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ACTIVITIES DESIGN OF MOVEMENTS AND PHASES OF THE MOON: SPATIAL SKILL AND ACADEMIC ACHIEVEMENT DEVELOPMENT

Abstract: The aim of this study is to examine the effects of activities developed on the subject of Moon Movements and Phases on the spatial skills and academic achievement of 5th-grade students. For this purpose, a mixed research method was used. In the quantitative dimension of the research, a quasi-experimental design with pretest-posttest control group was used, and in the qualitative dimension, interviews were conducted with the students in the experimental and control groups. The research was conducted with a total of 44 students attending 5th grade. The activities were prepared with the opinions of science teachers and field experts. In the research, two different measurement tools were used: Spatial Test Battery and The Achievement Test for Sun, Earth, Moon and Moon Movements and Phases. As a result of the analysis, no statistically significant difference was found between experimental and control groups in terms of achievement and spatial skills. In the analysis of qualitative data, content analysis was used. Accordingly, it was determined that the activities prepared for astronomy education by the researcher increased the spatial thinking skills of the students in the experimental group.

Keywords: Astronomy Education, Moon Movements and Phases, Science Education, Spatial Skill.

Introduction

Astronomy provides a universal understanding of space and depth for the use of all mankind. Therefore, countries now give great importance to space technologies, and from time to time, competitions in various fields leave their place to "space wars". In order to ensure the continuity of the developments, the current population needs qualified individuals.

Technological innovations and inventions arising from these needs and accepted as a turning point; caused change in economic, social and cultural fields. The change has deeply affected and continues to affect pre-established patterns, including individual habits. Education in particular is significantly affected by this change (Canlioglu, 2008; Demiralay & Karadeniz, 2009).

Spatial thinking, which is a way of thinking, requires knowing the relationships between measurement units, distance calculations, the basics of coordinate systems and the nature of space (National Research Council [NRC], 2006). It is synonymous with realizing where something is, where a place is, and how it relates to other places (Jo, 2011).

Spatial thinking is very important in education (Cuicatl-Cid, 2011). It is stated that science students have higher spatial skills compared to students studying a non-science field. It is indicated that those who are successful in physics and earth sciences are also successful in terms of spatial skills. For example, it was emphasized that if you want to be successful in physics course, spatial thinking is needed or taking a physics course will improve spatial thinking (Cuicatl-Cid, 2011). Understanding astronomical phenomena requires a complex spatial interpretation (Heywood, Parker, & Rowlands, 2013). In this context, it can be said that spatial thinking is also important for astronomy. Eratosthenes thought that the Earth was spherical from the shadow lengths in Alexandria and Syene, two cities in Egypt, and found the radius of the Earth by measuring the distance between the two cities. Likewise, astronomers constantly ask their students to conceptualize the work of Eratosthenes. They think students need spatial interpretation to learn this calculation (NRC, 2006). Another example can be given from the Solar System. Making decisions about orbits around the Sun by marking the path of the planets in the sky requires spatial visualization (Ingeborg, 2012).

In the literature, many studies with different age groups related to basic astronomy topics are found. Ozturk and Doganay (2013) examined the mental models and understanding of students about Earths' shape and gravity. Chen, Yang, Shen and Jeng (2007) tried to demonstrate the effectiveness of a virtual model related to the concept of Earth's movement in teaching. Hannust and Kikas (2007) examined the nature of astronomy knowledge and the exchange of knowledge during learning, for a total of 113 children aged 5-7. Sharp and Sharp (2007), on the other hand, conducted their research with children between the ages of 9-11 regarding knowledge acquisition and concept learning in astronomy. In addition to these studies, it is seen that the studies on the Moon and the movements of the Moon are in the literature. Parnafes (2012) examined misconceptions about Moon Phases. Trundle, Atwood, Christopher and Sackes (2010) tried to determine the effectiveness of the method of scientific inquiry into secondary school students' concepts about the Moon. Kucukozer (2008) reported the misconceptions of science teacher candidates' related Moon Phases. Mulholland and Ginns (2008) suggested that some astronomy concepts can be developed through teaching, but some misconceptions are very difficult to change. Jiwaji (2016) mentioned misconceptions in the literature and stated that astronomy has increased the interest in science and provided experiences that can eliminate errors regarding processes in nature. Stears, James and Good (2011) tried to reveal how teachers' conceptual understanding of astronomy developed with a training module and the reason for this change.

Despite the numerous researches on astronomy education, it is still a fact that students, teachers, prospective teachers and individuals who are not involved in any level of education need education. Unsolved learning and teaching difficulties remain for astronomy (Taylor, Barker, & Jones, 2003). Therefore, researchers are trying to integrate developing technology products with methods suitable for astronomy education and are looking for the best ways to solve the problem. As a result of the literature research; concepts such as Moon phases are intuitive and hard to learn, classroom activities such as the use of both visual and tangible models are needed to overcome these difficulties, models provide more explicit understanding of the concepts of astronomy, results such as researching how and at what stages of the curriculum concepts with more complex explanations should be taught rather than definition sentences. Besides, it has been revealed that more accurate and less complicated book images and representations are needed to express astronomy issues in writing, and that students need to raise their spatial thinking about the space in order to develop their daily life skills that can understand both drawings and impressions.

Since the distance and dimension perceptions of the learners are beyond their imagination and it includes a series of interesting phenomenon that they cannot encounter on Earth, they need to form the right configurations about the astronomy subjects they are highly interested in and curious about. Activities that will improve students' spatial skills and stimulants that will increase interest in the classroom environment and facilitate learning will enable students to get to know themselves better. Therefore, if a good engineer, astronomer, physicist, chemist, architect or scientist is to be trained in the future, the factors that stimulate the spatial skills of all students should be taken into consideration, and the educational process and the evaluation of the process should be planned accordingly. Therefore, science activities for astronomy education have been developed in this study. The reason for choosing astronomy subjects when preparing activities is because astronomy course is an area that requires abstract thinking and a strong spatial skill. With the study, it is expected that the students' astronomy achievements and spatial skills in the areas of surface development, block rotation and visual memory in the experimental group will be better compared to the control group. Accordingly, the research questions of the study were determined as follows:

(1) Do science activities, developed for astronomy education, have a positive effect on the spatial skills of 5th grade students?

(2) Do science activities, developed for astronomy education, have a positive effect on the astronomy achievement points of 5th grade students?

Method

Research Design

The research was conducted with a sequential explanatory mixed method. In the first dimension of the research, pre-test post-test quasi-experimental design with control group was used. In the second dimension, semi-structured interviews were conducted with students in order to obtain more in-depth information based on quantitative data.

Participants

In the study, a total of 44 students who studied in the 5th grade and taught by a science teacher who wanted to support the study voluntarily, were studied. There were 2 separate classes in the school where the study was conducted and these were equivalent to each other in terms of age and socioeconomic status. Demographic information was obtained from the school administration. One of these classes was randomly assigned.

Data Collection Tools

The Spatial Test Battery, developed by Center for Talented Youth of John Hopkins University and adapted to Turkish by Batdal-Karaduman (2012), was used to determine the spatial skill scores of 5th grade students. The Spatial Test Series is an integrated test consisting of three spatial subtests: Surface development, block rotation and visual memory. In order to determine the extent to which students made progress before and after the experimental study, The Achievement Test for Sun, Earth, Moon and Moon Movements and Phases was developed. This test consists of a total of 20 items. The Cronbach α reliability coefficient of the test, which was prepared by taking the opinions of 20 experts, was 0.70. After the implementation, an interview form was prepared for students to demonstrate how their spatial skills develop after implementation and to support the post test data.

Development of Activities for Astronomy

Before starting to develop activities, it was aimed to determine whether there is a need for a teaching material other than the national curriculum. For this purpose, national curricula, textbooks, international and national articles and theses were examined and interviews were made with science teachers. According to the interview results, the subjects that the students had the most difficulty in understanding were determined regarding the Sun, Earth and Moon and the

Movements and Phases of the Moon.

While designing the modules with the activities, it was decided to create 3 separate modules in order to carry out the applications in the experimental and control groups in a planned manner. The first of these is the "Teacher Guide", which includes lesson plans, activities in the subject content and answers to the activities in the students' workbooks. The reason why the teacher's guide is given as a separate module is because it guides the teacher who is implementing. The second module is the "Topic Booklet" that will be distributed to students as course material and includes the content, activities and worksheets. The subject booklet has been prepared to allow students to access the relevant content and to work with original activities. The last module is the "Student Work Booklet" which contains the activities and worksheets that the students are asked to do at home.

Implementation Process

The implementation process consists of a total of 3.5 weeks, total of 14 course hours. The lessons were taught in the experimental group by considering the lesson plans in the teacher's guide. In the experimental group it was taught with original activities which are not included in the national curriculum and can positively affect academic achievement with their spatial skills. For example estimating, drawing and modelling the position of the Sun, Earth and Moon by looking at the phase of any Moon; estimating, drawing and modelling the Moon phases on Earth by looking at the positions of the Sun, Earth and Moon in space; after a certain period of time between the phases of the Moon, predicting, drawing and modelling how the Moon will look from the Earth and how will be the positions of the Sun, Earth and Moon in space. In addition to these, activities related to the orbit of the Sun in the sky (daily and annual), the reason for the difference between the stellar moon and the synodic moon periods, the reason for the appearance of the same face of the Moon and the reason for the formation of the Moon phases. In the control group, study was conducted in a standard way in accordance with the relevant curriculum.

Analysis of the Data

Doubly MANOVA was used in the analysis of the data obtained from data of the achievement and spatial skill tests. In the analysis of interviews created for students after the implementation, video recordings and interview forms given to students were analyzed with content analysis.

Ethical Considerations

The research was carried out considering ethical principles. Necessary permissions were obtained from the relevant authorities during the entire data collection process and experimental implementation process. Practices were carried out in classrooms where a science teacher who wanted to participate voluntarily. The participants were informed that their personal information would not be shared. While presenting the findings, no information was given to offend the participants in any way. Attention was paid to the internal and external validity of the study.

Findings

Findings on Inferential Statistics

Statistics on multivariate analysis are given in Table 1.

Table 1. *Multivariate tests results*

Effect		Value	F	Hypothesis *df*	Sig.	Partial Eta Squared	Observed Power
Time*Group	Wilks' Lambda	0.95	0.970	2	0.388	0.045	0.207

As can be seen from Table 1, there is almost a medium-sized interaction in favour of the experimental group, although there was no statistically significant difference when the interactions of the variables between the groups (method) and within the groups (time) were significant (Wilks' Lambda = 0.95; $F(2, 41)=0.970$; $p>0.05$; Partial Eta Squared=0.045; Power=0.207). The results of the Mauchly's Test of Sphericity were examined to determine which independent variable the interaction that occurred in practice originated. When the results are examined, it is seen that the significance value is not calculated. This is because this test becomes meaningful if there are more than two measurements. In cases where the Sphericity assumption is broken, the possibility of making a Type 1 error increases. The results of the Greenhouse-Geisser test used to eliminate this problem are given in Table 2.

Table 2. *Tests of within-subjects contrasts*

		Type III SS	df	MS	F	Sig.	Partial Eta Squared
Time*Group	Achievement	60.266	1	60.266	0.326	0.571	0.008
	Spatial Skill	28.485	1	28.485	1.828	0.184	0.042

It is seen that the achievement and spatial skill scores of the students in different groups did not differ statistically before and after the implementation ($p>0.05$). However, when Eta Squared values are examined, the achievement scores are small; in spatial skill scores, it can be mentioned that there is a medium to small effect in practice. In practice, it is believed that the reason why difference is not statistically observed was due to the sample size. The insufficient number of students included in the research and control groups of the research is seen as a limitation of the research. How students' pre-test and post-test scores differ before and after the experiment is given in Figure 1.

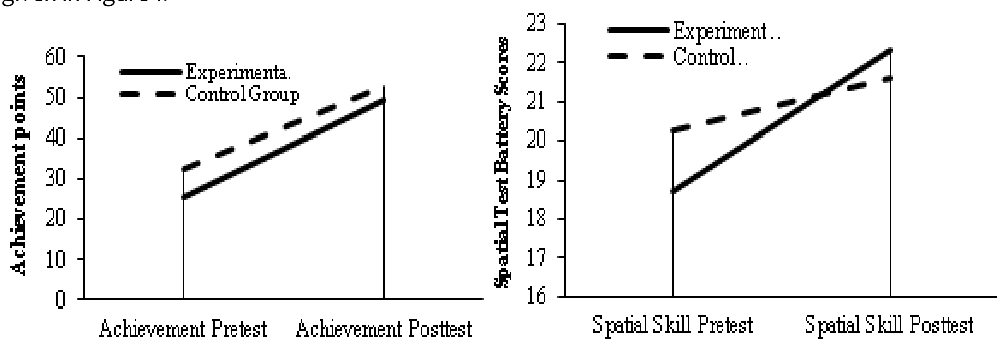

Figure 1. *Pre-test and post-test scores of students in the experimental and control groups*

Findings for the Qualitative Part of the Research

For the qualitative part of the research, A total of 12 students, 6 of whom were from the control group, were interviewed. The answers given by the students to the interview questions were analyzed by dividing them into different categories.

The reason why the same face of the Moon is constantly seen. The analysis of the answers given to this question was made by integrating the information and drawings written by the students on the interview form and the opinions they expressed in the video recordings. The answers given by the interviewed students regarding this issue are given in Table 3.

Table 3. *The answers given by the interviewed students to the first question*

	Student codes	Views
Experimental Group	E1	*"Ali loses time as he revolves around Ayse. Ali and Ayse's rotation periods around their axes must be the same."*
	E2	*"So as to Ali and Ayse to look face to face, their rotation period around their axes must be the same."*
	E3	*"Ali and Ayse have to move at the same speed. The Earth and Moon are already moving at the same speed."*
	E4	*"Ali must revolve at the same speed as Ayse to be able to see Ayse's face constantly."*
	E5	*"If the rotation periods are different, they cannot see face to face. They both have to rotate at the same period."*
	E6	*"Both must rotate at the same period."*
Control Group	C1	*"Ali's period of revolution around Ayse and period of rotation around its own axis must be the same."*
	C2	*"Ayse's rotation period around its own axis and Ali's period of revolution around Ayse should be equal."*
	C3	*"Ali's revolution and Ayse's rotation periods must be equal."*
	C4	*"The reason is that the Moon revolves around the Sun with the Earth."*
	C5	*"Ayse and Ali must rotate at the same time."*
	C6	*"The atmosphere of the Moon is thin."*

No student in the experimental group could make a correct explanation as to why the same face of the Moon is always seen from the Earth. "Why do we see the same face of the Moon?" When asked directly in the form of the question, it was seen that the children in the image given in the question 1 understand that which one represents the Moon and which represents the Earth, but they cannot make accurate explanations about how the Moon should move in order to see the same face of the Moon from Earth. It was also revealed that they thought that the 24-hour period of Earth's rotation is equal to the period of the Moon's rotation or revolution. Similarly, when the answers of the control group students were examined, it was seen that they gave similar answers with the experimental group. Only 1 student from the control group answered this question correctly. In this sense, it was seen that only the C1 coded student made the correct explanation and consistent with the question in the last achievement test and in the interview. When the students interviewed from the control group were questioned about how the Moon should move for the same face of the Moon to be seen from the Earth, the students with the codes C4 and C6, who could not express an opinion in written way, stated that the "Moon rotates around the Sun together with the Earth" and They made irrelevant statements on the subject as "thin moon atmosphere". The student with the code C5 could not make any explanation although the question was clearly repeated. In general, it was revealed that students who participated in the interview from both experimental and control groups made false explanations about the reason for seeing the same face of the Moon, as the Moon and Earth should move at the same speed and rotate simultaneously. Since the false explanations were similar in the experimental and control groups, the final achievement tests of the students interviewed from the experimental and control groups were examined and it was concluded that 4 people from the experimental group and 3 from the control group made the correct explanation of the problem related to the reason of seeing the same face of the Moon. Despite these results, only 1 out of the 12 students interviewed made the correct explanation for this question. In this sense, it can be said that the education given is not effective in understanding the reason of seeing the same face of the Moon.

Movement of the Sun, Earth and Moon relative to each other and their rotation and revolution. The second question of the interview form was written with the aim of questioning the students' knowledge about the movements of the Sun, Earth and Moon and the rotation and revolution period of these celestial bodies. In the "a" part of the problem, the students were asked to illustrate the Sun, Earth and Moon and show their directions of rotation and revolution. The drawings were examined by the researcher and it was determined whether the students made correct representations. In the part "b" of the problem, students were asked to show their drawings with play dough and flashlight. In the analysis of the part "b" of the 2nd question, the video recordings were examined and the conclusion was reached. In the part "c" of this question, the students were asked to tell the periods of the Sun, Earth, and Moon to return and rotate according to an observer from space and Earth. In the analysis of this part, video recordings were examined again. The data obtained from the students in the experimental and control groups regarding the Sun, Earth and Moon drawings are given in Table 4.

Table 4. *Analysis results of students in the experimental and control groups regarding the Sun, Earth and Moon drawings*

	Experimental Group							Control Group						
	E1	E2	E3	E4	E5	E6	*f*	C1	C2	C3	C4	C5	C6	*f*
The axial movement of the Sun	+	+	+	+	+	+	6	N	+	+	-	+	+	4
The axial movement of the Earth	+	+	+	+	+	+	6	+	+	+	+	+	+	6
The orbital motion of the Earth around the Sun	+	+	+	N	N	+	4	+	+	+	+	N	N	4
The axial movement of the Moon	+	+	+	+	+	+	6	+	+	+	+	N	+	5
The orbital motion of the Moon around the Earth	+	+	+	+	+	+	6	N	+	N	-	N	N	1
Motion of the Moon around the Sun	+	+	+	N	-	+	4	-	+	-	-	N	-	1
Total Correct Drawings							32	Total Correct Drawings						21

Note. f = Frequency of correct drawings, +: Correct answer, -: Wrong answer, *N*: Not indicated.

Accordingly, it was observed that students in the experimental group made better drawings than the control group. The student with the code E5 from the experimental group misinterpreted the movement of the Moon with the Earth around the Sun as if it were rotating round the Sun independently from the Earth. When the achievement test of this student was checked, it was seen that the student answered the question about this topic incorrectly in the final test. When we look at the drawings of the control group students, the orbit drawing was not seen, and all directions of movement were indicated by arrows. The students with the codes C1, C3, C4 and C6, just like the student with the code E5, drew the movement of the Moon around the Sun as if it were orbiting in a separate orbit independently from the Earth. The C4 coded student used serious false demonstrations in the direction of rotation of the Sun and the movement of the Moon. When the answers of these students to the question of the same subject were examined in the achievement test, it was seen that the students with the codes C1, C2 and C4 gave correct answers. In this case, it can be said that students with codes C1, C2 and C6 are inconsistent. In the part "b" of the 2nd question, the students in the experimental and control groups were asked to show the drawings they made in the part "a" of the 2nd question with play dough and flashlight. All students in the experimental group made accurate demonstrations about the movements of the Sun, Earth and Moon. When the students who did not show the directions of rotation and revolution in their drawings were asked to explain their drawings, it was observed that all but 1 made correct explanations. The E2 coded student showed the Earth's movement around the Sun clockwise, although his drawing and explanations are correct. In Table 12, the student with the code E5 corrected the error while showing the play dough, although he made a mistake while drawing the movement of the Moon around the Sun with the Earth. When we look at the demonstrations of the students in the control group, it was revealed that they continued their mistakes consistent with their drawings. Particularly, C6 coded student showed the movement of the Moon around the Sun independently from the Earth despite being asked again. In the last part of the second question, the students were asked questions about the rotation and revolution period of the Sun, Earth and Moon and the answers given are shown in Table 5.

Table 5. *Views of the experimental and control group students regarding the rotation and revolution periods of the Sun, Earth and Moon*

	Experimental Group							Control Group						
	E1	E2	E3	E4	E5	E6	*f*	C1	C2	C3	C4	C5	C6	*f*
The rotation period of the Earth around its axis	+	+	+	+	+	+	6	+	+	+	+	1 year	+	5
The revolution period of the Earth around the Sun	+	+	+	+	+	+	6	+	+	+	+	1 year	24 hours	4
The rotation period of the Moon around its axis (According to an observer looking from space or Earth)	+	+	1-2 week	1-2 week	+	+	4	+	+	+	1 day	+	1 year	4
The revolution period of the Moon around the Earth (According to an observer looking from space or Earth)	+	+	+	+	+	+	6	+	+	1 week	+	24 hours	+	4
The period that the Moon revolves around the Sun with the Earth (According to an observer looking from space or Earth)	+	+	+	+	+	+	6	+	+	+	+	+	+	6
Total Number of Correct Explanations							28	Total Number of Correct Explanations						23

Note. f = Frequency of Correct Explanation, +: Correct Answer.

It was observed that the number of correct explanations of the experimental group regarding the rotation and revolution period of the Sun, Earth and Moon was higher than the control group. However, it is seen that the students in the experimental group have problems in the period that the Moon rotates around its own axis. When the post tests of the students having this problem were examined, it was seen that the student with the code E3 answered both questions correctly about the rotation and revolution period of the Sun, Earth and Moon, and the student with the code E4 answered both questions incorrectly. When the answers of the control group students are analyzed, it is seen that there are big problems regarding the period. When the achievement tests of the students having problems related to the subject were examined, it was observed that the students with the codes C3 and C5 did all of the questions related to the periods incorrectly, the student with the code C4 did both questions correctly and the student with the code C6 answered one of these questions incorrectly. In this sense, it can be said that the experimental group is better than the control group, so the education given has a positive effect in the experimental group.

Drawing the position of the Sun, Earth and the Moon from the given photograph of the phase of the Moon, the order of the phases of the Moon, the intervals between phases and the causes of the phases of the Moon. Articles 1 and 2 of the 3rd question in the interview form were asked to measure the ability of the students to determine the position of the Sun, Earth and Moon and show it by drawing while the Moon phase of the photograph given. Articles 4 and 5 were asked to question students about the order of the phases of the Moon and the intervals between the principal and intermediate phases, and item 6 was asked to measure the extent to which the phases of the Moon could be explained. The answers given by the students regarding the 1st and 2nd items of the 3rd question are given in Table 6.

Table 6. *The skills of the students to determine the position of the Sun, Earth and Moon while experiencing the phase of the Moon whose photograph is given*

	Experimental Group							Control Group						
	E1	E2	E3	E4	E5	E6	*f*	C1	C2	C3	C4	C5	C6	*f*
To be able to say the name of the phase of the Moon in the 1st photo selected	+	+	+	-	+	+	5	+	-	+	-	-	-	2
To be able to say the name of the phase of the Moon in the 2nd selected photo	+	+	-	+	+	+	5	+	-	+	-	-	-	2
To be able to draw the position of the Sun, Earth and Moon during the phase of the Moon in the 1st photograph selected.	+	+	-	*	+	*	3	+	*	+	-	-	-	2
To be able to draw the position of the Sun, Earth and Moon during the phase of the Moon in the 2nd photograph selected.	+	+	*	+	+	-	4	-	*	+	-	-	-	1
Total Correct Answers							17	Total Correct Answers						7

Note. f = Frequency of Correct Answers, + = Correct Answers - = Wrong Answers. *These students could not answer the Moon's phase in the photograph shown. However, they were able to accurately draw the position of the Sun, Earth and Moon according to their wrong answer.

When Table 6 is examined, it is seen that the experimental group is better in the ability to predict the positions of the Sun, Earth and Moon from the phase of the given Moon compared to the control group. It was observed that students with the codes E1 and E2 did not make the incorrect drawings in any photograph. The student with the code E3 drew the waning gibbous moon phase after the full moon as the waxing gibbous before the full moon and gave the answer as the first quarter instead of last quarter. She/he made the drawing as first quarter. According to the wrong answer he/she gave, the drawing of this student was correct. The student with the code E4 called the waning crescent as waxing crescent and drew the position of the Sun, Earth and Moon during the waxing crescent correctly. E4 and E6 coded students were found to be compatible with the answers of their drawings, even if they misrepresented the name of the phase of the given Moon. When we look at the control group, it was seen that students other than C1 and C3 codes had problems with the names and drawings of the phases of the Moon. In the achievement test of the experimental and control groups, the answers given to the question asked in the format used in the interview form were examined. It is seen that the students with the codes E6 and E4 from the experimental group and the whole of the control group gave the incorrect answer to this question. In this sense, it can be said that the ability of the experimental group students to imagine the positions of the Sun, Earth and Moon from the phase of the given Moon is better than the control group.

Articles 3, 4 and 5 of the 3rd question were asked to measure students' knowledge about the order of the phases of the Moon, the intervals between phases and the classification of the main and intermediate phases. It is given in Table 7 created for this purpose.

Table 7. *Students' responses regarding the order of the phases of the Moon, the intervals between phases and the classification of the principal and intermediate phases*

	Experimental Group							Control Group						
	E1	E2	E3	E4	E5	E6	*f*	C1	C2	C3	C4	C5	C6	*f*
The order of Moon phases	+	+	-	-	-	-	2	+	+	-	+	-	-	3
The time between phases	+	+	+	+	+	+	6	-	-	-	-	-	-	0
Classification of the principal and intermediate phases	+	+	+	+	+	+	6	+	+	+	+	-	-	4
Total Correct Answers							14	Total Correct Answers						7

Note. f = Frequency of Correct Answers, *+* = Correct Answers, - = Wrong Answers.

It was seen that the experimental group had more accurate numbers compared to the control group regarding the order of the phases of the Moon, the time between phases and the classification of the principal and intermediate phases. However, it is seen that the students of the experimental and control groups have deficiencies related to the order of the phases of the Moon. In both groups, order errors such as confusing the phases of the first quarter and the last quarter with the crescent and gibbous Moon phases occurred. On the other hand, it can be said that the answers of the experimental group, such as classifying the principal and intermediate stages and telling the intervals between the stages, are quite good compared to the students in the control group. When the answers given by the experimental and control group students in the achievement test related to the order of the phases of the Moon were examined, it was observed that the students with the codes E5 and E6 from the experimental group and C4 and C6 codes from the control group gave the incorrect answers to these questions. The answers given by experimental and control group students to the 6th item of the 3rd question are given in Table 8.

Table 8. *The answers given by the interviewed students regarding the causes for the formation of the phases of the Moon*

	Student Codes	Views
Experimental Group	E1	*"Phases of the Moon occur when the Moon revolves around the Earth."*
	E2	*"The Sun illuminates the Moon as the Moon moves around the Earth. Light is reflected from the Moon to the Earth."*
	E3	*"Because the Moon is revolving around the Earth*
	E4	*"It occurs because the Moon is both rotating around itself and revolving around the Earth."*
	E5	*"It occurs when the Moon revolves around the Earth"*
	E6	*"When the Moon revolves around the Earth, the Sun rays hit the Moon and reflect Earth. We see that part of the Moon as bright. So the main reason for the formation of the phases of the Moon is that the Moon revolves around us."*
Control Group	C1	*"Rotation movement of the Moon and its orbital motion around the Earth are equal periods."*
	C2	*"Earth and Moon have equal revolution periods."*
	C3	*"The Moon is revolving around the Earth."*
	C4	*"The Moon is both rotating around itself and revolving around the Earth."*
	C5	*"The main reason for the formation of the phases of the Moon is that the Earth is revolving around the Sun and the Moon is revolving around the Earth."*
	C6	*"The Moon is both revolving around the Earth and the Sun."*

When the answers of the experimental and control group students in Table 10 are analyzed, it was seen that the closest answers to the correct answers were given by the experimental group. When we look at the control group, very different answers are seen. Apart from the answer given by the student with code C3, it is seen that other answers are not correct. When we look at the answers given by the experimental group to the achievement test, it is seen that the students with the codes of E1 and E2 and the C1, C2 and C5 codes of the control group gave the correct answers. It is noteworthy that the students in the experimental group made more accurate explanations than the control group, although they answered the question about the formation of the phases of the Moon in the test of achievement.

Estimating the phases of the Moon from the position of the Sun, Earth and Moon.

It was tried to determine the abilities of the Moon in the position of the Sun, Earth and Moon given in two dimensions for the students in the experimental and control groups included in the interview. Two-dimensional visuals prepared for this question were asked to the students and the answers of the students regarding the phase of the Moon were received (Table 9).

Table 9. *Answers regarding the interviewed students' predictions about the Moon phases from the positions of the Sun, Earth and Moon*

	Student Codes	Moon Phase	Student's answers
Experimental Group	E1	New moon, waxing crescent, first quarter	All were answered correctly.
	E2	Last quarter, first quarter, waning gibbous	All were answered correctly.
	E3	Last quarter, waning crescent, full moon	All were answered wrongly.
	E4	Waxing gibbous, full moon, waning crescent	All were answered correctly.
	E5	First-quarter, new moon, waning gibbous	All were answered correctly.
	E6	Waxing gibbous, last quarter, full moon	All were answered correctly.
Control Group	C1	Last quarter, waning gibbous, waxing crescent	The answer was given as first quarter instead of last quarter.
	C2	First-quarter, waning crescent, last quarter	The answer was given as first quarter instead of last quarter.
	C3	Full moon, new moon, last quarter	All were answered correctly.

C4	Waxing crescent, new moon, full moon	All were answered correctly.
C5	First-quarter, last quarter, full moon	All were answered wrongly.
C6	Waxing gibbous, new moon, waning crescent	All were answered wrongly.

As can be seen from Table 9, all the students in the experimental group were able to correctly predict the phases of the Moon from the location of the Sun, Earth and Moon, except the student with the code E3. When we look at the control group, it was revealed that the students with the codes C5 and C6 make false predictions, while the others were not as successful as the students in the experiment group. In the achievement test used in the research, there are 5 items to predict the phases of the Moon from the position of the Sun, Earth and Moon. When the responses of the students were analyzed, it was seen that the students with the code E1 in the experimental group responded to four of these five items, the students with the codes E2 and E3 responded three of them and the students in the other experimental group answered two of them correctly. When we look at the control group, it was seen that students with the codes C1, C2 and C4 were able to answer three of the five questions mentioned, and the others answered two of them. The students in the experimental group have been more successful than the control group in both achievement tests and interviews.

Drawing the Phases of the Moon in Two dimensions based on the three-dimensional model.

In the last of the interview questions, the skills of transferring the phases of the Moon to the paper plane were measured based on a model observed by the students. For this purpose, a ping-pong ball is hung in a cardboard box and holes are made on the sides of the box. A flashlight aligned with the ping-pong ball is placed on one side of the box. The students were asked to draw the phase of the Moon they saw and write their names on the interview forms while looking through the numbered holes. Findings obtained for this are given in Table 10.

Table 10. *Data on the interviewed students' skills to draw the phases of the Moon from the three-dimensional model*

	Student Codes	The shape of the Moon phase			The name of the Moon phase			
		1st blank	2nd blank	3rd blank	1st phase	2nd phase	3rd phase	*f*
Experimental Group	E1	+	+	+	-	+	-	4
	E2	+	+	+	+	+	+	6
	E3	+	-	+	-	-	-	2
	E4	+	+	+	-	+	-	4
	E5	+	+	+	-	+	-	4
	E6	+	+	+	+	+	+	6
	Total Correct Answers							26
Control Group	C1	+	+	+	+	+	+	6
	C2	+	+	+	+	-	+	5
	C3	+	+	+	+	+	+	6
	C4	+	-	+	-	-	-	2
	C5	+	+	+	-	+	-	4
	C6	-	-	-	+	+	+	3
	Total Correct Answers							26

Note. f = Frequency of Correct Answers, + = Correct Answers, - = Wrong Answers.

According to the data in Table 10, it is remarkable that the experimental group is more successful in transferring the shape of the Moon phases to the paper. However, it is seen that the control group is more successful than the experiment group regarding the names of the phases. The most important deficiencies that are noticeable in both experimental and control groups are confusing the phases of the first quarter and last quarter with the phases of full moon and new moon. Although the E1 coded student in the experimental group showed quite high success in the other items of the interview questions, in this section he confused the phases of the first quarter and the last quarter. Another point to focus on is that the student with the code E6 is very successful in this part. Likewise, the C6 coded student in the control group, although not performing well in the questions of the phases of the Moon, wrote all the phase names of the Moon correctly in this part. In the achievement test, the answers given by the students in the experimental and control groups were examined for the item prepared for this question. It was observed that students with code E1, E3 and E4 from the experimental group and students with code C1 and C6 from the control group responded correctly to the relevant item in the achievement test. It was observed that students with code E1, E3 and E4 from the experimental group and students with code C1 and C6 from the control group responded correctly to the relevant item in the achievement test.

Discussion and Conclusions

In the research, an original achievement test on the movements and phases of the Moon and modules about how this subject should be taught to develop spatial skills has been developed. It is thought that these materials will contribute to the literature and can be used by everybody.

It was observed that there was a difference between the pre-test and post-test achievement scores of the students in favor of the control group. Although there was no statistically significant difference when the post-test achievement scores of both groups were compared, it was observed that the post-test achievement score of the experimental group increased more than the post-test achievement score of the control group. In other words, the difference between the pre-test and post-test achievement scores of students in the experimental group is higher than the difference in the control group. As a result of the inferential statistics, it has been revealed that the education given has an impact, albeit at a low level.

When we consider the literature, it is seen that the result of the research is supported and the use of different methods, materials and environments in teaching astronomy increases the success levels of the participants in different age groups (Colombo, Aroca, & Silva, 2010; Frede, 2008; Kucukozer, Bostan & Isildak, 2010; Kucukozer, Korkusuz, Kucukozer, & Yurumezoglu, 2009; Ndihokubwayo, Uwamahoro, & Ndayambaje, 2018; Trumper, 2006; Trundle, Atwood, & Christopher, 2002, 2006, 2007; Turk, 2010). For example, Trundle et al. (2007) found that there was a significant increase in students' post-test results in their experimental research with 4th-grade students. Apart from these researches, Bakas and Mikropoulos (2003) suggested that students use concrete learning environments to interact with while understanding the movements of celestial bodies such as the Sun, Earth and Moon, and using the Sun, Earth and Moon model in teaching basic astronomy subjects. Fanetti (2001), on the other hand, reported that concretization using the model in the teaching of moon-related subjects did not yield effective results. However, Sarrazine (2005) proved that enriched learning environments have an important effect on the development of secondary school students concerning the Moon and the phases of the Moon. Skala, Slater and Adams (2000) have demonstrated the effectiveness of cooperative learning in the processing of astronomy lessons compared to traditional methods, and Kallery (2011) showed that students performed significantly about the positions of the Sun and Earth relative to each other as a result of video teaching. It is thought that the experiments carried out centuries ago, such as Eratosthenes determining the radius of the Earth, are important in understanding astronomy (Feigenberg, Lavrik, & Shunyakov, 2002). Accordingly, the literature in general; It provides information that different methods, models and drawings made by students increase the success of astronomy.

It is seen in the literature that different researches have been done on spatial ability and its dimensions. When studies focusing on spatial ability and 3-dimensional thinking skill are examined, it is seen that the researches using the experimental method increase the spatial ability. Clements, Sarama, Battista and Swaminathan (1997) stated that students' education in enriched environments has a positive effect on the development of spatial skills. Bayrak (2008), on the other hand, found that the test scores obtained as a result of the instruction carried out with the visual method were stronger and more meaningful than the previous ones. Yolcu (2008) used concrete materials and computer applications to develop the spatial skills of 6th-grade students and found that this program was effective in developing spatial skills. Yildiz (2009) enriched the learning environment by using virtual simulation to improve the spatial skills of 5th-grade students and observed that students' spatial visualization and mental rotation abilities increased significantly compared to the control group. Tentomas (2010) aimed to increase the spatial skills of students with three-dimensional geometry and the lesson plans they designed and showed that if the unit or lesson plans are prepared well, they increase the spatial skills of the students. Kok and Anass (2019) stated that traditional methods using textbooks and drawings are not suitable for spatial visualization skills and showed that a 3D software causes an increase in visualization skills. Accordingly, the literature supports that activities such as modelling, drawing and game used in the experimental group increase spatial thinking skill.

Considering the strong relationship of astronomy with science achievement and spatial skills together, it is thought that the results of our research are important to raise individuals who will do useful works at a universal level.

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