30 cm)
Plastik Kaşık (3 tane)
Plastik Çatal (3 tane)
Kağıt Peçete ( 3 tane)
İp ( 1 metre)
A4 kağıt ( 1 tane)
-Kendi malzemem 1
-Kendi malzemem 2

- **Not:** Yanında ( * ) işareti bulunan malzemeler sadece öğretmen tarafından/yardımıyla kullanılabilir. Bireysel olarak kullanılamaz.

**Seçtiğiniz Malzemeler :**

| Temel Malzemeler: | Diğer Malzemeler: |
|---|---|
| | 1) |
| | 2) |
| | 3) |
| | 4) |

# Tasarımı Planlama

Aşağıda verilen noktalı alana uzay aracınızın tasarımını çizmeniz bekleniyor. Dünya'dan yola çıkan bu uzay aracına verilen senaryoya göre uygun bulduğunuz çözümü çiziniz. Tasarımınızı bir sonraki aşamada modelleyeceğinizi göz önünde bulundurarak bir taslak çizim oluşturmanız gerekmektedir.

- **Modelinizin aşağıdaki şartları sağlaması gerekmektedir. Modeliniz değerlendirilirken bu şartları sağlayıp sağlamaması göz önünde bulundurulacaktır:**

1) Modelin kendi başına ayakta durabilmesi gereklidir.

2) Modelin parçalarının düşmemesi, devrilmemesi eğilmemesi gereklidir.

3) En az 3 malzeme kullanılmalıdır.

4) Modelinizin kendine ait bir adı olmalıdır.

**Not :** Çizimlerinizi kurşun kalemle yapmanız, değiştirmek istediğiniz yerleri silmenizi kolaylaştıracaktır.

# Model Tasarım- Test Etme

Şimdi mühendis takımı olarak tasarımınızı model haline getirmeniz gerekiyor. Modelinizi oluşturmak için takım halinde iş birliği yapmanız gerekmektedir çünkü süreniz kısıtlı. Model süreci 40 dakikadır. Ardından modelinizi test etmeniz gerekiyor.

**Test etme:** **Aşağıda belirtilen kriterlere göre modelinizi test etmeniz gerekiyor, bu aşamayı öğretmeninizle birlikte kaydetmeniz gerekiyor.**

| Puan | Kriter | Bizim puanımız |
|---|---|---|
| Evet : 5 puan<br>Hayır: 0 puan | Verilen süre içinde proje tamamlandı. | |
| Evet : 5 puan<br>Hayır: 0 puan | Model kendi başına ayakta durabiliyor ve devrilmiyor. | |
| Evet : 5 puan<br>Hayır: 0 puan | Hava tüpleri tamamlandı ve düşmüyor. | |
| Evet : 5 puan<br>Hayır: 0 puan | Delici alet tamamlandı ve düşmüyor. | |
| Evet : 5 puan<br>Hayır: 0 puan | Malzeme sınırları aşılmamış. | |

**TOPLAM PUAN:**

- ŞİMDİ SUNUM ZAMANI!

**Bütün gruplar modellerini diğer grupların önünde sunacaklar. Her takımın modellerini anlatarak sunmaları için 4 dakika süreleri var!**

# Değerlendirme

**Aşağıdaki soruları mühendis arkadaşlarınızla birlikte cevaplayınız.**

1) İç ve dış gezegenleri seçerken nelere dikkat ettiniz? Anlatınız.

2) Delici alet ve hava balonlarını tasarlarken bir mühendis olarak neleri dikkate aldınız? Açıklayın.

3) Modellemesini bitirdiğiniz çalışmada, daha iyi bir sonuç elde etmek için veya geliştirmek için hangi konular hakkında değişiklikler yapmalısınız? Nedenleri ile yazınız.

4) Diğer mühendis takımından devraldığınız projede hangi Mühendislik Tasarım Basamağından başlayacağınıza nasıl karar verdiniz? Açıklayın.

# Öz-Değerlendirme

**Aşağıdaki soruları mühendis arkadaşlarınızla birlikte cevaplayınız.**

1) Tasarlamış olduğunuz model ile verilen probleme sizce uygun çözümü bulabildiniz mi? Açıklayınız.

2) a) Süreç boyunca "Mühendislik Tasarım Basamakları"nı kullandınız mı? Size nasıl yardımı oldu? Mühendislik Tasarım Basamaları olmasaydı modeliniz probleme uygun bir çözüm olabilir miydi? Açıklayınız.

b) Mühendislik Tasarım Basamaklarından en çok zorlandığınız hangi basamaktı? Neden?

3) Problem çözümünde geliştirmeniz gereken parçalar veya değiştirmeniz gereken malzemeler var mı? Nedenleri ile birlikte açıklayınız.

4) a) Etkinlikler boyunca mühendis olarak çalışmaktan hoşladınız mı? Neden?

b) Etkinlikler boyunca mühendis olarak çalışmaktan zorlandığınız kısımlar oldu mu? Neden?

# Öz-Değerlendirme

**Aşağıda verilen soruya her grup üyesi kendi bireysel fikirlerini yazmalıdır. Yaptığımız mühendis tasarım etkinliklerini göz önünde bulundurarak verilen soruyu cevaplayınız.**

**Grup üyesi 1 =**

**1) İleride meslek olarak mühendislik seçmeyi düşünüyor musun?**

**a) Evet, mühendis olmak isterim ÇÜNKÜ : ..............................................................**

**b) Hayır, mühendis olmak istemem ÇÜNKÜ: ..............................................................**

**2) Hangi mühendislik dalı sana en ilgi çekici geliyor? Bir mühendis olacak olsan hangisi olmak isterdin?**

..............................................................

**Grup üyesi 2 =**

**1) İleride meslek olarak mühendislik seçmeyi düşünüyor musun?**

**a) Evet, mühendis olmak isterim ÇÜNKÜ : ..............................................................**

**b) Hayır, mühendis olmak istemem ÇÜNKÜ: ..............................................................**

**2) Hangi mühendislik dalı sana en ilgi çekici geliyor? Bir mühendis olacak olsan hangisi olmak isterdin?**

..............................................................

**Grup üyesi 3 =**

**1) İleride meslek olarak mühendislik seçmeyi düşünüyor musun?**

**a) Evet, mühendis olmak isterim ÇÜNKÜ : ..............................................................**

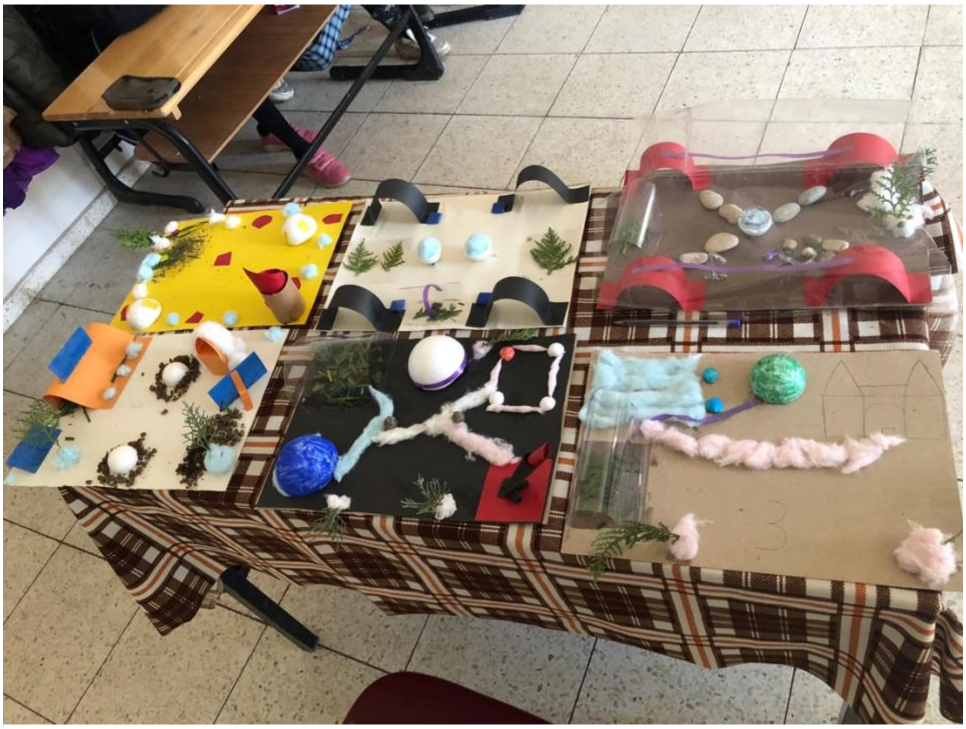
**b) Hayır, mühendis olmak istemem ÇÜNKÜ: ..............................................................**

**2) Hangi mühendislik dalı sana en ilgi çekici geliyor? Bir mühendis olacak olsan hangisi olmak isterdin?**

..............................................................

**APPENDIX- I**

**PROTOTYPES OF LIVING SPACE OF STUDENTS**



**APPENDIX- J**

**PROTOTYPES OF SPACECRAFTS OF STUDENTS**

## APPENDIX- K

## PERMISSION FOR USE OF THE SCALE OF 6TH GRADE STUDENTS UNDERSTANDİNG LEVEL OF ASTRONOMY CONCEPTS

▷ **Re: Tez Çalışması için Ölçek İzni hk.** kimden YAVUZ AKBAŞ **EK-5**

Metin (1 KB)

Pınar Hanım Merhaba,

Çalışmamızı araştırmanız için kullanmanızda bir sakınca yoktur.

Kolay gelsin.
İyi çalışmalar.

27 Eyl 2021 Pzt 20:36 tarihinde <pinar.baspinar@metu.edu.tr> şunu yazdı:

> Hocam merhaba,
>
> Ben Orta Doğu Teknik Üniversitesi - Fen Bilimleri Öğretimi programı yüksek lisans öğrencisi Pınar Başpınar. 2021-2022 eğitim yılında tez çalışması dönemindeyim. Tez çalışmasında konum, "Mühendislik tabanlı astronomi öğretiminin/etkinliklerinin 6. sınıf öğrencilerinin kavramsal anlamalarına etkisi" üzerine. Sizin 2005 yılında yayınlanan "İlköğretim 6. Sınıf Öğrencilerinin Astronomi ile İlgili Kavramları Anlama Düzeyi ve Kavram Yanılgıları" yayınınızda geliştirdiğiniz ölçeği eğer izniniz olursa, atıf vererek çalışmamda kullanmak istiyorum.
>
> Saygılarımla,
>
> Pınar Başpınar

## APPENDIX- L

## PERMISSION FOR USE OF SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS CAREER INTEREST SURVEY (STEM-CIS)

**Re: Tez Çalışması Ölçek İzni hk.** kimden İlbilge Dökme **EK-4** 06-12-2021 (23:16:55 +03)

Metin (3 KB)

Ölçeği kullanabilirsin

iPhone'umdan gönderildi

pinar.baspinar@metu.edu.tr şunları yazdı (6 Ara 2021 22:26):

[Alıntı Metni Sakla]

Hocam merhaba,

Öncelikle sizi tekrar rahatsız ettiğim için özür dilerim. Sizden 11 Ekim tarihinde "Fen, Teknoloji, Matematik ve Mühendislik Mesleklerine Yönelik İlgi Ölçeği" atıf ile araştırmamda kullanmak üzere izin almıştım. Geçmiş mailleri de aşağıda ilettim. Şu anda izin verdiğinize dair bir maili bölüme dilekçe ile iletmem gerekiyor. Ancak ben bana attığınız maili bulamıyorum bu benim hatam sanırım hiç bir şekilde de bulamadım. Bunun için tekrar yazmak istedim, tekrar izin için mail yazabilirseniz çok sevinirim. Sizi rahatsız ettiğim için tekrar özür dilerim.

Saygılarımla,

Pınar Başpınar

----- Pinar Baspinar <e202183@metu.edu.tr> tarafından yönlendirilen ileti -----
Tarih: Mon, 11 Oct 2021 21:45:02 +0300
Kimden: Pinar Baspinar <e202183@metu.edu.tr>
Konu: Fwd: Tez Çalışması Ölçek İzni hk.
Kime: ilbilgedokme@gazi.edu.tr

Hocam merhaba,

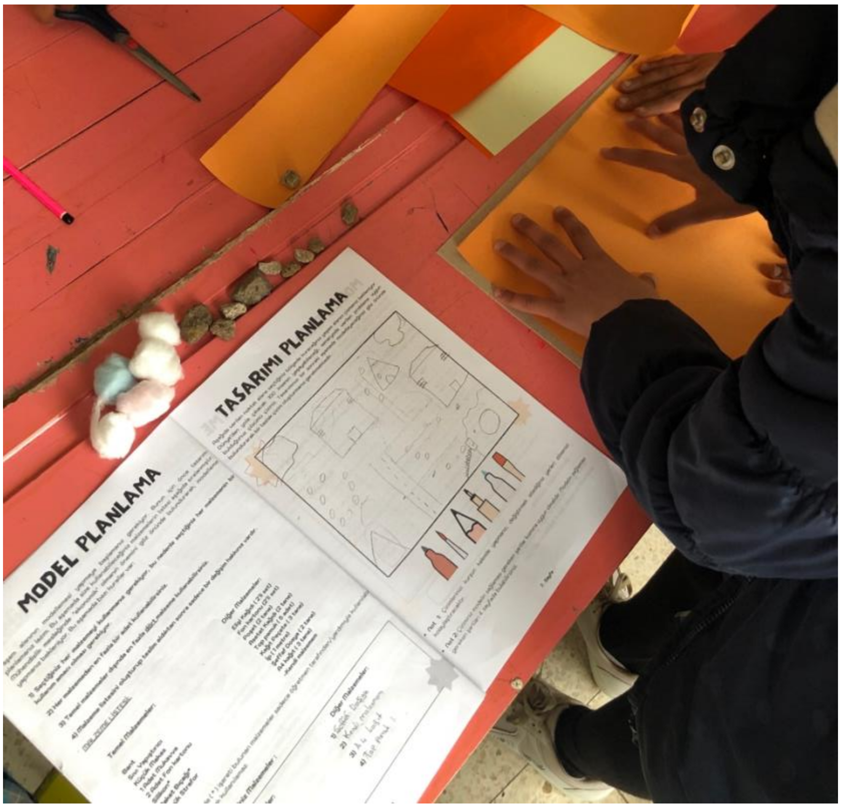
Ben Orta Doğu Teknik Üniversitesi - Fen Bilimleri Öğretimi programı yüksek lisans öğrencisi Pınar Başpınar. 2021-2022 eğitim yılında tez çalışması dönemindeyim. Uygulamalı bir çalışma yapacağım için etik izin sürecine girebilmem için öncelikle ölçek iznini almam gerekiyor. Olumlu veya olumsuz dönüş yapabilirseniz çok sevinirim. Bir önceki mailimi Size aşağıda iletiyorum.

## APPENDIX-M

## SAMPLE PHOTOS OF TREATMENT



ÖZ-DEĞERLENDİRME


MODEL PLANLAMA
TASARIMI PLANLAMA