SECONDARY SCHOOL STUDENTS' MENTAL MODELS OF THE SUN, THE EARTH, THE MOON AND THE SUN-EARTH-MOON SYSTEM[1]

Süleyman AYDIN
Assist. Prof. Dr, Ağrı İbrahim Çeçen University, yupul@hotmail.com
ORCID: 0000-0002-1759-0567

Pınar URAL KELEŞ
Assist. Prof. Dr, Ağrı İbrahim Çeçen University, pukeles@yahoo.com
ORCID: 0000-0001-6325-0152

Havva HAFIZOĞLU
Ağrı İbrahim Çeçen University, havva.hafizoglu@hotmail.com
ORCID: 0000-0002-6322-2503

ABSTRACT

The aim of this study is to determine the mental models of the secondary school students about the basic astronomy concepts of the Sun, Earth, Moon (SEM) System. For this purpose, seven open-ended questions developed by the researcher in order to reveal their mental models and were applied to the secondary school students after the necessary corrections were made by the three science educators. The sample of the study consisted of 198 students (50 fifth grade, 50 sixth grades, 50 seventh grades, 48 eighth grades) studying in two secondary schools in Ağrı city center. The data obtained from the study were analyzed and using the mental model determination process proposed by Vosniadou and Brewer (1992, 1994). It has been tried to determine mental models of students separalely for each grade level. Findings from the research data revealed that students were "primitive" in 5th grade, had a "synthesis model" in 6th grade, "primitive and synthesis models" were in balanced level in 7th grade. In the 8th grade, most of the students had a synthesis model but the number of students at the scientific level was more than the other classes.

Keywords: Science education, astronomi education, Sun-Earth-Moon (SEM) system, secondary students' mental models.

---

[1]This article has been presented in "2 nd Internatıonal Symposıum of Educatıon and Values" as an oral presentation in Lara/ANTALYA in 17-20 October 2018

INTRODUCTION

The importance of astronomy education and training in science education is great. The developments in astronomy and space sciences, which have accelerated in recent years, also accelerate the developments in other basic sciences. Astronomy, however, can be considered as an excellent educational tool that can be used to teach people the right and logical thinking. Developed countries such as the US use astronomy effectively to direct students to the science and to make students love science (Tunca, 2000). When we think about its place in the educational process of Astronomy, it has benefited effectively to endear science to students, to ensure the students' interests to science and therefore, we see that astronomy concepts and subjects were involved in the curriculum of various levels both in abroad and in Turkey (Tunca, 2005). The basis of astronomy to be included in the curriculum is that there is a clear commitment between astronomy and science (Gülseçen, 2005), and that astronomy is widely used in mathematics and physics, chemistry, biology and geology (Percy, 1998; Tunca, 2005; Sakallı, 2008). In addition, it is argued that astronomy is a discipline that teaches the person the right and logical thinking effectively (Tunca, 2005). Concerning the importance of astronomy education, Percy (1998) said that there were still important astronomical practices in our daily lives and they were more useful than experimental methods because they have an observational dimension. He also stated that interest in science and technology could be increased with astronomy subjects. Brogt (2007) states that, because astronomy education is a new field, researchers who have knowledge and experience in different fields have entered the field, and that there is a need for researchers who have a background in astronomy and education in order to advance the field of astronomy education as a field of research. The deep relationship between astronomy and natural sciences and the intense interest of individuals in understanding celestial bodies (earth, moon, day and night formation, seasonal change etc.) led researchers to explore student perceptions of basic astronomy concepts (Vosniadou and Brewer, 1992, 1994; Trumper, 2001, 2003, Suzuki, 2003).

Basic concepts related to astronomy in science and technology education program being implemented in Turkey since 2005, were as follows.

In fifth grade; "Sun, Earth and Moon shape, size, Earth and Moon movements, Moon phases, day and night formation", in sixth grade; "What The Earth's crust is made up of?" and in eighth grade; "Formation of the Universe and Earth" (Timur et al, 2013).

In 2013 Science program in Turkey implemented as follows; fifth Grade, 7th Unit: "Mystery of Earth's Crust / Earth and Universe:

In this unit, it was aimed that the students get to know the components that make up the crust, the effect of erosion and landslide on the crust, groundwater, surface waters and knowledge about air, soil, water pollution, skill and career awareness about fossil science. In sixth grade, 8th Unit: Our World, Moon and Life Source Sun / Earth and Universe: In this unit, the students were expected to recognize the layers of Earth, Sun and Moon with relative dimensions and forms, to make a model by explaining the Moon's rotation and entanglement

movements, and to establish a relationship between Earth and Moon and to gain knowledge and skills about the results of this relationship and their impact on daily life (https://ridvansoydemir.wordpress.com, 2013).

The links between Astronomy and Science in the Turkish Education System in the updated science education program in 2017-2018 academic year were given as follows by Republic of Turkey Ministry of National Education Board of Education (*http://mufredat.meb.gov.tr, 2018*).

Table 1. SEM Subjects in The Updated Science Education Program in The Academic Year of 2017-2018

Class	Unite	Achievements	Hours	Percent (%)
5. Class	Sun, Earth and Moon	F.5.1.1.1. Explains the properties of The Sun. The geometric shape, layers and rotational motion of the sun are mentioned. F.5.1.1.2. Prepare the model to compare the size of the Sun with the size of the Earth. F.5.1.2.1. Explains the properties of The Moon. The size of The Moon, geometric shape of The Moon, surface structure and its atmosphere are mentioned. F.5.1.2.2. They discuss the ideas that they produced about living creatures in the moon. F.5.1.3.1. Explains the rotation and revolutional movements of the Moon. F.5.1.3.2. Explains the relationship between the Moon's phases and the Moon's revolutional movement around the Earth. F.5.1.4.1. prepares a model representing the movement of Sun, Earth and Moon relative to each other.	24	16.6
6. Class	The solar system and eclipses	F.6.1.1.1. Compares the planets in the solar system with each other. F.6.1.1.2. They form a model by ordering the planets in the solar system according to their proximity to the Sun. F.6.1.2.1. Estimates how the eclipse occurs. F.6.1.2.2. Estimates how the lunar eclipse occurs. F.6.1.2.3. Creates a model representing Sun and Moon eclipse.	14	9.7
8. Class	Seasons and climates	F.8.1.1.1. Make predictions about the formation of seasons. The relationship between the rotation axis of the Earth and the plane of rotation around the Sun is mentioned.	8	5.5

Source: (*http://mufredat.meb.gov.tr, 2018*).

According to the Table 1; It was seen that In the 2018-2019 education program of the Ministry of National Education, the 5th grade students have been informed about the characteristics of the Sun, the Earth and the Moon, the relationship between each other and their rotational movements at the rate 16.6% of the annual curriculum, the 6th grade students are given information about the planets and their properties in the solar system in 9.7% of the curriculum and the 8th grade students were given information about the axis of rotation of the Earth 8 hours of in 5.5% percentage of the annual curriculum. 2018- 2019 academic curriculum has updated version of 2017 program and in the program, some minor simplifications were made in the "Earth and the Universe" the unit, as well as in other units.

There are differences between the scientific explanations and the explanations of children by synthesizing their daily observations about the celestial bodies and their phenomena (Vosniadou & Brewer, 1992, 1994). These are explained as follows:

- Children's unsufficient basic understanding about gravity rules,

- Children's understanding of celestial bodies (such as the Sun and Moon) developed by the angle of view of the assumption of being on Earth perspective, is based on a World based perspective (Plummer, et all, 2014; cited in Ozgul et al, 2018).

MODELS AND MENTAL MODELS

Models are scientific and mental activities used to facilitate the understanding of complex events (Paton, 1996; cited in Berber and Güzel, 2009; Canpolat et al., 2004;).According to Norman (1983), the models are common experiences that can be shown or schematized by a system or event.

In the studies on the classification of the models, regarding the models, it is possible to encounter various classifications such as;

- Scientific / non-scientific models,

- Models in terms of appearance (concrete-abstract models), models in terms of functions (descriptive, explanatory, descriptive models) (Güneş, Gülçiçek and Bağcı, 2003).

Many teachers take care to teach lessons in accordance with the explanations in the textbooks. Therefore, the models used in textbooks are important in learning and teaching. Many science teachers think that they use the models in science books and that it is not appropriate for them to change according to their needs; because they believe that the most popular models will be made by scientists (Güneş, Gülçiçek & Bağcı, 2004; Harrison, 2001; Van Driel & Verloop, 1999, 2002). The inclusion of models and especially scientific models in the education process gives the students the opportunity to learn the discipline-specific field information and seeing the emergence of scientific knowledge (Unal and Ergin, 2006).

A mental model is an internal representation of the structural similarities of events or processes (Greca and Moreira, 2001). Questions about the theoretical and practical knowledge of the target concept should be taken into consideration in revealing mental models (Kurnaz, 2011). Conceptual models are external representations of facts, objects and ideas that people structure and share (Nersessian, 1992; Franco and Colinvaux, 2000; Güneş et al., 2004; Unal and Ergin, 2006). Mental models are internal / cognitive presentations in the minds of individuals. (Bower and Morrow, 1990; Rapp, 2005; Harrison and Treagust, 1996). Hestenes (2006) establishes the facts with mental models and the network of conceptual configurations as in Figure 1.
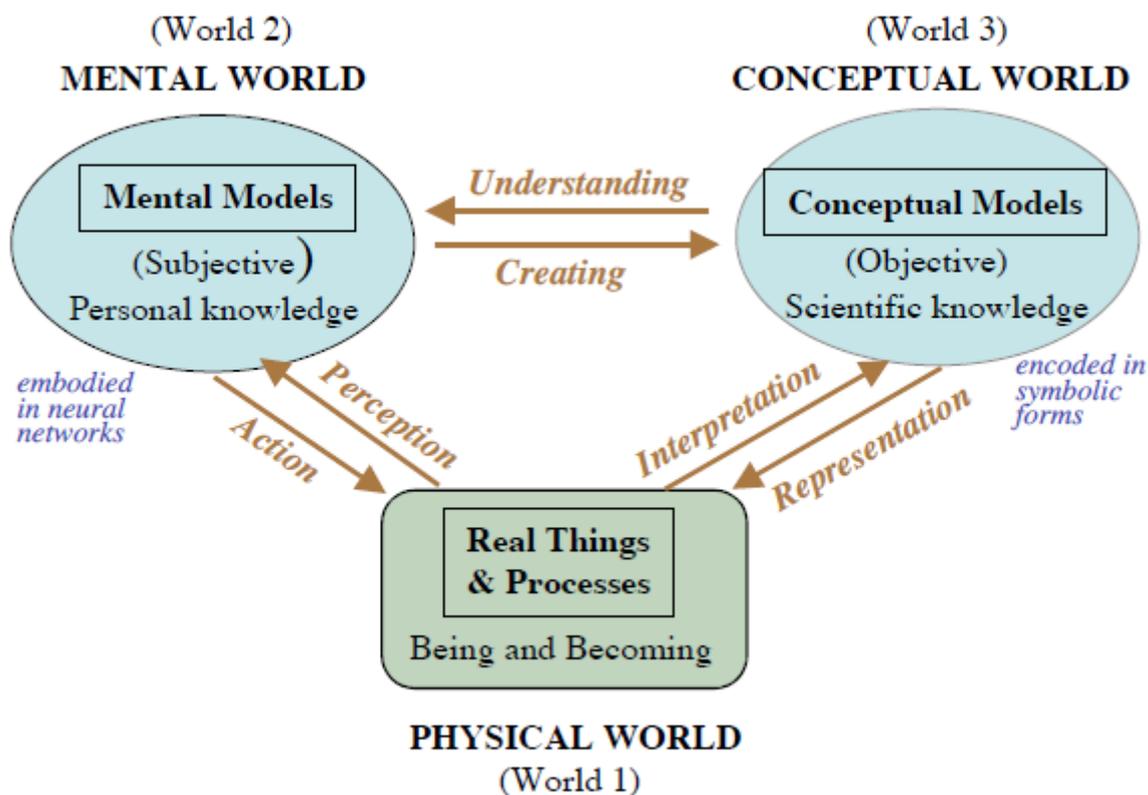
Figure 1. Mental Models vs. Conceptual Models

Source: (Hestenes, 2006).

In this study, it is aimed to reveal students' mental models about Sun-Earth-Moon (SEM) and Sun-Earth-Moon System.

METHOD

Within the scope of the study, a case study method descriptive approach has been adopted since the mental models of the students were examined. In the detailed explanation of the situation examined, in descriptions, in evaluation as it is, and in describing the relationships between events or situations, description studies has been defined as effective (Çepni, 2012). In this study, a longitudinal study case study design is used in the context of descriptive approach. The special case of this study is the mental models of secondary school students with the concept of SEM and related to the SEM system.

Sample

The study group of the study consisted of 198 students (50 fifth grade, 50 sixth grade, 50 seventh grade, 48 eighth grade) studying in a secondary school in the city center of Ağrı in the 2017-2018 academic year.

Data Collection Tool

In revealing mental models, questions related to the theoretical and practical knowledge of the target concept should be taken into consideration (Kurnaz, 2011). In this study, 7 open-ended interview questions were prepared by the researcher. With open-ended questions directed to students firstly, students' descriptions of celestial bodies were examined, then mental models were mentioned. Questions have been prepared by taking into consideration the 5th and 6th grade science and technology course curriculum, studies in the related literature (Trundle, et all, 2006; Mulholland and Ginns, 2008; Subramaniam and Padalkar, 2009) and expert opinions.

Open-ended questions:

1- What comes into your mind when you hear the concept of the sun? Please explain.

2- What comes into your mind when you hear the concept of the world? Please explain.

3 - What comes into your mind when you hear the moon concept? Please explain.

4- What kind of shape do you think the sun has? Show by drawing.

5- What kind of a shape do you think the world has? Show by drawing.

6- What kind of shape do you think the moon has? Show by drawing.

7- Draw a picture showing the Sun, Earth and Moon together. Show in your picture how the Sun, Earth and Moon are moving according to you. Write down the names of the celestial bodies you draw.

Data Analysis

The mental models proposed by Vosniadou and Brewer (1992, 1994) were used in the process of mental modeling. These models are primitive, synthesis and scientific models. The primitive model includes student responses that do not overlap with scientific information. The student responses evaluated in this model are far from school information about target concepts. Synthesis model includes student responses that partially overlap or do not overlap with scientific information. The students classified in this model have non-scientific knowledge even though they have partially acquired school knowledge. The scientific model includes scientific student answers about the target concepts. Based on this information, it has been tried to determine which students have scientific, synthesis or primitive models. The model in which the answers given in the study were suitable was analyzed by analyzing and interpreting the questions one by one.

FINDINGS

The findings of the study consisted of the answers obtained from the open-ended questions that the students answered.

Students' mental models about Sun, Earth, Moon and Sun-Earth-Moon system were shown in table 2 as percentage and frequency separately. After the mental models of the 5th, 6th, 7th and 8th grades wee found seperately, findings were presented in graphical form.

For the 5th grade; As shown in the graph, the questions were analyzed one by one and the percentages and frequencies of primitive, synthesis and scientific models were calculated.

In grade 5; Figure 2 shows that the percentage of students with a primitive model was higher than the percentage of students who have a synthesis model. The percentage of students with a scientific model is very low.

Some examples of student responses;

S:50. "When I hear the concept of the Earth, I think of the forest, the sea and the sky". It was taken as a primitive model.

S:47. "The Earth is a kind of planet where living things live and is part of the sun. It is the living space where people, animals, plants live. It is our place of living with water resources. There is a hot core in the world that we live on". This was evaluated as synthesis model.

S:1. "The moon is Earth's satellite. Moon Reflects the light it receives from the sun.". It was taken as a scientific model.
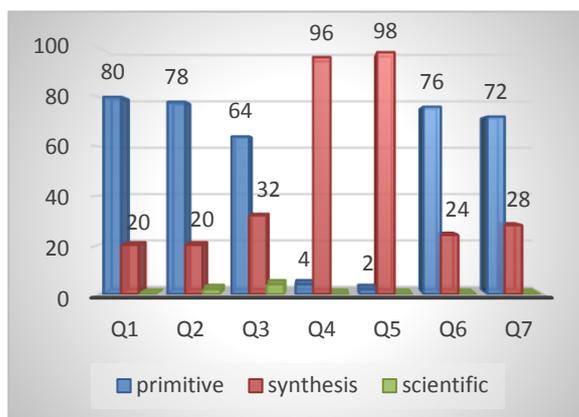

Figure 2. 5th Class Results

For the 6th grade: Figure 3 shows that the percentage of students with the synthesis model is higher. Then comes the primitive model and scientific model respectively. After Grade 8 students, it is the second class with a higher percentage of the Scientific model.

Some examples of student responses;

S:46. "The Sun: a celestial body that keeps us warm is a round object that is yellow in color and it is a circle." İt was taken as a primitive model.

Aydın, S., Ural Keleş, P. and Hafızoğlu, H. (2018). Secondary School Students' Mental Models of The Sun, The Earth, The Moon And The Sun-Earth-Moon System, International Journal of Eurasia Social Sciences, Vol: 9, Issue: 34, pp. (2425-2437).

S:44. "The moon is the earth's satellite. Moon pulls water on Earth. it's called tide. The moon has stages like the first- quarter, last quarter, crescent, full moon. The Earth revolves around the Moon". This was taken as a synthesis model.

S:37. "The world is in the shape of a geoid. Depressed from the top and bottom, the side appears bulging (Indicated correctly in the figüre.).". It was taken as a scientific model.
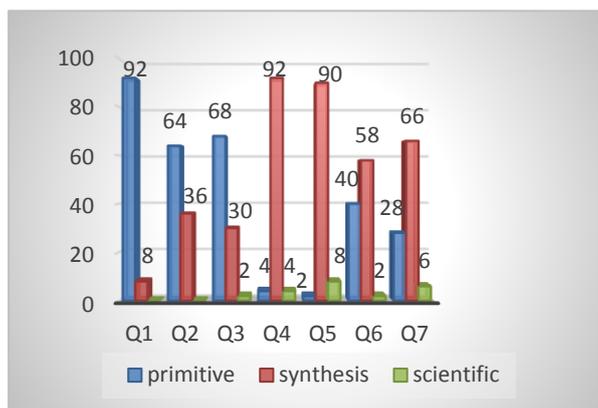

Figure 3. 6th Class Results.

For the 7 th grade: in this class, it is seen as in figure 4 that the number of students who have primitive and synthesis models is equal. And it was observed that no student had a scientific model.

Some examples of student responses;

S:18. "The world is very big. It was taken as a primitive model.

S:8. "World: The planet in which we live, is a planet where all kinds of creatures can live because of oxygen. It was taken as a synthesis model.
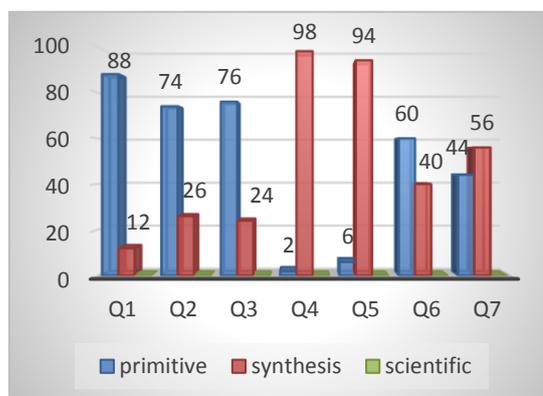

Figure 4. 7th Class Results

For the 8th grade: as it was seen from the Figure 5, the number of students with a synthesis model is more than the number of students with other models. In the 8th grade, the number of students with a scientific model was found to be higher than the other classes. For example:

S:47. "Moon: small white ball shining at night". It was taken as a primitive model.

S:6. "Moon: is the satellite of the world. It is also a small source of light". This was taken as a synthesis model.

S:48. "Sun: It is a star in the Milky Way galaxy that gives its name to the solar system and illuminates and warms our World". It was taken as a scientific model.
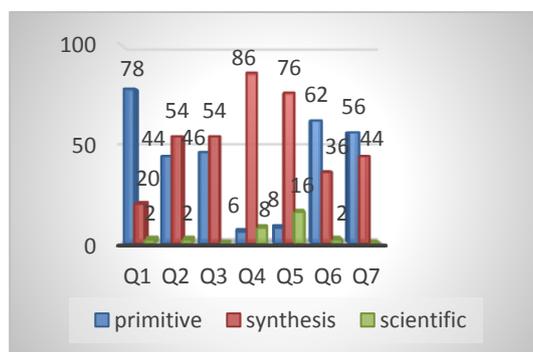

Figure 5. 8th Grade Results

Table 2. The Distribution of Student Mental Models

	Primitive model		Synthesis model		Scientific model		Unanswered	
	f	%	f	%	f	%	f	%
Sun	162	81.8	30	15.15	6	3.03	-	-
Earth	133	67.2	60	29.3	14	7.07	1	0.5
Moon	121	61.1	70	35.35	5	2.5	2	1.01
SEM	194	97.9	-	-	3	1.5	1	0.5

The distribution of student mental models shows that as summarized in Table 2, that the students had the mostly primitive model from these three models.

Up to 98% of the students have a primitive model of the solar system.

82% of the students have a primitive model about the Sun, 67% of the Earth and 61% of the Moon. The percentage of students with a scientific model is very low, around 1%.

RESULTS, DISCUSSION AND SUGGESTIONS

In this study, SEM concepts and mental models of SEM system were examined. Similar to this study, Kurnaz and Değirmenci (2011) carried out the study to reveal the mental models of 7th grade students about SEM and SEM system. Based on the findings obtained, the main conclusion is that students mostly have a synthesis model in terms of SEM and SEM system. In other words, students do not fully accept or understand the scientific models presented, but instead admit them by integrating them with primitive models.

Baloğlu Uğurlu (2005) aimed to determine the 6th grade students' level of misconceptions and misconceptions about the concepts related to the Earth and Universe in her study. The results of the study in which a questionnaire was applied to collect data, showed that Earth's movement and seasons and celestial bodies in the universe and were among the subjects that close to half of the students have misunderstood. However, it has been seen that the students have learned the appearance of the Earth, the movements of the Earth, that the Earth was a planet, that the Sun was a star and the Sun> World> Moon ranking in a good way.

Ekiz and Akbaş (2005), have done a study related to astronomy to determine 6th grade elementary school students' misconceptions about the concepts; Universe, Solar system, Planet, Star, Satellite, Orbit, Sun to understand the level of misconceptions. In the study, questionnaires and interviews were applied in order to collect data and the obtained data were analyzed by using classifications showing comprehension levels.

Babaoğlu, & Keleş, (2017) had studied the determination of 6th grade students' perceptions regarding the concepts of "the Earth", "the Moon" and "the Sun". In their study they have found the results parallel to this study, while 6th grade students participating in the study had lacking and pseudo-scientific concepts related to the subjects of 'the Earth', 'the Moon' and 'the Sun' before the application, most of the students were seen to express these astronomy concepts with more scientific terms, and their perceptions changed in scientific direction after the related unit taught.

Babaoglu, & Keles, (2018) have searched a different study entitled "Determination of 6th Grade Students' Perceptions of the Concepts of "Star", "Planet" and "Moon, Sun and Earth" and the result of the study showed that while the participating 6th grade students had missing information and non-scientific understanding about the concepts of "star", "planet" and "Moon, Sun and Earth" before the application, the students' explanations and perceptions about the shapes and characteristics of stars and sizes and locations of the Moon, Earth and Sun after the application showed positive changes in their scientific perceptions of these concepts. The results of their study were same with this study.

This study and similar studies (Baloğlu Uğurlu, 2005; Ekiz and Akbaş, 2005; Babaoğlu, & Keleş, 2017; Babaoğlu, & Keleş, 2018; Kurnaz and Değermenci 2012) with astronomical concepts show us that students do not understand these concepts adequately and some cannot reflect what they know. It is more important to discuss this framework since the study is primarily aimed at finding mental models. The majority of the students were found

to have a synthesis model after the primitive model. The most interesting result of this study is that almost all of the students do not have a scientific model. With regard to SEM (Sun, Earth, Moon system), almost all students gave appropriate answers to the primitive model.

Based on the findings obtained from this study, which was conducted in order to reveal the mental models of the students about the Sun, the Earth, the Moon and SEM system, the main result is that the students mostly have primitive models regarding the Sun, Earth, Moon and SEM system.

As a result, the majority of students are far from scientific knowledge. According to these results, it can be suggested that teachers use the visuals to make them more memorable when describing the Sun, Earth and Moon concepts. More importantly, by associating students with daily life in order to be familiar with the environment they live in, ensuring the participation of the student in the lesson will minimize the errors in the education that may occur. In lectures teachers might use materials characterizing SEM system or modeling earth and moon. Trying to comprehend the SEM system as a whole is one of the measures that can be taken.

REFERENCES

Babaoğlu, G., & Keleş, Ö. (2017). Determination of 6th Grade Students' Perceptions Regarding the Concepts of 'The Earth', 'The Moon and 'The Sun'. *Journal of Theory and Practice in Education*, *13*(4), 601-636.

Babaoğlu, G., & Keleş, Ö. (2018). 6. Sınıf Öğrencilerinin "Yıldız", "Gezegen" ve "Ay, Dünya ve Güneş" Kavramlarına Yönelik Algılarının Belirlenmesi. *Karaelmas Eğitim Bilimleri Dergisi*, *6*(1).

Baloglu Ugurlu, N. (2005). Ilköğretim 6. Sınıf Öğrencilerinin Dünya ve Evren Konusu İle İlgili Kavram Yanılgıları (Misconceptions of The Sixth Year Students of Primary Education on The Earth and The Universe). *GÜ, Gazi Eğitim Fakültesi Dergisi, 25 (1), 229, 246*.

Berber, N.,C. ve Güzel, H., (2009). Fen ve Matematik Öğretmen Adaylarının Modellerin Bilim ve Fendeki Rolüne ve Amacına İlişkin Algıları, Selçuk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 21, 87-97.

Bower, G. H. & Morrow, G. (1990). Mental Models in Narrative Comprehension, *Science*, 247, 44-48.

Brogt, E., (2007). Astronomy Education: Becoming a Hybrid Researcher., Journal of Research Practice, 3, 1, Article M2.

Canpolat, N., Pınarbaşı, T., Bayrakçeken, S. ve Geban, Ö., (2004). Kavramsal Değişim Yaklaşımı- III: Model Kullanımı, Kastamonu Eğitim Dergisi, 12, 2, 377-384.

Çepni, S. (2012). *Araştırma ve Proje Çalışmalarına Giriş* (6. Baskı). Trabzon: Celepler Matbaacılık.

Ekiz, D., & Akbaş, Y. (2005). İlköğretim 6. sınıf Öğrencilerinin Astronomi İle İlgili Kavramları anlama Düzeyi ve Kavram Yanılgıları. *Milli Eğitim Dergisi*, *165*, 61-78.

Franco, C. & Colinvaux, D. (2000). Grasping Mental Models, J.K.Gilbert & C.J. Boulter (Eds.), *Developing Models in Science Education*, Kluwer Academic Publishers, England.

Greca, I. M. and Moreıra, M. A. (2001). Mental, Physical and Mathematical Models in the Teaching And Learning of Physics. *Inc. Science Education*, 86, 106-121.

Gülseçen, H., (2005). Bilgi Teknolojisinin Astronomi Araştırmalarına ve Eğitim Öğretimine Etkileri, http://www.fedu.metu.edu.tr/UFBMEK-5/b_kitabi/PDF/Astronomi/Panel/t1-4d.pdf, Retriewed: 20 Mayıs 2018.

Güneş, B. Gülçiçek, Ç. & Bağcı, N. (2004). Eğitim Fakültelerindeki Fen ve Matematik Öğretim Elemanlarının Model ve Modelleme Hakkındaki Görüşlerinin İncelenmesi. *TÜFED-TUSED,* 1 (1), 35-45.

Güneş, B., Gülçiçek, Ç., & Bağcı, N. (2003). Fen bilimlerinde Kullanılan Modellerle İlgili Öğretmen Görüşmelerinin Tespit Edilmesi. *XII. Eğitim Bilimleri Kongresi*, 2023–2036, Antalya.

Harrison, A. G. & Treagust, D. F. (1996). Secondary Students' Mental Models of Atoms and Molecules: Implications for Teaching Chemistry, *Science Education*, 80 (5), 509-534.

Harrison, A. G. (2001). How do Teachers and Textbook Writers Model Scientific Ideas for Students? *Research in Science Education,* 31, 401–435.

Hestenes, D. (2006). Notes for a Modeling Theory. In *Proceedings of the 2006 GIREP conference: Modeling in Physics and Physics Education* (Vol. 31, p. 27). Amsterdam: University of Amsterdam.

http://mufredat.meb.gov.tr/Dosyalar/201812312311937-FEN%20B%C4%B0L%C4%B0MLER%C4%B0%20%C3%96%C4%9ERET%C4%B0M%20PROGRAMI2018.pdf. Retriewed: 18.11.2018.

https://ridvansoydemir.wordpress.com/2013-fen-bilimleri-ogretim-programi/ Retriewed: 15.11.2018.

Kurnaz M. A. (2011). *Enerji Konusunda Model Tabanlı Öğrenme Yaklaşımına Göre Tasarlanan Öğrenme Ortamlarının Zihinsel Model Gelişimine Etkisi*. Yayınlanmamış Doktora Tezi, Karadeniz Teknik Üniversitesi, Trabzon, Türkiye.

Kurnaz, M.A. & Değermenci, A. (2012) 7. Sınıf Öğrencilerinin Güneş, Dünya ve Ay İle İlgili Zihinsel Modelleri. *Elementary Education Online*, 11(1), 137-150, 2012. *İlköğretim Online,* 11(1), 137-150. [Online]: http://ilkogretim-online.org.tr. Retriewed: 10.11.2018.

Kurnaz, M. A., & Değirmenci, A. (2011). Temel Astronomi Kavramlarına İlişkin Öğrenci Algılamalarının Sınıf Seviyelerine Göre Karşılaştırması. Mehmet Akif Ersoy Üniversitesi Eğitim Fakültesi Dergisi, Yıl 11, Sayı 22, Aralık 2011, 91 – 112.

Mulholland, J., & Ginns, I. (2008). College Moon Project Australia: Preservice Teachers Learning about The Moon's Phases. *Research in Science Education*, *38*(3), 385-399.

Nersessian, N. J. (1992). How do Scientist Think? Capturing The Dynamics of Conceptual Change in Science, In R. N. Giere (Eds.), *Cognitive Models of Science* (3-44). University of Minnesota Press, Minneapolis.

Norman, D., (1983). Some Observations on Mental Models, D. Gentner ve A. L. Stevens, Mental Models, Lawrence Erlbaum Associates, Hillsdale, İngiltere.

Özgül, S.G., B. Akman & M. Saçkes (2018). Çocukların Dünya'nın Şekli ve Gece-Gündüz Kavramlarına Yönelik Zihinsel Modelleri, *E-Uluslararası Eğitim Araştırmaları Dergisi,* Cilt: 9, Sayı: 1, 2018, ss. 66-82, DOI: 10.19160/ijer.379293.

Paton, R.C. (1996). On a Apparently Simple Modelling Problem in Biology. International Journal of Science Education, 18(1), 55–64.

Percy, J., R., 1998. Variable Stars in Astronomical Research, Education, and Development, Astrophysics and Space Science, 258, 357-365.

Plummer, J. D., Kocareli, A., Slagle, C., Diane, J., Kocareli, A., & Slagle, C. (2014). Learning to Explain Astronomy Across Moving Frames of Reference : Exploring the Role of Classroom and Planetarium-Based Instructional Contexts, 693(October 2016). http://doi.org/10.1080/09500693.2013.843211.

Rapp, D. (2005). Mental Models: Theoretical Issues for Visualizations in Science Education, John K. Gilbert (Eds.), *Visualization in Science Education* (43-60). Netherlands.

Sakallı, S., 2008. İlk ve Ortaöğretimde Astronomi Uygulamaları, Yüksek Lisans Tezi, Ankara Üniversitesi, Fen Bilimleri Enstitüsü, Ankara, Türkiye.

Subramaniam, K. & Padalkar, S. (2009). Visualisation and Reasoning in Explaining the Phases of The Moon. *International Journal of Science Education,* 31(3), 395–417.

Suzuki, M. (2003). Conversations About The Moon with Prospective Teachers in Japan. *Science Education*, 87(6), 892–910.

Timur, S., Karatay, R., & Timur, B. (2013). 2005 ve 2013 Yılı Fen Dersi Öğretim Programlarının Karşılaştırılması. *Adıyaman Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, *2013,* (15).

Trumper, R. (2001). A Cross-College Age Study of Science and Nonscience Students' Conceptions of Basic Astronomy Concepts in Pre-service Training for High-School Teachers, *Journal of Science Education and Technology*, 10(2), 189-195.

Trumper, R. (2003). The Need for Change in Elementary School Teacher Training—a Cross-College Age Study of Future Teachers' Conceptions of Basic Astronomy Concepts, *Teaching and Teacher Education*, 19, 309–323.

Trundle, K. C., Atwood, R. K. & Christopher, J. E. (2006). Preservice Elementary Teachers' Knowledge of Observable Moon Phases and Pattern of Change in Phases. *Journal of Science Teacher Education*, 17, 87–101.

Tunca, Z. (2005). Türkiye'de İlk ve Ortaöğretimde Astronomi Eğitim ve Öğretiminin Dünü, Bugünü, *www. fedu. metu. edu. tr/UFBMEK-5/b_kitabi/PDF/Astronomi/Panel/t1-3d. pdf*. Retrieved: 20.10. 2018.

Ünal, G. ve Ergin, Ö., (2006). Fen Eğitimi ve Modeller, Milli Eğitim Dergisi, 171, 188-196.

Van Driel, J. H. & Verloop, N. (1999). Teacher Knowledge of Models and Modelling in Science. *International Journal of Science Education,* 21 (11), 1141-1153.

Van Driel, J. H. & Verloop, N. (2002). Experienced Teachers' Knowledge of Teaching and Learning of Models and Modelling in Science Education. *International Journal of Science Educatio,* 24 (12), 1255-1273.

Vosniadou, S., & Brewer, W. F. (1992). Mental Models of the Earth: a Study of Conceptual Change in Childhood. *Cognitive Psychology*, *24*, 535–585.

Vosniadou, S., & Brewer, W. F. (1994). Mental Models of the Day/Night Cycle. *Cognitive Science*, *18*, 123–183.