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AN INVESTIGATION INTO THE EFFECTS OF PLANETARIUM-SUPPORTED TEACHING ON 6TH-GRADE STUDENTS' MENTAL MODELS ABOUT THE SOLAR SYSTEM

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Abstract: This study aims to investigate the effects of science teaching supported using the planetarium on mental models of 6th-grade students. This study was conducted in the first semester of the 2018-2019 school year in a province in the west of Turkey. In this study, 39 6th-grade middle school students participated. Data were collected using a mental model test developed by the researchers of this study. The lessons were taught to the experimental and control groups based on the 2018 Science Class Curriculum. In addition, activities were performed with the experimental group with a mobile planetarium one week after the teaching of the subject was finished. Data obtained from the mental model test were analyzed, taking the descriptions and visualizations of the students into account and categorized into primitive, synthesis and scientific mental model. The findings suggest that planetarium supported teaching in the experimental group is more effective on mental models of the students compared to teaching in the control group.

Key words: Astronomy education, mental model, mobile planetarium**.**

1. Introduction

Planetariums are structures that help better learning of astronomy and space science, wherein the sky is projected onto a dome-shaped screen using an optic projector with realistic simulations. Planetariums are divided into two types, stationery and mobile planetariums. Stationary planetariums have semi-spherical screens with their projectors placed in the middle of the hall. Seats are placed so that the visitors can watch the screen and the show comfortably (Lacin Simsek, 2011). On the other hand, mobile planetariums are semi-spherical travelling planetariums that can be inflated in a short time. A mobile planetarium consists of semi-dome shaped inflatable material, projector, fisheye and special digital computer. Mobile planetarium services are provided by some companies today and they may be hired for a wide range of projects, including fairs, shopping centers and festivals, when necessary. Thanks to its easy installation, it can be installed in the schoolyard or multi-purpose saloon of the school upon appointment and students can make use of it. Thus, mobile planetariums may be hired for regions where there are no stationary planetariums, as they are easy to install and can be installed anywhere. They give the students in the regions where there are no stationary planetariums a chance to learn the space and secrets of space. Moreover, they avoid parents' consent and travel costs required in the case of stationary planetariums.

It has been observed that research on practice-based and non-classroom environments play a significant role in the field of astronomy along with the effectiveness of astronomy which has been increasing recently (Carsten-Conner, Larson, Arseneau and Herrick, 2015; Colombo, Silva and Aroca, 2010; Fisher, 1997; Gillette, 2013; Mallon and Bruce, 1982; Petrie, 2013; Plummer, 2009; Ridky, 1974; Sontay, Tutar and Karamustafaoglu, 2016; Thornburgh, 2017; Turk and Kalkan, 2015). For example, it was concluded in a study by Carsten-Conner et al. (2015) that use of mobile planetariums contributed to the knowledge of students on astronomy, whereas the studies by Mallon and Bruce (1982), Sumners and Reiff (2004), Thornburgh, (2017) led to conclude that planetariums could be utilized for developing a positive attitude toward astronomy. In addition, it was concluded in the study

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by Thornburgh (2017) that planetarium shows were found attractive also by teachers, and they were pleased with the interest of their students in this kind of activity. Besides, it was observed in Gillette (2013) and Turk and Kalkan's (2015) studies that the planetarium enhanced the learning of students.

Planetariums are one of the environments which arouse curiosity and excitement for the students and help them see the space up closer and learn the mysteries of it (Lacin Simsek 2011). Communicating accurate and precise knowledge on astronomy to the students is important and previous research shows that planetariums are more effective in acquiring accurate and precise knowledge about astronomy in a short time compared to classrooms (Mallon and Buruce 1982; Plummer 2009; Turk, 2010). There is evidence in the literature that there are many measurement tools to find out the status of the students in the field of astronomy, including achievement tests, interview forms and mental model tests (Gorecek Baybars and Can 2018; Kurnaz and Degermenci 2012; Sontay et al. 2016; Turk 2010). An overall review of the studies in the literature leads us to deduce that measurement tools like academic achievement tests, interviews and interview forms play a significant role for the researchers to observe the existing situations or examine the effects of activities which are performed in addition to teaching and that mental model tests have come into prominence since 2011 (Harman, 2017; Kurnaz and Degermenci, 2012). A mental model is a whole of facts, images and actions individuals create in their minds. Thus, it is quite challenging to find out what the individual's mental model is, how it is created and what it means (Kayhan, 2010). This is because mental models are limited to individuals' conceptions of the world and they can be developed and used based on the belief of the individuals (Franco and Colinvaux, 2000). Mental models are mental representations created by individuals in consequence of cognitive processes (Vosniadou and Brewer, 1992; Vosniadou and Brewer, 1994).

This study aims to investigate the effects of planetarium supported science teaching on the mental models of students. Within this context, the research question of this study are as follows:

What are the effects of planetarium supported science teaching on the mental models of students about the subject of 'Solar System' taught at 6th-grade? In addition, answers to the following sub-problems were sought.

- ✓ What are the effects of the teaching given in the experimental group on mental models of 6th-grade students about the solar system?
- ✓ What are the effects of the teaching given in the control group on mental models of 6th-grade students about the solar system?
- ✓ Are there any differences between the effects of the teaching given in experimental and control groups on mental models of 6th-grade students about the solar system?

This study is expected to contribute to the field in certain aspects. First of all, an activity has been designed within the scope of this study by taking the points to consider in out-of-school learning environments into account. In addition, this activity involves utilizing a mobile planetarium. As noted above, planetariums are not everywhere, and using stationary planetariums comes with many responsibilities. Teachers can perform the activity performed within the scope of this study in their own schools or classrooms. Moreover, this study investigates the effects of planetariums, one of the non-classroom environments, on mental models of students. The findings obtained in this study are also expected to provide information on whether out-of-school learning environments serve as an effective means of improving mental models related to astronomy concepts.

2. Method

2. 1. Research Design

The quasi-experimental design with a pre-test - post-test control group was used in this study. Quasi-experimental design involves a comparison of two groups taking specific variables into consideration (Büyüköztürk, Kılıç Çakmak, Akgün, Karadeniz and Demirel, 2016). An attempt was made to create two identical groups based on the scores obtained by the students on the pre-tests.

2.1.1. Participants

Convenience sampling was used, which is based on avoiding the loss of money, work, and time of the researcher. There were four 6th-grade classes in the school where this study was conducted. One experimental and one control group was selected among the 6th-grade classes who participated in this study. Pretest results of the groups were considered for selecting the experimental and control group. The study group of this research comprised of 39 students studying at a state school of a middle socio-economical level located in Menteşe county of Muğla Province (a province in western Turkey) in the fall semester of 2018-2019 School Year. Out of 39 students, 19 constituted the control group and 20 constituted the experimental group.

2.1.2. Data Collection Tool and Data Collection

Data were collected using the Mental Model Test (MMT) developed by researchers. Before starting to develop the test, the 6th-grade Science Lesson Curriculum for the year 2018 (applicable curriculum) was examined. "Solar system and eclipses" was the first chapter to be studied according to the curriculum. This chapter consists of two subjects. Only the "Solar System" is handled within this study. Under this subject, the headings solar system, basic features of planets, satellites of planets, asteroids and meteors are taught. The mental model test was designed to include students' descriptions and visualizations of the solar system, considering topics and titles. Opinions of a physicist were taken for content validity. Necessary arrangements were made in line with the opinions of the physicist and a preliminary pilot study was conducted with 30 eighth grade students. A preliminary pilot study was intended to determine to what extent the data collection tool was clear and understandable. Thus, it was checked whether the students understood the items and answered them. A pilot study for the mental model test was conducted in the spring semester of 2017-2018 school year with 103 eighth grade students (different from the preliminary pilot study). Following the pilot study, a reliability analysis of data collection was carried out. Moreover, it was determined that one class hour (40 minutes) was required for both preliminary pilot and pilot study and for answering the mental model test. The Mental Model Test, consisting of 14 open-ended items (see Appendix A), was developed by the researchers to assess students' conceptual understandings of astronomical phenomena.

Because there are no stationary planetariums in Muğla and for the reasons relating to its cost and responsibility, a mobile planetarium which can be hired for science festivals was contacted. Subsequently, the researcher examined the studies in the literature and searched which teaching strategies could be used before, during, and after the planetarium visit and what could the strengths and weaknesses be. Subsequently, draft plans for the planetarium's activity were prepared and presented to experts for analysis. The planetarium activity plan was finalized in accordance with expert opinion.

Before starting teaching, based on permissions obtained and communication established with school management, four 6th-grade branches of the school were given a mental model test in the first week of the school year. Pretests were analyzed and out of two branches that have close mental models, one branch was determined as a control group and the other as an experimental group. Science teacher, after necessary information, accomplished teaching experimental and control group the "Solar System" within a period scheduled according to Science Teaching Curriculum for the year 2018. The control group was given a post-test one week after the end of teaching. The experimental group, additionally, performed planetarium activity in the schoolyard. Planetarium activity was planned to take place in three stages (before the visit-during the visit-after the visit) and performed accordingly. Before the visit, students in the experimental group were delivered a short presentation on the planetarium. The presentation explained to students what a planetarium is and for what purposes it is used, its benefits and types and informed them about its features giving examples of planetariums in Turkey and in the world. It also informed the students about the points they need to pay attention to when they are at the planetarium. During the visit, the students were presented two films in accordance with targeted achievements about the solar system, contents of the course-book and the students' age group. The first film introduced to students' planets in order, starting from dwarf planet Pluto, the farthest planet from the sun, which is not a planet any more to Mercury, the closest planet to the sun. In addition, the first film provided students with the information on which planets have satellites and names of their satellites, whether planets have rings, the structure of planets, in other words, substances they are made up of, category of planets (terrestrial, gaseous, inner planet, outer planet), whether they have atmospheres, the direction of rotation of planets, their temperatures and distance to the sun as well as their close appearances. The second film gave information about the concepts of sun, meteor and asteroid. The students nearly travelled around the celestial objects, saw them closer and learned about every celestial body. The students had information spending a certain time for each celestial body, both through computer presentation and explanations of the expert. The second film provided students with information both audio and visual that the sun is a medium-sized star, a natural source of light and heat for the earth and that eight planets revolve around the sun in a specific orbit. It also presented audiovisual information to students explaining that piece of rock that burns when it enters the earth's atmosphere is called a meteor and that large and small pieces of rocks that are smaller than planets and revolve around the sun are asteroids. During the visit to the planetarium, a handbook (A Handbook of Sky Friend) was designed, which prioritizes students not to miss the movie presentation and fill it easily (Figure 1).

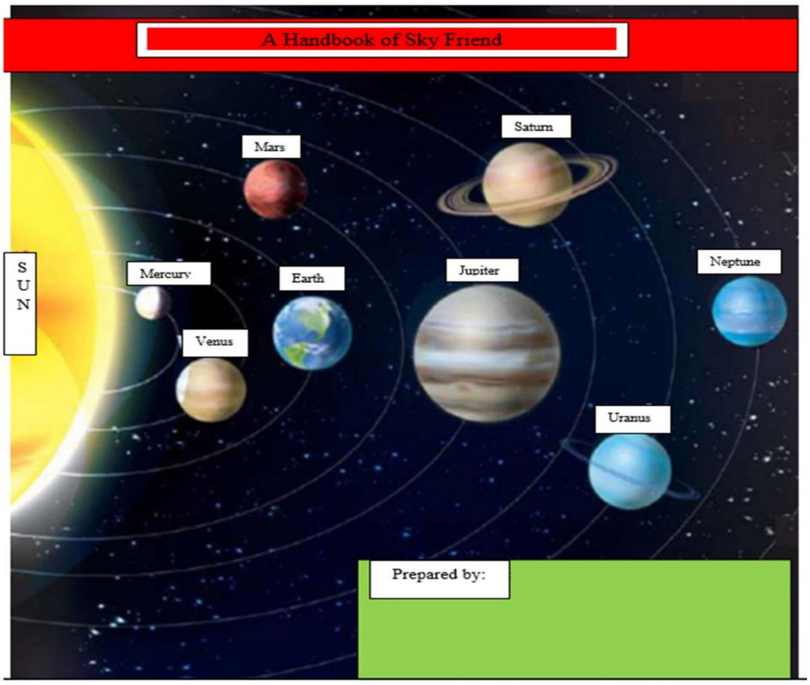


Figure 1. *Handbook of Sky Friend-Outer Cover*

Separate sections and text boxes were created in the handbook for each celestial body. There were choices which students could tick based on the features the celestial body given in the text box had, and spaces were left for the students to write down any features they heard or saw about the related celestial body (Figure 2). The students were given a 15-minute free time after the film. Meanwhile, students asked questions about the planetarium and activity to the teacher, researcher and expert using the question-answer method. The planetarium visit took two hours in total. After the visit, two post-planetariums visit activities were planned. These activities were named game (I know and play) and poster (Sky Friend) activities.

For the game activity, 32 question cards were prepared so that each card included one question. In this activity, the player rolls the dice and moves on. The questions in boxes are related to subjects of astronomy they studied in the class, and they observed in the planetarium. In poster activity, the students are required to prepare posters under the headings (Inner planets, Outer planets, Terrestrial Planets, Gaseous Planets and Solar System) determined by the researcher. For the students to design posters, cardboards, scissors, glue and color pens were supplied by the researcher. Each student group made a presentation in the classroom on the poster designed. The experimental group was subjected to a post-test one week after the planetarium activity with the experimental group.

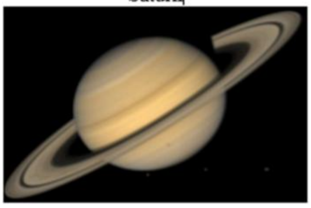
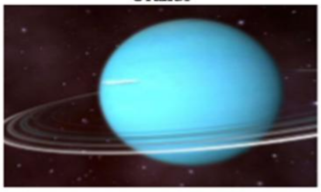
Jupiter 	Terrestrial planet ( )	Gaseous planet ( )
	Inner planet ( )	Outer planet ( )
	Has a ring ( )	No ring ( )
	Satellite number:	
	Other features	
Saturn 	Terrestrial planet ( )	Gaseous planet ( )
	Inner planet ( )	Outer planet ( )
	Has a ring ( )	No ring ( )
	Satellite number:	
	Other features:	
Uranus 	Terrestrial planet ( )	Gaseous planet ( )
	Inner planet ( )	Outer planet ( )
	Has a ring ( )	No ring ( )
	Satellite number:	
	Other features:	

Figure 2. *Handbook of Sky Friend-Inner Page Example*

2.1.3. Data Analysis

Data of mental model tests were analyzed in three categories, taking the research in the literature into consideration: scientific, synthesis and primitive model (Gorecek Baybars and Cil, 2019; Harman, 2017; Kurnaz and Degermenci, 2012; Vosniadou and Brewer, 1992). The category into which students' mental models fell was determined by evaluating together the descriptive and visualization questions asked of students for each concept. Mental models of students who gave information of scientific nature concerning both description and visualization of the concept were considered as a scientific model; mental models of students who gave information of unscientific nature about only one of description and visualization were considered as synthesis model and mental models of students who gave information of unscientific nature concerning both description and visualization were considered as a primitive model.

3. Findings

In this section, findings related to sub-questions are reported under separate headings for each celestial body. In addition, examples of answers of students were given under the headings. For example, EG1: refers to the experimental group pretest student numbered 1.

3.1. Mental Models of Students about Sun

Mental models of students obtained through analysis of the 1st / 1st and 2nd / 2nd questions in the mental model test are given in Table 1.

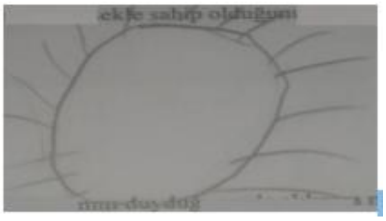
Table 1. *Mental models of the students about the sun*

Mental Model Category	Experimental Group				Control Group			
	Pre-test		Post-test		Pre-test		Post-test	
	f	%	f	%	f	%	f	%
Scientific Model	-	-	11	55	-	-	-	-
Synthesis Model	20	100	9	45	19	100	19	100
Primitive model	-	-	-	-	-	-	-	-

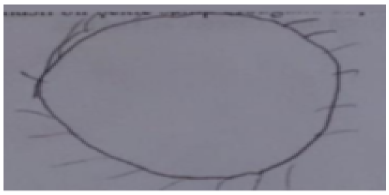
Note: *f = number of students; % = percentage.*

An examination of Table 1 reveals that all the students in experimental and control groups had, before teaching, synthesis mental model. Table 1 shows that according to post-test results, 55% of the 20-student experimental group had a scientific model after teaching, whereas 45% of the group had a synthesis model. Post-test results of the control group showed that all the students had a synthesis mental model.

CG3 (*Example of the synthesis model): The sun rises in the morning and gives off light.*



EG16 (*Example of the scientific model): It is a very hot star with layers, which is the source of light and heat for earth. It is a medium-sized star.*



3.2. Mental Models of the Students about Earth

Mental models of students obtained through analysis of the 3rd / 3rd and 4th/ 4th questions in the mental model test are given in Table 2.

Table 2. *Mental models of the students about earth*

Mental Model Category	Experimental Group				Control Group			
	Pre-test		Post-test		Pre-test		Post-test	
	f	%	f	%	f	%	f	%
Scientific Model	-	-	7	35	-	-	-	-
Synthesis Model	20	100	13	65	19	100	19	100
Primitive model	-	-	-	-	-	-	-	-

It is observed in the examination of Table 2 that all the experimental and control group students, before teaching, had synthesis mental model and this did not change for the control group even after teaching. According to Table 2, a percentt of 35% of the students in the experimental group had a scientific model, whereas 65% of the same group had synthesis mental model after teaching.

EG12 (*Example of the scientific model):*

"It is the only planet where living creatures exist. Its only natural satellite is the Moon. It is a terrestrial planet — in other words, an inner planet. 70% of its surface is covered with water and 30% consists of continents."

3.3. Mental Models of Students about Moon

Mental models of students obtained through analysis of the 5th and 6th questions in the mental model test are given in Table 3.

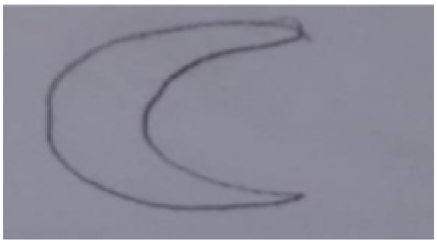
Table 3. *Mental models of the students about moon*

Mental Model Category	Experimental Group				Control Group			
	Pre-test		Post-test		Pre-test		Post-test	
	f	%	f	%	f	%	f	%
Scientific Model	-	-	11	55	-	-	-	-
Synthesis Model	20	100	9	45	19	100	19	100
Primitive model	-	-	-	-	-	-	-	-

Table 3 shows that all students from–the experimental and control group, before teaching, had a synthesis mental model and this did not change for the control group even after teaching. After teaching, 55% of the students in the experimental group had a scientific model, whereas 45% of the group had synthesis mental model according to the table.

EG16 (*Example of the synthesis model):*

The satellite of earth reflects the light from the sun. 3/4 of it is covered with water.



3.4. Mental Models of Students about Planet

Mental models of students obtained through analysis of the 7th / 7th and 8th / 8th questions in the mental model test are given in Table 4.

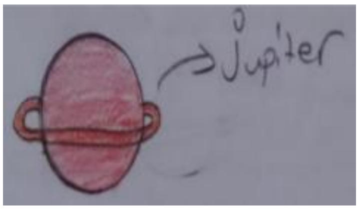
Table 4. *Mental models of the students about planet*

Mental Model Category	Experimental Group				Control Group			
	Pre-test		Post-test		Pre-test		Post-test	
	f	%	f	%	f	%	f	%
Scientific Model	-	-	-	-	-	-	-	-
Synthesis Model	10	50	14	70	9	47.4	14	73.7
Primitive model	10	50	6	30	10	52.6	5	26.3

Table 4 shows that 50% of the students in the experimental group had a primitive mental model and 50% had synthesis mental model before teaching. On the other hand, after teaching, 70% of the same group had synthesis and 30% had a primitive mental model. According to Table 4, as for control group students, before teaching, 47,4% had a synthesis mental model and 52,6% had a primitive model. However, after teaching, 73.7% of the group had a synthesis model and 26,3% had the primitive model.

CG14 (*Example of the synthesis model):*

All planets, stars, sun, earth, moon.



3.5. Mental Models of the Students about Meteor

Mental models of students obtained through analysis of the 9th / 9th and 10th / 10th questions in the mental model test are given in Table 5.

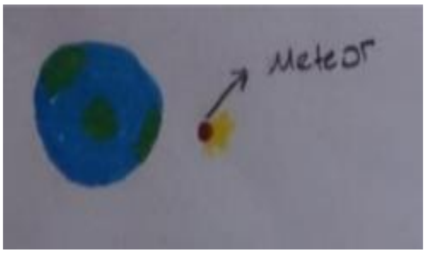
Table 5. *Mental models of the students about meteors*

Mental Model Category	Experimental Group				Control Group			
	Pre-test		Post-test		Pre-test		Post-test	
	f	%	f	%	f	%	f	%
Scientific Model	-	-	8	40	-		-	-
Synthesis Model	12	60	8	40	10	52.6	9	47.4
Primitive model	8	40	4	20	9	47.4	10	52.6

Table 5 shows that, in the pre-test, 60% of the students in the experimental group had a synthesis mental model and 40% had a primitive mental model. After the intervention (post-test), 40% of the students demonstrated a scientific mental model, 40% remained at the synthesis level, and 20% still had a primitive model. Table 5 also shows that 52.6 % of the students in the control group had a / the synthesis mental model and 47.4% of the group had a / the primitive mental model according to pre-test results. However, 47.4% of the group had the synthesis model and 52.6% had the primitive mental model according to post-test results.

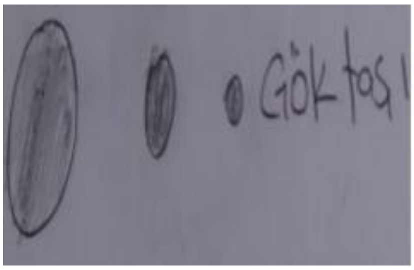
EG12 (*Example of scientific model)*

Pieces of rock that enter the earth's atmosphere and start to burn.



CG18 (Example of the primitive model):

A planet which is a satellite.



3.6. Mental Models of the Students about Asteroid

Mental models of students obtained through analysis of the 11th / 11th and 12th /12th questions in the mental model test are given in Table 6.

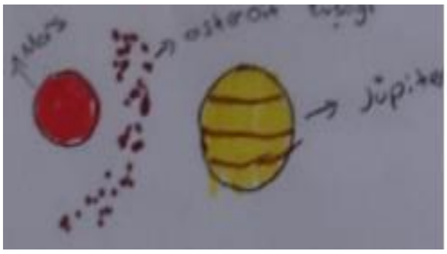
Table 6. *Mental models of the students about asteroids*

Mental Model Category	Experimental Group				Control Group			
	Pre-test		Post-test		Pre-test		Post-test	
	f	%	f	%	f	%	f	%
Scientific Model	-	-	4	20	-	-	-	-
Synthesis Model	6	30	12	60	-	-	10	52.6
Primitive model	14	70	4	20	19	100	9	47.4

As seen in Table 6, prior to the intervention, the majority of students in the experimental group (70%) demonstrated a primitive understanding of asteroids, while the remaining 30% exhibited synthesis-level models. After the planetarium-supported instruction, there was a noticeable shift: 20% reached the scientific model category, 60% moved to synthesis, and only 20% remained at the primitive level. Table 6 reveals that all control group students initially held primitive mental models. Following the conventional instruction, however, a slight improvement was observed, with 52.6% shifting to the synthesis category, while 47.4% still remained at the primitive level. Notably, no students in the control group demonstrated scientific-level mental models either before or after the instruction.

EG12 (Example of the scientific model):

Pieces of rocks that are the residue of formation of the solar system and between Mars and Jupiter.



EG14 (Example of the primitive model):

Small pieces.

3.7. Mental Models of the Students about the "Solar System"

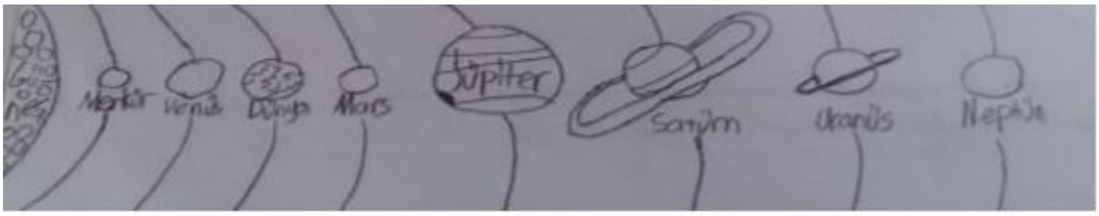
Mental models of students about the "solar system" obtained through analysis of the 13th / 13th and 14th / 14th questions in the mental model test are given in Table 7.

Table 7. *Mental models of the students about the solar system*

Mental Model Category	Experimental Group				Control Group			
	Pre-test		Post-test		Pre-test		Post-test	
	F	%	f	%	f	%	f	%
Scientific Model	-	-	2	10	-	-	-	-
Synthesis Model	-	-	18	90	-	-	2	10.5
Primitive model	20	100	-	-	19	100	17	89.5

According to Table 7, all students in the experimental group initially demonstrated a primitive mental model of the Solar System. However, following the planetarium-supported instruction, there was a substantial improvement: 90% of the students progressed to a synthesis-level understanding, and 10% reached the scientific model level. In contrast, the control group showed minimal change. While all students began with primitive models, only a slight shift was observed in the post-test: 10.5% moved to the synthesis level, but the majority (89.5%) remained at the primitive stage. This suggests that traditional instruction had limited impact on improving students' conceptual understanding of the Solar System.

EG17 (*Example of the synthesis model): Planet, system and combination come.*



In addition to descriptive percentages of student responses, chi-square tests were conducted to determine whether the differences in mental model distributions between the experimental and control groups were statistically significant. Cramér's V was calculated to assess the effect size for each concept. The results are presented in Table 8.

Table 8. *Effect Size Summary Table*

Concept	Chi-square (X^2)	p-value	Cramer's V	Effect Size Interpretat
Sun				Not applicable (Only 1 group had scientific models)
Earth	5.9	0.015	0.39	Moderate
Moon	11.97	0.0005	0.55	Large
Planet	0.0	1.0	0.0	None
Meteor	10.61	0.005	0.52	Large
Asteroid	6.08	0.048	0.39	Moderate
Solar System	31.8	1e-07	0.9	Very Large

As seen in the table, statistically significant differences were found for six out of seven concepts, with particularly large effects observed in the concepts of the Solar System ($\chi^2 = 31.80$, $p < .001$, $V = 0.90$), Moon ($\chi^2 = 11.97$, $p < .001$, $V = 0.55$), and Meteor ($\chi^2 = 10.61$, $p = .005$, $V = 0.52$). Only the Planet concept showed no significant difference ($\chi^2 = 0.00$, $p = 1.00$, $V = 0.00$), indicating that the instruction had a similar impact across both groups for that concept.

3. Conclusion

When we examine mental model pre-test results of students in experimental and control groups about the sun, earth and moon, we can see that students in both groups are in the category of synthesis model (Table 1-2-3). On the other hand, in the examination of the post-test results the sun, earth and moon topics, we can observe that students from the control group keep the synthesis mental model while some of the students from the experimental group move to the scientific model (Table 1-2-3). When we look at the answers given in the category of the synthesis model, we find that the students have false notions about the sun like or such as "The sun rises during the day and disappears at night" and "The sun is a planet". Students also have false notions about the moon "The moon rises at night", "The moon is a source of light" and "The moon is a planet". This shows similarity with several research results in literature. Vosniadou and Brewer (1994) examined mental models of children about the day-night cycle in their study conducted with the first, third and fifth-grade students. They found that children mistakenly believed that "The sun comes down behind the mountains, clouds obscure the sun". In her study, Senel Coruhlu (2013) discovered that seventh-grade students had the misconception that "the sun which is in the solar system is a planet". A similar point was noted by Iyibil (2010) for candidate teachers who studied in different programs. Kurnaz and Degermeci (2012) stated in their research that 7th grade students had a mental model at the level of a synthesis model about shapes and motions of the concepts sun, earth and moon. Harman (2017) found that mental models of 5th, 6th, 7th and 8th grade students about the sun, earth and moon were mostly at the synthesis model level. Although students encounter the Sun, Earth, and Moon frequently both in daily life and in earlier school years, it is notable that many of them do not progress beyond primitive or synthesis-level mental models. This indicates that repeated exposure alone is insufficient for developing scientifically sound understandings.

In examining the pre-test results of the students' mental model of the planet in the experimental and control groups, we find that the results are close in terms of the synthesis and primitive model categories (Table 4). It is observed in the examination of the post-test results there is a positive change from the primitive model to synthesis model in the case experimental group (Table 4). This overlaps studies in the literature (Emrahoglu and Ozturk, 2009; Gorecek Baybars and Can, 2018). Students tend to visualize a planet as resembling Saturn, likely due to its distinctive rings, which make it more recognizable. In addition, their verbal descriptions often rely on simply listing the names of planets, rather than explaining their properties or characteristics. Furthermore, planets are typically illustrated with a ring in drawings of students.

When we examine mental model pre-test results of students in experimental and control groups about the meteor, we observe that there are more students in the synthesis model category (Table 5). Students meet the concept of the meteor in the 6th-grade for the first time within the teaching curriculum. Since pre-tests are performed before teaching, the reason for this may be interpreted as students may learn about the concepts outside the school, as well. As can be seen in the post-test results, there is a positive change in the experimental group and some of the students moved to a scientific mental model. On the other hand, a negative change is noted in mental models of control group students about meteors (Table 5).

In the examination of mental model pre-test results of students in experimental and control groups about the asteroid, it is observed that experimental group students have the primitive model, whereas students from the control have a mental model at the primitive model level. This may be explained by the fact that the concept of an asteroid was unfamiliar to most students prior to the instruction, resulting in primitive mental models in both groups. Students in the experimental group have a synthesis model about asteroids that may be interpreted in a way that out-of-school learning took place. In the examination of mental model post-test results of students in experimental and control groups about the asteroid, it is seen that there is a positive change in both groups and some of the students in the experimental group have scientific mental model, while some of the students in the control group have synthesis mental model (Table 6).

When mental models of students about the solar system are examined (Table 7), it is seen that both the experimental and control group students have the primitive mental model according to the pre-test results. This result shows similarity with studies (Canales, Camacho and Cazares, 2013; Gorecek Baybars and Can, 2018; Jones, Lynch and Reesink, 1987) in the literature. It was found that students made irrelevant explanations in their descriptions about the solar system (e.g., energy system) while they drew spherical planets in order following the sun in their solar system drawings. In the examination of mental models of students about solar system (Table 7), it is observed that according to post-test results, experimental group students concentrate in the synthesis model category while few students are in the scientific mental model category. When the post-test results of the control group are examined, it is concluded that students have more of a primitive mental model, whereas few students take place in the synthesis mental model category.

In the overall evaluation of effects of the planetarium supported science teaching on mental models of students, positive changes are noted in post-tests (Table 1-2-3-4-5-6-7). As for the effects of teaching in the control group on mental models of students, positive changes for some astronomy concepts are observed (Table 5-6-7), while no changes are observed for some of them (Table 1-2-3-4). If a comparison is made between the experimental group and the control group, it is possible to assert that teaching in the experimental group is more effective on improving mental models compared to teaching in the control group. In addition to descriptive findings, inferential analyses provided further evidence of the effectiveness of the planetarium-supported instruction. Chi-square tests revealed statistically significant differences in post-test mental model distributions between the experimental and control groups for six of the seven astronomy concepts. The most notable effects were observed in the concepts of Solar System, Moon, and Meteor, with large to very large effect sizes (Cramér's V = 0.52–0.90). These results demonstrate that planetarium-supported instruction not only improves conceptual understanding at a descriptive level but also leads to statistically meaningful gains in students' mental model development. The lack of significant difference for the concept of "Planet" may suggest that this concept is already relatively familiar to students through prior exposure or informal learning sources.There may be several underlying reasons for this. The first reason may be the effects of activities performed during and after the planetarium visit. Students have an opportunity to refresh the knowledge they acquired in the lesson with the planetarium activity. According to Hanker (2008), refreshing knowledge and restructuring mental models in the light of new knowledge helps ensure the permanence of knowledge. Moreover, planetarium activity might have aroused curiosity and excitement for every student because of the reasons, including the absence of a stationary planetarium in Muğla and limited opportunity of benefiting from a planetarium. As a result, the students may have become eager to learn. Another reason may be that the planetarium activity was performed considering the points to be considered for out-of-school activities (before, during and after the activity). Additionally, the fact that planetariums appeal to multiple senses, concretize abstract scientific concepts, and provide meaningful learning could have contributed to improving mental models. Based on the results of this study, teachers and researchers may be recommended to utilize planetariums in teaching "Solar System." Teachers may be caused to positively affect students in comprehending the subject and improve their mental models using the activities designed within the scope of this research in teaching "Solar System." This study was conducted with the participation of 39 students. This study may be conducted on larger samples and at various educational levels for more comprehensive handling of the effects of teaching.

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Appendix A. Mental Model Test (English Version)

Name – Surname: ....
Gender: Female ( ) Male ( ) **Date:** ....
Class: ....

Note: There are no right or wrong answers. Please answer sincerely. Your handwriting, drawing quality, or spelling will not be evaluated.

✳ Instructions:

This test aims to explore your understanding of concepts related to astronomy. Please answer each question in writing, and provide drawings where required.

The Sun

1. What comes to your mind when you hear the word "Sun"? Please explain.
2. What kind of shape do you think the Sun has? Please explain by drawing.

The Earth

3. What comes to your mind when you hear the word "Earth"? Please explain.
4. What kind of shape do you think the Earth has? Please explain by drawing.

The Moon

5. What comes to your mind when you hear the word "Moon"? Please explain.
6. What kind of shape do you think the Moon has? Please explain by drawing.

Planets

7. What comes to your mind when you hear the word "Planet"? Please explain.
8. What kind of shape do you think a planet has? Please draw and indicate which planet you are depicting.

Meteor

9. What comes to your mind when you hear the word "Meteor"? Please explain.
10. What kind of shape do you think a meteor has? Please explain by drawing.

Asteroid

11. What comes to your mind when you hear the word "Asteroid"? Please explain.
12. What kind of shape do you think an asteroid has? Please explain by drawing.

Solar System

13. What comes to your mind when you hear the phrase "Solar System"? Please explain.
14. What kind of shape do you think the Solar System has? Please draw and indicate the celestial objects in your drawing.