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# Determining the Level of Knowledge and Mental Models of Secondary School Students Regarding the Solar System

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**Abstract**
The aim of this study was to determine the level of knowledge and mental models of secondary school students regarding the solar system. The study was performed with 65 eighth grade students attending a secondary school in a provincial center in northern Turkey. In this study, students were asked to draw the solar system, and to write the names of the planets in the proper order. Descriptive analysis was performed on the drawings and written descriptions provided by the students, with the data being evaluated based on five different levels previously used by Bartoszeck et al. (2008) and Uzunkayak (2009a; 2009b). Based on the study results, it was determined that the students lacked sufficient knowledge regarding the solar system, and that they possessed erroneous information regarding the order and sizes of the planets. In addition, none of the students were able to write down the eight planets of the solar system, which further illustrated their lack of knowledge on this subject.
**Keywords:** Solar System, Secondary School Student, Mental Model, Knowlede, Science Education

## 1. Introduction

Astronomy is one of the most ancient fields of science (Trumper, 2006). For centuries, space and celestial objects have been an area of interest and research for humanity. Many celestial objects such as stars and planets were regularly observed and followed by humans, who endeavored to predict their movement across the heavens. Although scientists have learned much information about the universe until today, the universe continues to hold many more mysteries waiting to be discovered (Bektaşlı, 2013).

The sun resides at the center of the solar system, which is located on the Orion Arm of the Milky Way Galaxy, one of the billions of galaxies in the universe. There are eight planets under the gravitational attraction of the sun. The terrestrial planets of the solar system, so-called because of their rocky surfaces, include Mercury, Venus, Earth, and Mars, the four planets closest to the sun. After Mars, the next planets of the solar system are the gas giants, Jupiter and Saturn. The ice giant planets, which are also the planets most distant from the sun, are Uranus and Neptune (URL-1). The planetary orbits in the solar system, and the distances of the planets from the sun, are shown in Figure 1 and Figure 2.

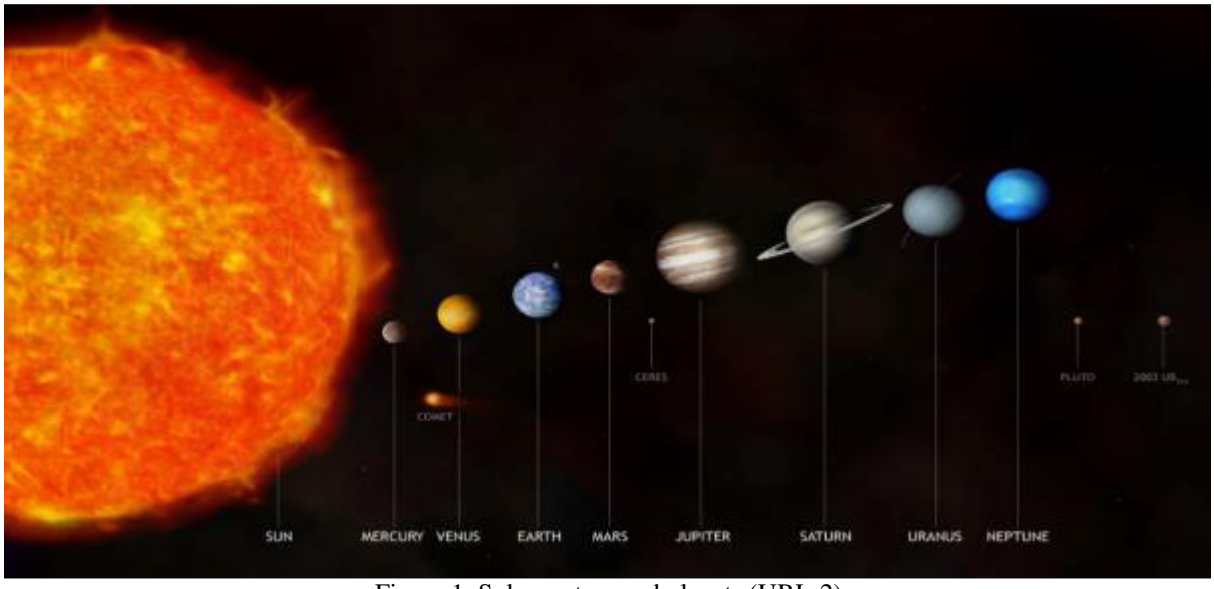


Figure 1. Solar system and planets (URL-2)

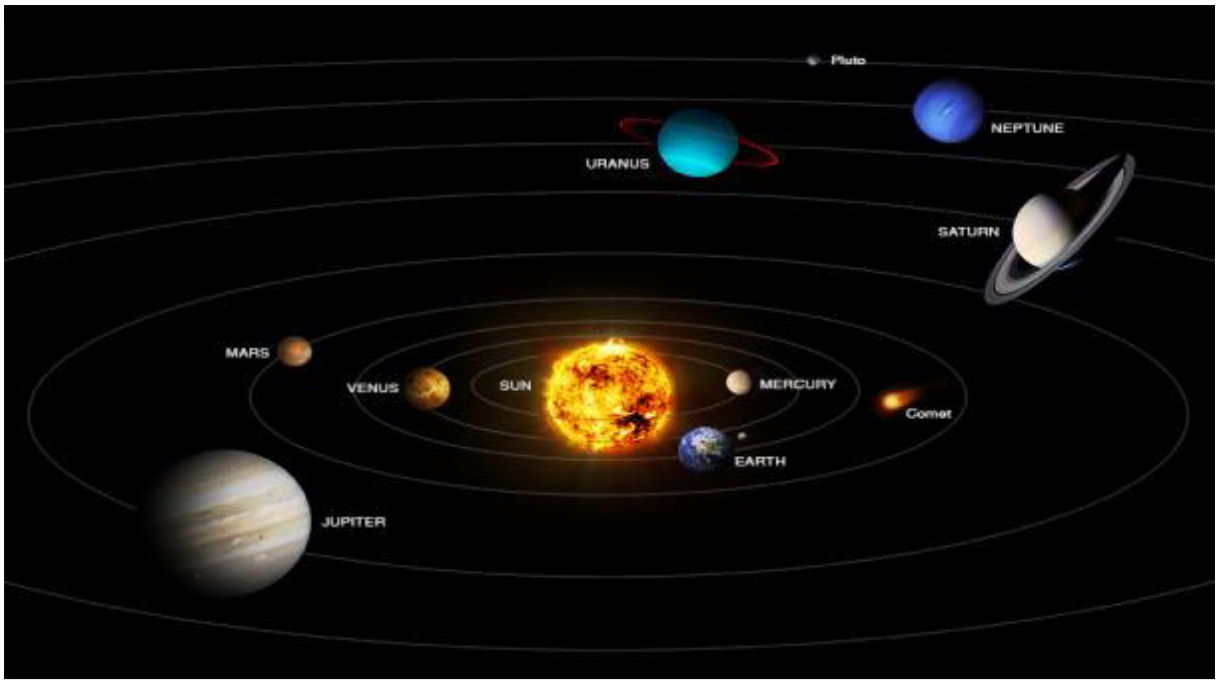



Figure 2. Solar system and planets (URL-3)

Astronomy occupies an important place in science education. As a branch of science that teaches individuals how to think correctly and rationally, many countries use astronomy and space science to effectively promote interest among students towards the sciences, and to encourage them to work and deal in science (Tunca, 2000).

Mental models are mental representations of the beliefs, thoughts, and perceptions that individuals form based on their cognitive processes (Harrison & Treagust, 2000). Learners use mental models to describe and explain events, to solve problems, and to share their thoughts with others (Buckley & Boulter, 2000; Harrison & Treagust, 2000). Studies that evaluate and describe mental models regarding astronomy concepts (Vosniadou & Brewer, 1992; Sezen, 2002; Panagiotaki, Nobes & Potton, 2008) generally describe three different models, which are the primate model, the synthesis model, and the scientific model. Primitive models are the non-scientific opinions of individuals (Sezen, 2002), while scientific models are models based on scientific knowledge (Vosniadou & Brewer, 1992). Synthesis models, on the other hand, represent the synthesis of children's primitive models with the scientific models they encounter during their education (Franco & Colinvaux, 2000; Harrison & Treagust, 2000; Sezen, 2002).

Studies in the literature on astronomy-related subjects with elementary and secondary school students include Vosniadou and Brewer's (1992) study on the mental models of elementary school students regarding the earth; Barnett and Morran's (2002) study on the alternative frameworks of elementary school students regarding the phases of the moon and the lunar eclipse; Cin's (2007) study on the alternative ideas of elementary school students regarding the shape of the earth, and its distance from the sun and the Moon; Starakis and Halkia's (2010) study on the views of elementary school students regarding the movements of the Moon; Öztürk and Doğanay's (2013) study on the understanding and mental models of fifth and eighth grade students regarding the shape of the earth and gravity; and Calderon-Canales et al.'s (2013) study on the mental models of elementary school students regarding the solar system.

To contribute and provide further depth to the existing literature, the current study aimed to determine and classify, through the use of drawings, the level of knowledge and mental models of secondary school students regarding the solar system. Astronomy is an area that is more abstract and difficult to understand compared to other fields; therefore, the current study was important in that it determined the level of knowledge of students on the subject of astronomy, as well as their deficiencies/inadequacies in this area. This study also provides recommendations for remedying the lack of knowledge and the deficiencies/inadequacies of students in this area, describing potential courses of action for teachers.

## 2. Methodology

The study was performed with 65 eight grade students attending a secondary school in a provincial center in northern Turkey. In this study, the students were given an open-ended questions asking them to draw the solar system, and to write down the names of the planets in the proper order. The names of the students were kept confidential, being coded as ($F_n$). Several examples of the answers given by the students are provided in this

manuscript.

*2.1 Data Analysis*

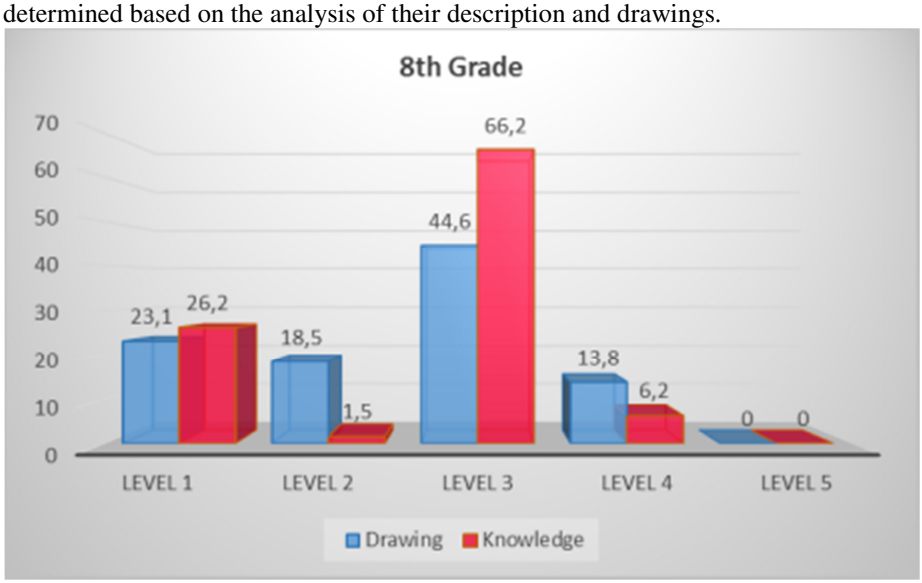
The drawings and written description obtained during this study were divided into different groups based on the five levels used by Bartoszeck et al. (2008), and Uzunkavak (2009a) and Uzunkavak (2009b); the answers of the students were then evaluated through descriptive analysis. The levels used for evaluating the data are shown in Table 1.

Table 1. The Levels and Descriptions Used for Evaluating the Knowledge and Drawings of the Students

| Levels | Statements |
|---|---|
| **Level 1** | No Knowledge/Drawing |
| **Level 2** | Wrong Knowledge/Drawing |
| **Level 3** | Partly Correct Knowledge/Drawing |
| **Level 4** | Incomplete Knowledge/Drawing |
| **Level 5** | Completely Accurate and Complete Knowledge/Drawing |

## 3. Results

In this study, students were asked to demonstrate their knowledge regarding the solar system through drawings and written descriptions. Graph 1 illustrates the distribution of the students' level of knowledge regarding the solar system, determined based on the analysis of their description and drawings.




Graph 1. The percentage distribution of the students' level of knowledge regarding the solar system

Graph 1 indicates that 23.1% of the secondary school students could not provide any drawings, while 26.2% could not provide any written descriptions. In addition, 18.6% of the students provided erroneous drawings, while 44.6% provided partially correct drawings. It was also observed that 66.2% of the students provided written descriptions that illustrated partially correct knowledge on the subject. Only 13.8% of the students provided incomplete drawings, while 6.2% provided incomplete written descriptions that indicated incomplete knowledge. None of the students were able to provide a fully correct and complete description of the solar system.

Examples of student drawings and written descriptions corresponding to level 2 answers are shown in Figure 3.

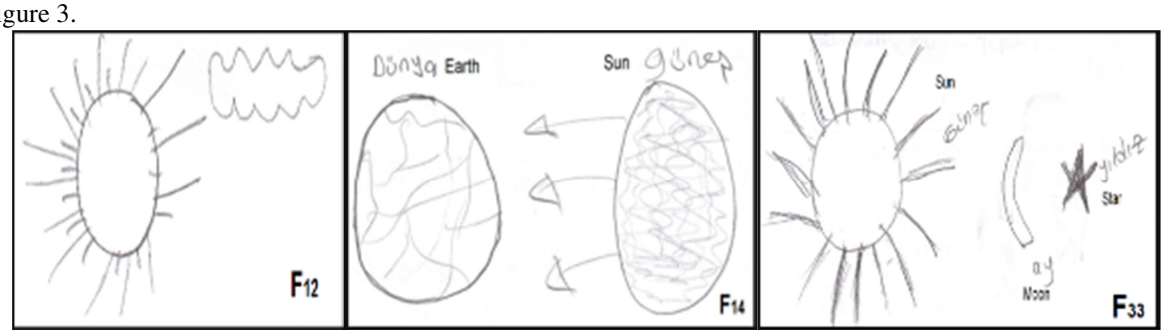



Figure 3. Examples of drawings and written descriptions corresponding to level 2 knowledge

According to the student drawings and descriptions shown in Figure 3, one of the students (***F12***) provided an incorrect drawing that depicting the solar system with the sun and clouds. In other words, the student drew the sun as he saw it in the earth's atmosphere, while failing to draw the planets that are part of the solar system. Another student (***F14***) provided an incorrect drawing where the solar system consisted only of the sun and earth. In addition, the student depicted the earth and sun as if they had the same size, which indicated that he incorrect knowledge about their sizes. Another student (***F33***) drew the solar system by showing the moon, sun and a star (only one). This student's drawing and description of the solar system failed to mention the planets, and erroneously included a star (other than the sun) into the solar system.

Examples of student drawings and written descriptions corresponding to level 3 answers are provided below.

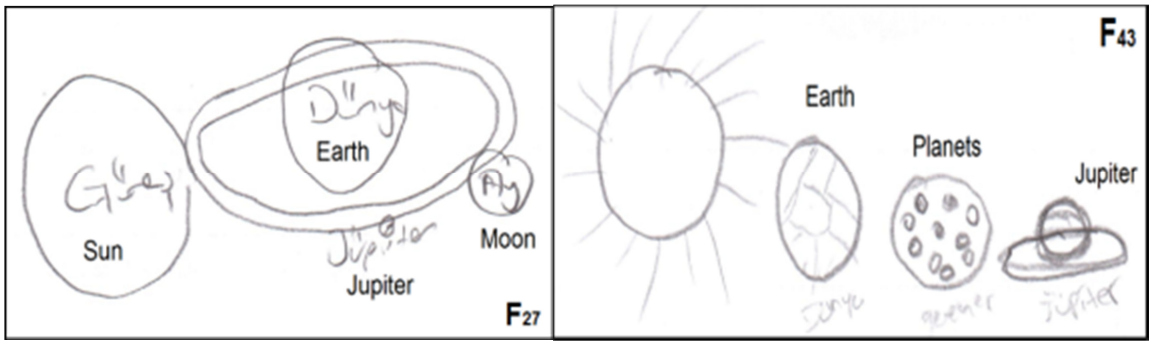



Figure 4. Examples of drawings and written descriptions corresponding to level 3 answers

According to the student drawings and descriptions shown in Figure 4, one of the students (***F27***) drew the solar system by showing only the Sun, Earth, Moon, and Jupiter, and by erroneously depicting both the Moon and Jupiter as orbiting around the earth. Another student (***F43***) drew the solar system by showing the Sun, Earth, Jupiter, and a cluster of other planets. This student also drew a ring structure around Jupiter. In both drawings, the students reflected inaccurate knowledge on the size of planets.

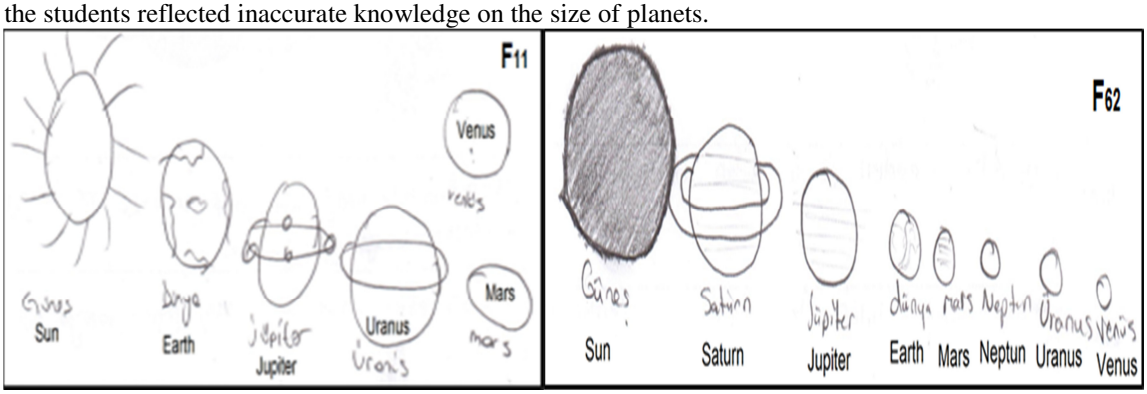



Figure 5. Examples of drawings and written descriptions corresponding to level 3 answers

According to the student drawings and descriptions shown in Figure 5, one of the students (***F11***) drew the solar system by including the Sun, Earth, Jupiter, Uranus, Mars and Venus. The student depicted ring structures around Jupiter and Uranus, as well as four small structures orbiting Jupiter. The student was able to draw and name only five of the eight planets in the solar system. Another student (***F62***) drew the solar system by showing the Sun, Saturn, Jupiter, Earth, Mars, Neptune, Uranus, and Venus. The student drew a ring structure around Saturn, but also drew the planets smaller as their distance from the sun increased. In both drawings, the students illustrated the sizes and ordering of the planets inaccurately, while also failing to write the names of all eight planets.

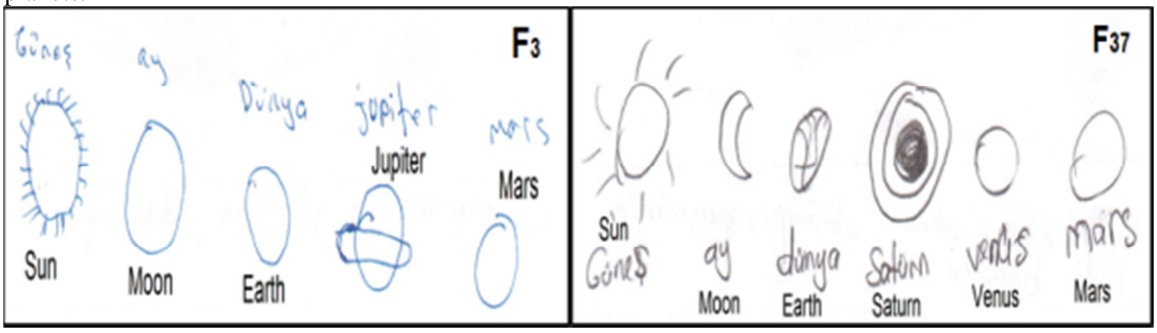



Figure 6. Examples of drawings and written descriptions corresponding to level 3 answers

According to the drawings and descriptions shown in Figure 6, one of the students (***F*** $_{3}$) drew the solar system by showing the Sun, Moon, Earth, Jupiter, and Mars. The student also drew a ring structure around Jupiter. The student was thus able to draw and name only three of the eight planets in the solar system. Similarly, another student (***F*** $_{37}$) illustrated the solar system by showing only the Sun, Moon, Earth, Saturn, Venus, and Mars. This student, who drew a ring structure around Saturn, was only able to name four of the solar system's eight planets. In both drawings, the student erroneously illustrated the moon not as a satellite orbiting the Earth, but instead as a planet of its own. In addition, the planet sizes, the relative distances of the planets to the Sun, and the order of the planets were also inaccurate in these drawings.

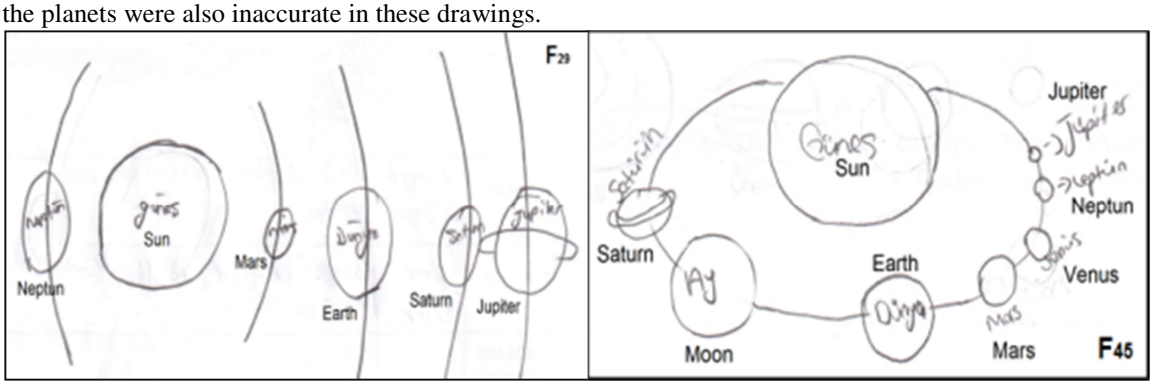



Figure 7. Examples of drawings and written descriptions corresponding to level 3 answers

According to the drawings and descriptions shown in Figure 7, one of the students (***F*** $_{29}$) drew the solar system by placing the sun at the center, and showing the planets in various orbits. The student drew a ring structure around Jupiter, while showing and naming only five of the solar system's eight planets; the ordering of the planets was also inaccurate. Another student (***F*** $_{45}$) also drew a picture with the sun at the center of the solar system, by erroneously positioning all of the planets in the same, single orbit. The student, who drew a ring structure around Saturn, was able to name and draw seven of the solar system's eight planets. However, the student also drew and described the moon as a planet. In both drawings, the students reflected inaccurate knowledge about the sizes of planets.

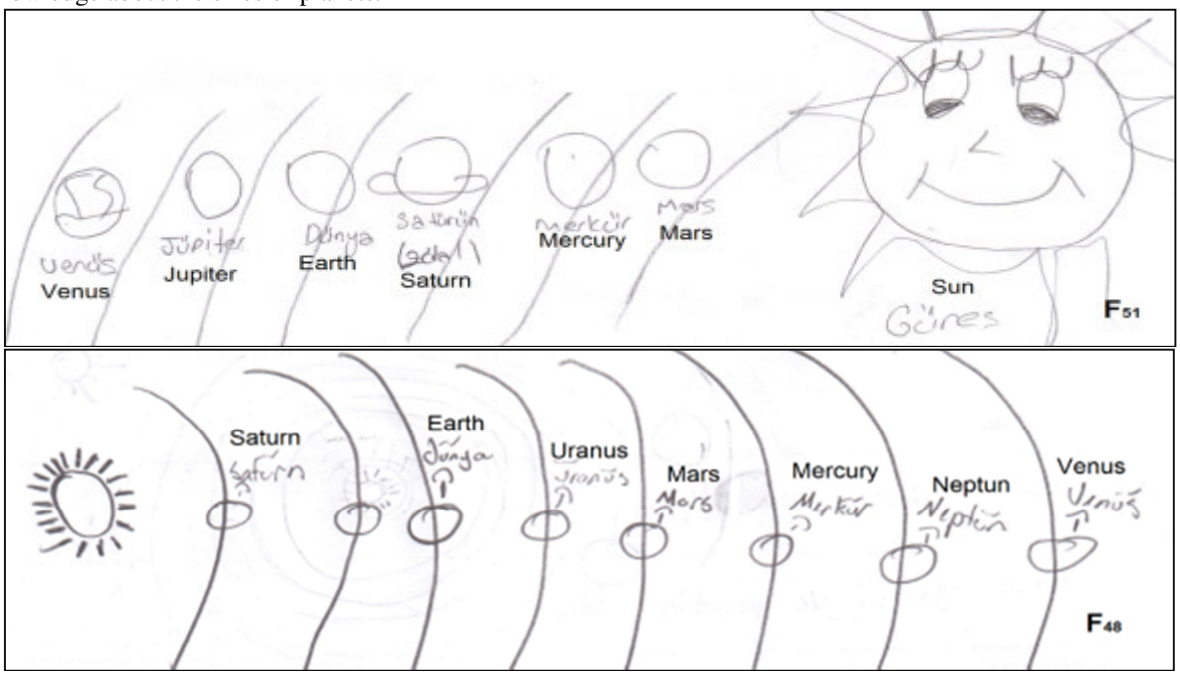



Figure 8. Examples of drawings and written descriptions corresponding to level 3 answers

According to the drawings and descriptions shown in Figure 8, one of the students (***F*** $_{51}$) drew the planets of the solar system in specific orbits. The student drew a ring structure around Saturn, and was able to draw and name six of the solar system's eight planets. Another student (***F*** $_{48}$) also drew the planets in specific orbits, and was able to draw and name seven of the planets. In both drawings, the ordering of the planets was inaccurate, and the planets were all drawn the same size.

Examples of student drawings and written descriptions corresponding to level 4 answers are shown in Figure 9.

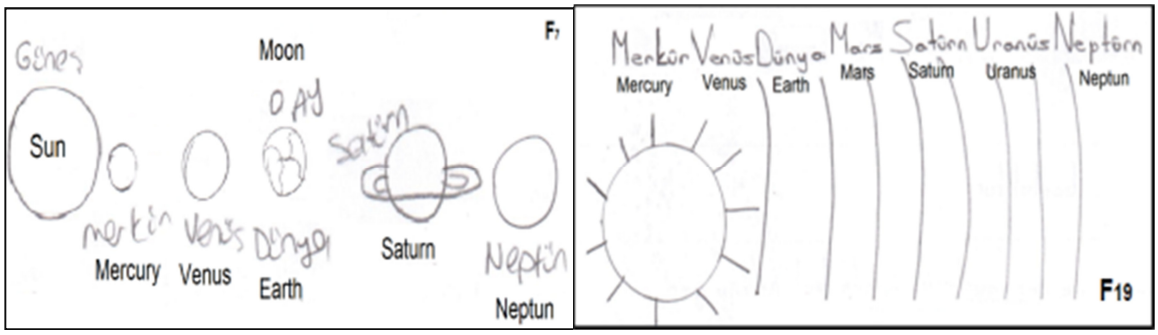
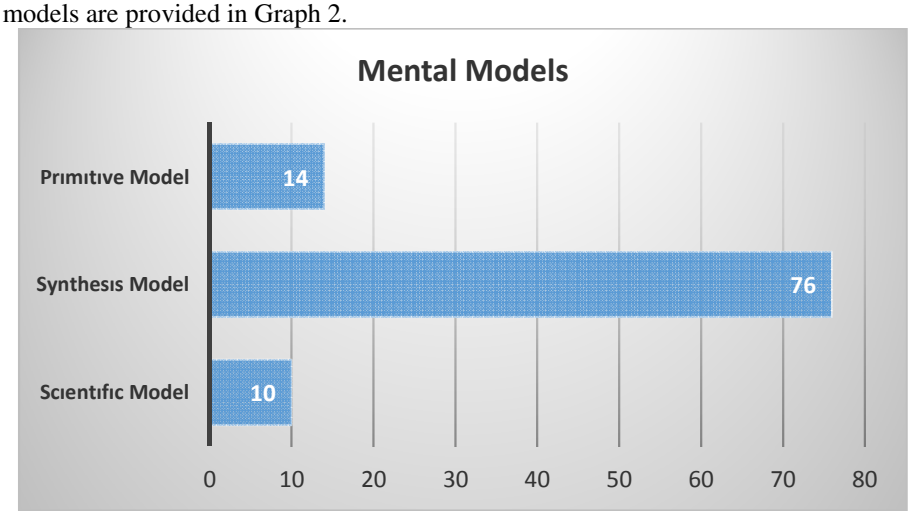



Figure 9. Examples of drawings and written descriptions corresponding to level 4 answers

According to the drawings and descriptions shown in Figure 9, one of the students ($F_7$) was able to draw five of the eight planets, which he was able to size correctly, and illustrate in the right order according to their distance from the sun. In addition, the student correctly showed the moon as a satellite of the earth. Another student ($F_{19}$) showed the planets of the solar system in specific orbits; however, he did so not by drawing round planetary forms, but instead by writing the names of the planets directly into his drawing (inside the orbits). The student was able to write seven of the solar system's eight planets, which he wrote in the proper order according to their distance from the sun.

The drawings and written descriptions of the students indicated that they possessed different mental models regarding the solar system. An overall evaluation of the students' mental models indicated that the large majority (76%) had synthesis models, while only a few (10%) had scientific models. The distribution of the students' mental models are provided in Graph 2.




Graph 2. Students' mental models

## 4. Conclusions and Recommendations

Based on the study results, we determined that the participating secondary school students generally lacked adequate knowledge regarding the solar system, and that they possessed erroneous information regarding the order of the planets and their sizes. In addition, some of the students drew the moon as a planet of the solar system rather than a satellite of the earth, thus illustrating that their knowledge about the moon was inaccurate. It was observed that most students were aware that planets move in specific orbits within the solar system. None of the students were able to write all eight of the solar system planets, which indicated the inadequacy of their general knowledge on this subject.

The results of the study also illustrated that the eighth grade students developed different mental models regarding the solar system, and that these models were mainly based on synthesis. The study findings clearly indicate that the majority of the students have been unable to acquire a scientific understanding of the solar system. Öztürk and Doğanay (2013) reached similar conclusions in their study evaluating the mental models and understanding of fifth and eighth grade students regarding the shape of the earth and gravity.

Based on the results of the current study, we believe that it is important that teachers first attempt to determine the astronomy-related preliminary knowledge and misconceptions of students before teaching the subject of astronomy, and that they organize educational activities aiming to resolve the students' lack of knowledge and misconceptions on the subject. To remedy the students' lack of knowledge on astronomy, and to contribute to the development of their ability to think in three dimensions, teachers can use concept networks, three-dimensional models and visuals, concept maps, concept caricatures, informative texts, analogies, and texts

on conceptual changes. In addition, we believe that the use of observation-based activities, as well as the utilization of animations and simulations that enable students to better understand the objects and systems in the universe along with their sizes and distances, will be both important and useful in increasing students' interest towards astronomy, and encouraging them to think/focus on this subject.

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