A LIVELY ELECTRONIC COMPENDIUM OF RESEARCH, NEWS, RESOURCES, AND OPINION

Astronomy Education Review

2009, AER, 8, 010104-1, 10.3847/AER2009006

The Effect of 3D Computer Modeling and Observation-Based Instruction on the Conceptual Change Regarding Basic Concepts of Astronomy in Elementary School Students

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Received: 12/19/08, Revised: 01/29/09, Published: 04/14/09, Corrected: 08/19/09

Abstract

This study has examined the impact of teaching certain basic concepts of astronomy through a predict-observe-explain strategy, which includes three-dimensional (3D) computer modeling and observations on conceptual changes seen in sixth-grade elementary school children (aged 11–13; number of students: 131). A pre- and postastronomy instruction conceptual survey and interviews were used to evaluate the conceptual changes. In the analysis of the data, the methodology used was the classification of explanations with similar meanings under the same categories. The most significant finding of the study was that instruction supported by observations and 3D computer modeling was significantly effective in bringing about conceptual change and learning.

1. INTRODUCTION

Students come into science classes with their own ideas about the natural world. These ideas are sometimes naive and nonscientific, although they may make sense to the students. Such ideas are called misconceptions, alternative conceptions, or childrens' science and often go unarticulated and unchanged in the science classroom (Gilbert and Watts 1983). In the field of science education, studies conducted over the last 40 years have established that students have certain misconceptions in many subjects (Pfundt and Duit 2006). One of the main topics of research concerns studies conducted on the phenomena and concepts of astronomy. It can be seen that most of these researches have explored the phenomena of the shape of the Earth, day and night, the seasons, eclipses, and the phases of the Moon. While in many countries of Europe and in the United States, studies on these topics are quite numerous, there are only a limited number and only some new examples of such studies in Turkey. Since 2004, elementary school curriculums in Turkey have been reformulated based on constructivist learning theory. With this transformation, terms such as "misconception" and "conceptual change" have been included in these school programs. In the new curriculum, teaching astronomical phenomena and concepts begins in kindergarten and continues over the course of the elementary school years. Whereas teachers are warned about possible misconceptions that students may have about each topic, no information is offered to them about a strategy that they might adopt to bring about conceptual change and eliminate such misconceptions (Küçüközer *et al.* 2008). For example, even though, on the subject of astronomy, information about misconceptions has been included in the program ("Some students may think that the seasons occur because the Earth is coming closer or moving away from the Sun as it revolves around it" or "Students should be warned about the misconception of thinking that the dark parts seen in the phases of the Moon are caused by the shadow of the Earth"), it can be seen that teachers are provided this information only as a warning. Under the circumstances, the present study may provide guidance to teachers in this context.

In this context, the purpose of this study is to probe elementary school students' conceptions about astronomical phenomena before and after instruction and to determine the effect of teaching activities on conceptual change.

1.1. The Theoretical Framework

The theoretical framework of this study is based on constructivist and conceptual change theories. Constructivism teaches that humans actively construct or create understanding from their experiences by using their already existing conceptual framework. Knowledge, then, is constructed within certain social and material contexts in interaction with existing knowledge and new experiences or ideas. Furthermore, our knowledge about the world is not a mere copy of the reality outside us; it is our tentative construction about it. Scientific truth is not absolute but relative and so may change over time. (Driver and Bell 1986; Widodo, Duit, and Müller 2002). For researchers who have subscribed to constructivism, students' existing knowledge and understanding is of the greatest importance because of how this can affect the learning process. Learning is accepted as a process whereby the student's existing foundation of knowledge is reconfigured with new knowledge. The results of many studies have shown that, however, students' existing knowledge is often in conflict with scientific concepts and as such, displays resistance to change. This has led researchers to seek answers to the question of how to change misconceptions into scientific concepts. In this context, various authors have developed theories of conceptual change (Tyson *et al.* 1997). Among the theories set forth, that of Posner *et al.* (1982) was the one to attract the greatest attention from science educators. This theory asserts that four conditions must be present to effect conceptual change. These include *dissatisfaction* with one's current conception, followed by the degree to which the new concept is deemed *intelligible*, *plausible*, and *fruitful*. There are some teaching strategies suggested by researchers for the realization of conceptual change. Scott, Asoko, and Driver (1992) have identified two main groupings of special teaching strategies to promote conceptual change. The first group is based upon cognitive conflict and the resolution of conflicting perspectives while the second group builds on learners' existing ideas and extends them through, for example, metaphors and analogies. Furthermore, a teaching strategy formulated by White and Gunstone (1992), based upon the assertions of constructivism and predict-observe-explain (POE) strategy, was used to provide conceptual conflicts that facilitated conceptual change. In the first step of this strategy, students make predictions about a situation or an event and then they conduct an experiment or carry out observations and articulate their results from the observation stage. Finally, they are asked to explain the similarities or differences between the predictions and the observation results. Although the use of POE tasks has been reported extensively in literature, the number of studies in which computer-supported POE tasks were used is quite limited (Kearney and Treagust 2001).

1.2. Primary School Students' Conceptions about Basic Astronomical Phenomena

A number of studies carried out in different countries for different age groups focused on basic astronomical phenomena (Pfundt and Duit 2006). The results of many studies show that not only children (Baxter 1989; Dove 2002; Sharp 1996; Trumper 2001a; Valanides *et al.* 2000; Vosniadou and Brewer 1992, 1994), but also adults (Küçüközer 2007; Parker and Heywood 1998; Trumper 2000, 2001b) have misconceptions and difficulties in explaining basic astronomical phenomena. In fact, Trumper (2006) says, "*future elementary school teachers have more alternative conceptions about basic astronomy concepts than typical junior high school students*."

Some results of studies conducted with primary school students about astronomical phenomena such as as day and night, the seasons, the phases of the Moon, and the stars are presented in Table 1.

Table 1. Some misconceptions of elementary school students established through studies related to astronomy

Phenomena	Misconceptions (Literature)
Day-Night	• It becomes night because the Sun goes behind the mountains" (Baxter 1989; Vosniadou and Brewer 1994). • When the clouds block the Sun it becomes night (Baxter 1989; Vosniadou and Brewer 1994; Sharp 1996). • It becomes night when the Moon blocks the Sun" (Baxter 1989; Sharp 1996; Dunlop 2000). • The Earth's revolving around the Sun" (Baxter 1989; Dunlop 2000; Trumper 2001a; Dove 2002). • The Sun's revolving around the Earth" (Baxter 1989; Dunlop 2000; Trumper 2001a).
Seasons	• Distance to the Sun—when it is closer it becomes summer and when it is farther away it becomes winter—(Baxter 1989; Sharp 1996; Dunlop 2000; Trumper 2001a). • Changes of the distances between the Earth, the Sun, and the Moon" (Trumper 2001a) • Earth's revolving around the Sun" (Dunlop 2000). • The Earth faces the Sun during the summer and faces the Moon during the winter" (Sharp 1996). • Blocking of intensive winter clouds by the sunlight (Baxter 1989; Dunlop 2000). • The moon's position either in front of the Earth or behind it (Sharp 1996). • During the summer days the amount of the sunlight increases (Dunlop 2000). • Cold planets sour some certain amount of the light coming from the Sun (Baxter 1989). • In order to make it summer or winter the Sun goes to the other side of the Earth (Baxter 1989).
The phases of the Moon	• The shadow of the Earth causes phases of the Moon—confusing the eclipse with the phases—(Baxter 1989; Sharp 1996; Dunlop 2000; Trumper 2001a; Barnett and Morran 2002; Trundle *et al.* 2007). • Blocking of clouds of some parts of the Moon (Baxter 1989; Sharp 1996; Dunlop 2000). • Shadow of a planet causes phases of the Moon (Baxter 1989). • Shadow of the Sun causes phases of the Moon (Baxter 1989; Trumper 2001a). • During the same day different phases of the Moon can be seen from different cities (Dunlop 2000).
Stars	• "Stars do not move" (Dunlop 2000). • "The Sun is not a star" (Sharp 1996; Dunlop 2000). • "Stars are such beings that they only stay during the night in the sky" (Sharp 1996). • Stars are closer to the Earth than the planets are (Sharp 1996; Dunlop 2000). • Stars are smaller than the Earth (or the Moon and the Sun) or same size (Sharp 1996). • Stars are like the planets (Dunlop 2000).

As can be seen in Table 1, elementary school students in different countries have similar misconceptions about day and night, the seasons, the phases of the Moon, and the stars. In fact, these misconceptions have not only been observed in elementary school students but also in high school and university students as well (Küçüközer 2007).

1.3. Teaching of Astronomy

Topics of astronomy attract the interest of almost everyone. This interest may be said to have increased in recent years as a result of NASA's launching of manless space probes to Mars and because of the satellites that are being sent off for different purposes by various countries and the many telecasts of channels such as National Geographic, which have presentational programs on space. In addition, eclipses that occur at certain times of the year as well as shooting stars have always had a share in stimulating this growing interest. The teaching of astronomical phenomena and concepts is quite often problematic in formal curriculums. This is because presenting three-dimensional (3D) space by making use of two-dimensional diagrams (Parker and Heywood 1998), using misleading diagrams (Ojala 1997), employing books in which diagrams and texts do not correspond (Pena and Gil Quilez 2001; Vosniadou 1991), and using ambiguous terminology (Parker and Heywood 1998) may have a puzzling effect on students' understanding and may lead them to generate their own conceptions. A look into studies conducted in recent years shows that researchers are acknowledging student misconceptions and supporting teaching practices through activities that promote conceptual change. Such studies have used teaching tools that include 3D modeling, demonstrations, class discussion, and projects. The results of some studies in this context have been presented below.

Bakas and Mikropoulos (2003) carried out an empirical research on 102 secondary school students (aged 11–13) about the movements of the Earth and Sun, the day and night cycle, and the change of seasons. They designed and developed an educational tool (3D virtual environment) that would help children overcome their misconceptions. All the students in the study (100%) offered scientifically acceptable explanations for day and night after instruction. Concerning the alternation of the seasons, most of the students (85%) claimed that the angle of the Sun's rays to the Earth is the cause of the phenomenon. The researchers pointed out that, after interaction with the virtual environment, students created fewer, more concrete, and scientifically accepted mental models.

Trundle *et al.* (2007) investigated 48 fourth-grade students' knowledge of observable phases of the Moon and patterns of change, as well as their conceptual understanding of the cause of the Moon's phases, before and after special instruction. The instruction involved evaluating empirical evidence that was contrary to their beliefs, using conceptual models or analogies and demonstrations. Prior to instruction, 39 children indicated they expected the phases of the Moon to appear in a predictable sequence, and nine students indicated the phases would appear in random order. After instruction, all 48 children indicated that phases of the Moon appeared in a predictable sequence, and most attempted to draw both a waxing and waning sequence. The children made 460 Moon drawings before instruction and only 232 (50.4%) of those shapes were scientific representations. After instruction, 771 Moon drawings were made, and 720 (93.4%) of those shapes were scientific. The results of the postinstruction interviews also were surprisingly positive, as eight out of ten students showed excellent scientific understanding of the cause of the Moon phases and the other two students showed a partial scientific understanding with no evidence of alternative conceptions on the cause of the Moon's phases. Barnett and Morran (2002) investigated 14 fifth-grade students' alternative framework phases of the Moon and eclipses before and after instruction using project-based, space-science curriculum. Before instruction, the interviews revealed that six of the 14 students had similar fragmented understanding and hence were categorized as having incomplete understanding according to their rubric. Several students were unable to articulate a description of the shape of the Earth's shadow or the role that the Earth's shadow played during the occurrence of a lunar eclipse. In addition, several students also had difficulty in articulating the position of the Moon during a lunar eclipse and why we see the phases of the Moon. Student misconceptions about the phases of the Moon, were: "phases of the Moon are caused by the Earth's rotation," "the phases of the Moon are caused by the shadow of the Earth." After instruction, several students developed a solid understanding of the similarities and differences between eclipses and phases of the Moon. Five of the students developed a sound understanding while four students developed partial understanding. Five students still had incomplete understanding at the conclusion of the course. Generally, students could articulate their understanding more concisely and were seen to have understood the causes of the Moon's phases and were able to explain the difference between an eclipse and full Moon.

Kikas (1998) carried out a longitudinal study of the influence of education on children's (aged 10 to 11 years) ability to define and explain astronomical concepts (equator, axis, orbit, day/night cycle, and seasonal changes). The activities in the lessons were grouped into five major blocks: checking homework, introducing new material, reading the book, checking new material, and solving problems. The results indicated that after 2 months, students were able to recall the scientific explanations given in the lessons, but that after 4 years they could only provide everyday and inaccurate explanations. Kikas (1998) pointed out that the scientifically correct answers of the fifth-graders did not mean that they had understood the phenomena; the correct answers only repeated the wording in the books, which the students were able to provide without fully understanding them. The impact of teaching where stress is on memorizing thus may seem great shortly after learning, but such teaching is not effective in a longer perspective.

A statistical comparison was carried out between textbook-based instruction and instruction that takes into consideration students' preconceptions about the shape of Earth and the day and night cycle with 63 fifth-grade students in Cyprus, Diakidoy and Kendeou (2001). This comparison included explanations and demonstrations designed to maximize the plausibility of the scientific concepts presented as well as of class discussions. Results indicated that the experimental instruction had a strong positive effect on learning and understanding. In contrast, the standard instruction did not lead to significant pretest/post-test gains.

2. METHODOLOGY

With this study it was aimed to determine the participants' ideas about the concepts and phenomena of day and night, the seasons, the phases of the Moon, the stars, shooting stars, and the brightest star prior to and after the teaching. Teaching activities and materials are prepared to promote conceptual change. The most important feature of these activities is that they are based on POE-supported 3D modeling and observation. Data collection, analysis, and the activities prepared are mentioned below.

2.1. Data Collection and Analysis

In this study, a qualitative approach was used to understand and describe students' conceptions about astronomical phenomena before and after instruction since qualitative methods could provide detailed data that offered the possibility of better understanding and describing students' comprehension of concepts.

The sampling of 131 students (aged 11–13) in the study was chosen from two different secondary schools located in the city center of Balıkesir (Turkey). An "astronomy concepts test (ACT)" was prepared on the basis of related literature (Küçüközer 2007; Trumper 2001a) for the purpose of determining elementary sixth-grade students' conceptions before and after instruction. The ACT contained questions on the concepts and phenomena of day and night, the seasons, the phases of the Moon, the stars, shooting stars, and the brightest star. The content validity of the ACT was established by consulting with three academics specializing in physics education. Each class took approximately 30–40 min to answer the questions in the ACT.

In addition, semistructured individual interviews were conducted with eight students after the instruction. During the interview, if students displayed a change in their concepts for the questions they answered before and after the instruction, to define the reason for the change these students were asked the question, "The answer you gave to this question before is different from your answer now; why did you change your mind?"

The students' conceptions about astronomical phenomena before and after instruction were thus determined from an analysis of the answers given to each question on the ACT. Explanations that were similar to each other were classified under the same categories, and the data collected under these categories were analyzed (Driver and Erickson 1983). The categorizations were mostly based on conceptions that had been reported in previous studies. Moreover, students' pre- and post-teaching explanations about each question were grouped as scientific and nonscientific, their frequencies calculated and analyzed with χ^2 technique.

2.2. Teaching Activities

According to the constructivist theory, on which this study was based, students' existing knowledge and understanding are of the greatest importance during the learning process. This theory suggests that knowledge is constructed within certain social and material contexts in interaction with existing knowledge by a person. In preparation of the teaching activities and materials, students' existing knowledge was taken into account and POE strategy, one of the special teaching strategies to promote conceptual change, was used in the form of 3D computer modeling (as animations) and observations in activities.

Teaching lasted for 5 weeks (three 40 min class hours a week). In this study, only the results obtained from the concepts and phenomena of day and night, the seasons, the phases of the Moon, the stars, shooting stars, and the brightest star were presented. Additionally, sky observations in one night a week for 3 weeks were performed with each class.

During the teaching, in the activities about the phenomena of day and night, the seasons, and the phases of the Moon POE-supported 3D modeling was used. The 3D computer models were prepared using a 3D STUDIO MAX 8 (trial) program in order to describe 3D space and astronomical scales more accurately. This program is a professional 3D animation rendering and modeling software package used mostly by design visualization specialists, game developers, and visual effects artists. In Table 2, an activity about the phenomena of the phases of the Moon can be seen (Küçüközer 2008). In general, the activities are performed as this: first, the students were asked to make predictions about a phenomenon; then, using 3D modeling, existence of the phenomenon was observed; and finally, the students were asked to explain the differences and the similarities between their predictions and their observations. In the prediction and explanation phase the students worked in groups to discuss their ideas and come to a conclusion. In the observation phase they watched the 3D models presented by their teacher. Thereafter, they were asked to discuss and make conclusions about the 3D models they watched.

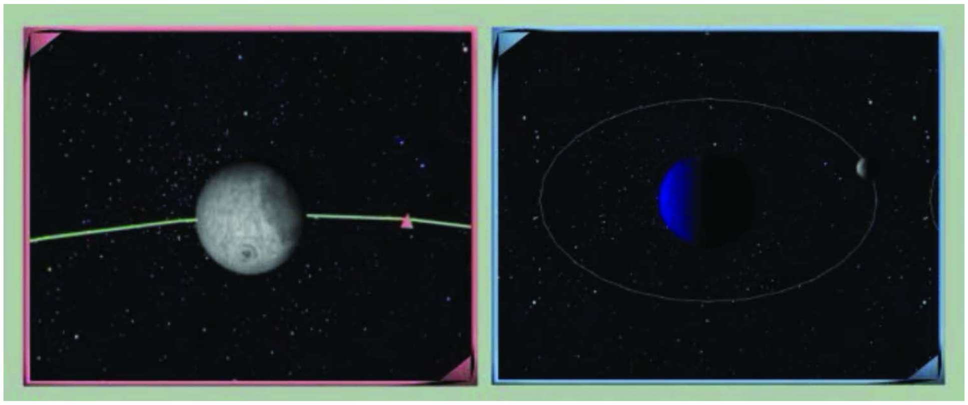
Table 2. POE activity about the phases of the Moon

Predict

• After showing figures about the different phases of the Moon, students were asked to predict the cause of phases of the Moon.

Observe

• The 3D modeling below was shown to the students. The 3D modeling employed two cameras to simultaneously show both the Moon from the Earth and the position of the Moon in the Earth's orbit. On the same screen, one camera showed the Moon from the Earth, while, at the same time, the second camera showed the relative positions of the Moon and the Earth as viewed from space.



• By pausing the modeling a few times, the different Moon phases and the location of the Moon when seen from the Earth were observed, and a class discussion was held.

Explain

• Students are asked to explain the similarities or differences between their predictions and observations.

In the teaching activities about stars, shooting stars, and the brightest star concepts and phenomena POE strategy-supported observations were used. In the night-observations, the students were able to observe Jupiter, Saturn, the Moon, and stars such as Vega, Antares, and Deneb. The manner in which these POE strategy-supported observations were used has been shown in Table 3.

Table 3. POE activity about the Jupiter observation

Predict

You will soon be looking at Jupiter through the telescope. Please describe what you expect to see.

Observe

Make your observation with the telescope. Please write down what you see.

Table 3. (*Continued.*)

Jupiter and its four satellites

The Moon

Explain

Explain the similarities or differences between your predictions and observations.

Prior to observing planets and stars, the students were asked to discuss and make predictions about what the differences between a star and a planet are and which star is the brightest. Before each planet and star observation students' predictions about what they would see were taken; after the observations class discussions were made. After completing all the observations, class discussions about differences and similarities they discovered between their predictions and observations were held. In the proceeding activities, after taking students' predictions about where stars would go in the daytime and what shooting stars and comets might be, they were shown pictures about these phenomena and had to discuss them.

In both in-class and observation activities the teacher took the role of a guide in the learning environment, initiator and director of the student discussions, and authority who makes necessary explanations.

3. RESULTS

3.1. Day and Night Cycle

To find out what conceptions students had about the reasons for the occurrence of the cycle of day and night, the question was asked, "What do you think causes the day and night cycle?"

Table 4. Conceptions related to the day-night cycle (*n* = 131)

Conceptions	Before Instruction *f* (%)	After Instruction *f* (%)
The Earth rotates on its axis—SU	83 (63.36)	102 (77.86)
Explanations derived from other people (living creatures, life experiences, the world)	19 (14.50)	5 (3.82)
The Earth revolves around the Sun	13 (9.92)	12 (9.16)
The Sun revolves around the Earth	8 (6.11)	5 (3.82)
The Moon revolves around the Sun	4 (3.05)	4 (3.05)
Distance from the Sun	1 (0.08)	—
Uncodable	2 (1.53)	2 (1.53)
No explanation	1 (0.08)	1 (0.08)

Note: Scientific understanding: SU, the others are nonscientific understanding.

As seen in Table 4, before instruction, 63.36% of the students gave the acceptable explanation that "the rotation of the Earth on its own axis causes day and night." The dominating conception in the category of "explanations derived from other people (living creatures, life experiences, and the world)" was that day and night were for people, living creatures, and the world, and that if they did not exist, there would be no night and day. While such a misconception, to the best of our knowledge, has not been encountered in literature among elementary school children, a similar misconception has in fact been observed in a study performed with a younger age group (5 to 6) (Valanides *et al.* 2000). In the categories of "the Earth revolves around the Sun" or "the Sun revolves around the Earth," students stated that day and night occurred because either the Earth revolves around the Sun or the Sun revolves around the Earth. Conceptions such as this have also been revealed in previous studies (Baxter 1989; Dunlop 2000; Trumper 2001a). In the category of children "showing the Moon as the reason," student concepts are typically, "day and night occur because the Earth revolves around the Moon" or "when the Moon is in front of the Earth, night occurs and when it recedes, the Earth sees the Sun and day occurs." Baxter (1989), Sharp (1996), and Dunlop (2000), too, reported this type of misconception.

The ratio of students who offered accurate explanations after instruction rose to about 78%, increasing by 15% over the corresponding ratio before instruction. Although the ratio in the category of "explanations derived from other people (living creatures, life experiences, the world)" showed a distinct decrease, the categories of "the Earth revolves around the Sun," "the Sun revolves around the Earth," and "the Moon revolves around the Sun" did not display a significant decrease in the ratio of accurate explanations as compared with that prior to instruction. On the basis of these data, then, it can be said that instruction is effective, although partially, in the teaching of a concept, but that it is not effective in changing certain misconceptions.

Frequencies and results of the χ^2-test of students' scientific and nonscientific understandings in pre- and post-tests about day-night are given in Table 5.

Table 5. χ^2-results about day-night

	Pretest (*f*)	Post-test (*f*)	χ^2	*p*
Scientific understanding	83	102	5.96	0.0146
Nonscientific understanding	48	29		

As could be seen in Table 5, there is no statistically significant difference between the frequencies of those who give scientific and nonscientific answers before and after teaching ($\chi^2_{(1,131)}=5.96$; $p>0.01$). Although it is not statistically significant at the $p=0.01$ level, one could see that there is an increase in the frequency of the scientific answers and a decrease in the frequency of the nonscientific answers. These results indicate that the teaching had some change in the students' understanding of the phenomenon.

3.2. The Seasons

The question on "what causes the seasons" was asked to find out what conceptions students had concerning the reason for the seasons. As can be seen in Table 6, where the findings derived from this question have been shown, prior to instruction, only 4.58% of students offered the explanation of "the tilt of the Earth's axis," which is the category that is considered scientifically accurate.

Table 6. Conceptions related to the seasons ($n=131$)

Conceptions	Before Instruction *f* (%)	After Instruction *f* (%)
The tilt of the Earth's axis—SU	6 (4.58)	61 (46.57)
The Earth revolves around the Sun	67 (51.15)	45 (34.35)
Explanations derived from other people (living creatures, life experiences, and the world.	27 (20.61)	5 (3.82)
The Earth rotates on its axis	6 (4.58)	—
Distance from the Sun	5 (3.82)	7 (5.34)
The Earth revolves around the Sun and rotates on its axis	2 (1.53)	3 (2.29)
The Sun revolves around the Earth	2 (1.53)	—
Uncodable	2 (1.53)	2 (1.53)
No explanation	14 (10.69)	8 (6.11)

Note: Scientific understanding: SU, the others are nonscientific understanding.

Among the inaccurate explanations, the category that recorded the greatest ratio was "the Earth revolves around the Sun" (51.15%). Children offering explanations in this category said, "*The seasons occur because the Earth revolves around the Sun. I learned this in elementary school*." As can be seen, children having this misconception usually refer to their previous schooling in explaining the reason for their way of thinking. The ratio of the category "explanations derived from other people (living creatures, life experiences, and the world)" is significantly high. Some of the beliefs in this category were: "*The reason seasons occur is because when it is continuously hot, there will be drought. Human beings cannot live in places like the desert. When it is cold, it is very cold. Human beings cannot live in a place that is covered in ice*" and "*If there were no seasons, for example, if the Earth couldn't absorb water, it could not flourish. That's why we need seasons and that's why they occur*." Most of the children subscribing to the category of "the Earth rotates on its axis" supported their explanation by stating that the seasons occurred because the Earth rotated around its axis. Students indicating the category "distance from the Sun" offered the explanation that "*when the Earth is revolving around the Sun, it must sometimes come near and sometimes move away. When it is far from the Earth, it is winter and when it is close, it is summer*." The students supporting this category expressed the belief that as the Earth revolves around the Sun, it should sometimes be near the Earth and sometimes far and that this is why the seasons occur. The above misconceptions have also been reported in many previous studies (Baxter 1989; Sharp 1996; Dunlop 2000; Valanides *et al.* 2000; Trumper 2001a).

After instruction, about half of the students offered accepted and accurate scientific explanations that fitted the category of "the tilt of the Earth's axis." The ratio of explanations in this category showed a significant increase compared to that prior to instruction. While noticeable decreases were seen in the conceptions of "the Earth revolves around the Sun," "explanations derived from other people (living creatures, life experiences, the world)," and the conception of "the Earth rotates on its axis," there was a slight increase in the conception stated as "the Earth revolves around the Sun and rotates on its axis." On the basis of the data obtained, it can be said that instruction led to positive changes with respect to the concept of the seasons. In the interviews after instruction, the students stated that 3D modeling and images caused positive changes in their conceptualizing the seasons. In this context, data from the interview held with Student 1 have been included below.

> **Student 1:** Before, that is before this lesson, I used to think that the Earth orbited around the Sun and that was why the seasons occurred. Now I've learned that it is because of the slant of the axis.
> **Researcher:** Why did you change your mind?
> **Student 1:** Well, our teacher showed us—what was the name of that—showed us something on the computer and then we discussed it among ourselves before and after we saw it. That was what really made me change my mind. When you see it in movement on the computer, it's like you're actually seeing how the seasons occur. The revolving, it seems, causes the change of seasons, and the slant in the axis makes them occur. At the end of our discusssions, we had all agreed.

Interviews with other students showed that before instruction, just like Student 1, these students too thought that "the Earth's revolving around the Sun" was the reason for the seasons. After the instruction, all of the students stated, like Student 1, that the seasons occurred because of the "slant in the axis." All of the students interviewed stated that the 3D modeling used in the class was effective in making them change their conceptions about the seasons.

Frequencies and results of the χ^2-test of students' scientific and nonscientific understandings in pre- and post-tests about seasons are given in Table 7.

Table 7. χ^2-results about seasons

	Pretest (f)	Post-test (f)	χ^2	p
Scientific understanding	6	61	58.48	0.00001[a]
Nonscientific understanding	125	70		

[a]$p < 0.01$.

As could be seen in Table 7, there is a statistically significant difference between the frequencies of those who gave scientific and nonscientific answers before and after teaching favoring those who gave scientifically sound answers ($\chi^2_{(1,131)} = 58.48$; $p > 0.01$).

3.3. Stars

The question "Where are the stars during the day?" was asked to discover what ideas students had about the stars. Table 8 presents students' conceptions of the stars before and after instruction. Most of the students offered a correct explanation in the category "in the same place." The majority of the students explained, "*in the same place but they cannot be seen during the day due to the sunlight*."

Table 8. Conceptions related to the stars ($n = 131$)

Conceptions	Before Instruction *f* (%)	After Instruction *f* (%)
At the same place—SU	89 (67.94)	114 (87.02)
Due to clouds we cannot see them during the day	12 (9.16)	3 (2.29)
They are on the dark side of the Earth	9 (6.87)	3 (2.29)
Stars reflect sunlight as planets	9 (6.87)	3 (2.29)
They shine at night but go out in daytime	3 (2.29)	—
Uncodable	5 (3.82)	4 (3.05)
No explanation	4 (3.05)	4 (3.05)

Note: Scientific understanding: SU, the others are nonscientific understanding.

In the category "we cannot see them during the day due to the clouds," students offered the explanation, "*They can be seen at night but cannot be seen in the daytime because of the clouds. The clouds prevent them from being seen*." The students in this category believe that the stars can be seen in the nighttime because there are no clouds, and that they cannot be seen in the daytime because of the clouds. In the category, "they are on the dark side of the Earth," students offered the explanations, "*We cannot see them in the daytime because the Earth is revolving. They can be seen when it's dark*," or "*They are on the dark side of the Earth, on the night side*." Similar explanations belonging in this category were also seen in older students (Lemmer *et al.* 2003). In the category, "stars reflect sunlight like the planets," students offered the explanations, "*Stars are like the planets; they are seen during the night and they reflect the sunlight*" or "*they are in the sky but we cannot see them during the day because they do not generate light themselves. They only reflect light coming from the Sun during the night*." This misconception is similar to that revealed by Dunlop (2000), which was "stars are like the planets."

Following instruction, 87.02% of the students offered accurate explanations. There was thus a 20% increase in the ratio of accurate explanations compared to before the students had received the instruction. Students' explanations were again similar to those offered before the instruction. Although incorrect explanation categories were also seen after instruction, there were significant decreases in their ratios.

Frequencies and results of the χ^2-test of students' scientific and nonscientific understandings in pre- and post-tests about stars are given in Table 9.

Table 9. χ^2-results about stars

	Pretest (*f*)	Post-test (*f*)	χ^2	*p*
Scientific understanding	89	114	12.6	0.00004[a]
Nonscientific understanding	42	17		

[a] $p < 0.01$.

As could be seen in Table 9, there is a statistically significant difference between the frequencies of those who gave scientific and nonscientific answers before and after teaching favoring those who gave scientifically sound answers ($\chi^2_{(1,131)} = 12.6$; $p > 0.01$).

3.4. Shooting Stars

To discover what ideas students had about shooting stars, the question was asked, "On a clear night while watching the sky, Ahmet screamed with excitement, 'I saw a star gliding!' What do you think Ahmet meant by saying 'a star was gliding?' " Table 10 presents students' conceptions about shooting stars before and after instruction.

Table 10. Conceptions related to the shooting stars ($n = 131$)

Conceptions	**Before Instruction *f* (%)**	**After Instruction *f* (%)**
Moving of a meteor in the Earth's atmosphere—SU	16 (12.21)	69 (52.67)
The shooting star considered as an event related to the stars	66 (50.38)	43 (32.82)
Someone dying/making a wish	11 (8.39)	3 (2.29)
Comets	3 (2.29)	1 (0.76)
Uncodable	6 (4.58)	2 (1.53)
No explanation	29 (22.14)	13 (9.92)

Note: Scientific understanding: SU, the others are nonscientific understanding.

Before the instruction, 9.1% of students offered acceptably accurate explanations. The explanations in this category were mostly "*falling stars are caused by a burning meteor, which has fallen into our atmosphere*" or "*the burning in the atmosphere of a meteor, which has fallen out of orbit*."

More than half of the students spoke of shooting stars as an event that had something to do with stars, comprising the category "the shooting star is believed to be an event related to the stars."

Most of the responses were: "*shooting stars happen when stars move around in space and change their place*," "*a star that loses its energy falls into a void or toward the Earth,*" "*stars stay where they are but because the earth is revolving they appear to be falling,*" or "*shooting stars are the explosion of the star at the end of its life*." In the category of "someone dying/making a wish," students offered explanations for the phenomenon, which originated from what they had heard from other people or in the movies. These explanations, based on superstition, were: "*When a star falls, it means somebody has died; this is what my uncle told me. You also make a wish but I don't really understand why we do that*," "*I saw it in a movie once—people die when a star falls*," or "*they say somebody dies when a star falls and also that you're supposed to make a wish*." In the category of "comets," most students offered the explanation, "*a shooting star is when a comet disappears from sight*." As far as we know, such a question has never been asked in a study with students. Thus the conceptions involving inaccurate explanations obtained in this study have been set forth in literature for the first time. It has only been in the work of Küçüközer (2007) that similar ideas have been set forth regarding the conception of "shooting stars are events related to the stars."

After instruction, 52.67% of students offered accurate explanations, raising the ratio of accurate explanations by 40% as compared to the period prior to instruction. There was an 18% decrease in the category of "the shooting star considered as an event related to the stars." Again, descriptions in this category were much like those before the instruction. The category of "someone dying, making a wish" was seen after instruction as well, though at a lower level. A look into the data collected for this question shows that instruction (discussions held during the observations) generally led to positive changes in conceptions of shooting stars. Data from interviews with Student 2 and Student 1 in this context have been given below.

> **Student 2:** Before, it was like a falling star. I used to think, I mean, that it was really a star and that a star went from one place to another. Now I know that, like we discussed while we were making our observations last night, this event occurs when a meteor enters the atmosphere and that it breaks up and burns—that's what a shooting star is.
> **Student 1:** I thought a shooting star was when a star died it would explode and that it was the fire caused by the explosion. I know now—we discussed this last night when we were observing—that it has nothing to do with the stars and that meteors enter our atmosphere and burn. That's what they're call "shooting stars," it seems.

The students interviewed about shooting stars all stated before the instruction that they had thought that this event had something to do with the stars and that after the instruction, just like Students 1 and 2, they had learned that these events had nothing to do with the stars and that they were caused when a meteor entered the atmosphere. These students asserted that the discussions held during the observations had been effective in making them change their conceptions.Frequencies and results of the χ^2-test of students' scientific and nonscientific understandings in pre- and post-tests about shooting stars are given in Table 11.

Table 11. χ^2-results about shooting stars

	Pretest (*f*)	Post-test (*f*)	χ^2	*p*
Scientific understanding	16	69	47.09	0.00001[a]
Nonscientific understanding	115	62		

[a]$p<0.01$.

As could be seen in Table 11, there is a statistically significant difference between the frequencies of those who gave scientific and nonscientific answers before and after teaching favoring those who gave scientifically sound answers ($\chi^2_{(1,131)}=47.09; p<0.01$).

3.5. The Brightest Star

The following question was asked to discover what conceptions students had about the brightest star: "Imagine that you are someplace far away from the lights and pollution of the city on a summer's night. Which is the brightest star you can see when you look at the night sky? Explain your answer briefly." Table 12 presents students' conceptions on the brightest star before and after instruction.

Table 12. Conceptions related to the brightest star ($n=131$)

Conceptions	Before Instruction *f* (%)	After Instruction *f* (%)
Vega—SU	1 (0.76)	32 (24.43)
Arcturus—SU	—	8 (6.11)
North Star (Polaris)	86 (65.65)	64 (48.85)
Shepherd's star	8 (6.11)	2 (1.53)
The Moon	6 (4.58)	4 (3.05)
Comet	6 (4.58)	8 (6.11)
The nearest star	5 (3.82)	1 (0.76)
All the same	2 (1.53)	—
Uncodable	2 (1.53)	2 (1.53)
No explanation	10 (7.63)	10 (7.63)

Note: Scientific understanding: SU, the others are nonscientific understanding.

As can be seen in Table 12, only one student offered a scientifically acceptable explanation before the instruction. This student said, "*A star called Vega. I had heard of this somewhere, I can't remember exactly and I may have just read about it*."

The "North Star (Polaris)" was the category for which students wrote out the most misconceptions. Most of the students wrote in this category, "*it helps us find our way, a very bright star, that's why it's the brightest star in the sky, this is what our elementary school teacher had told us*" or "*the North Star is the brightest star because it always shows us where North is*." The majority of the students said that their elementary school teacher had taught them that the North Star was the brightest star in the sky. In the "Shepherd's star (Venus)" category, most of the student explanations were, "*it's called the Shepherd's star, my father (or mother, brother, sister…) had said so. When we looked at it, it really looked big and very bright*." In this category, students spoke about what is called the "Shepherd's star" or "morning star" in folklore but is really not a star at all but the planet Venus. Indeed, when we look up at the sky, if Venus has not yet set, it is the brightest celestial body after the Moon. Because students did not know the differences between a star and a planet and also because Venus is called the "Shepherd's star" or the "morning star" in folklore, they said that the brightest star was the Shepherd's star. In the "Moon" category, student explanations were, "*because the biggest star is the Moon, I think it's the Moon" or "it's because the Moon is the brightest*." To the best of our knowledge, no question of this kind has ever been asked in any study conducted with elementary school students. Thus, the present study sets forth all the conceptions that make up incorrect explanations for the first time in literature.

After the instruction, about one-fourth of the students offered a scientifically acceptable explanation. Although this was a low number, it was significantly higher compared to the figure before instruction. The students mostly said in their explanations, "*I learned this in the class and from my observations at night*." In reality, the brightest star that can be seen in the Earth's sky is Sirius. This star, together with the second and third brightest stars, are the stars that are usually seen in the Southern Hemisphere. The brightest stars in the Northern Hemisphere are Arcturus and then Vega. Arcturus is not in its main star sequence at this time but is in its red giant stages. Because of this, the brightest star that students can see from where they are at night is Vega. This is why we can accept the response of "Vega" as correct. In making their observations with the naked eye, the students concluded that the brightest star was Vega. While an approximate 18% decrease was seen in the "North Star" category, the "Shepherd's star," "Moon," and "closest star" categories were offered by a very few students. The "shooting star" category, however, showed a slight increase. It was seen that the explanations in these categories were similar to the ones given prior to instruction. In general, the data from the period after instruction showed that observations led to a slight change in students' conceptions. In the interviews, two students showed that their notion before instruction that the North Star is the brightest star remained the same following the instruction. One of these students said he had not participated in that day's observations, but the other insisted on his notion about the North Star despite having participated. The other six students who were interviewed stated that the brightest star is Vega although they had had different views before instruction. The interview with Student 3 in this context follows.

> **Student 3:** I thought that the brightest star, is, er, the North Star, and I think our elementary school teacher taught us that. This star is always visible, and it always shows the direction of north. But in the observations we made last night, that night, when we looked closely we could see Vega, Deneb, Altair and there was also Antares, and we discovered that they were brighter than the North Star. I don't understand why our teachers taught us those things.

As can be seen above, Student 3 said that she had received her preinstruction notion of the North Star as the brightest star from her elementary school teacher, and then after the observations, she had learned that the brightest star was in fact Vega.

Frequencies and results of the χ^2-test of students' scientific and nonscientific understandings in pre- and post-tests about brightest stars are given in Table 13.

Table 13. χ^2-results about brightest stars

	Pretest (*f*)	**Post-test (*f*)**	χ^2	***p***
Scientific understanding	1	40	41.75	0.00001[a]
Nonscientific understanding	130	91		

[a] $p < 0.01$.

As could be seen in Table 13, there is a statistically significant difference between the frequencies of those who gave scientific and nonscientific answers before and after teaching favoring those who gave scientifically sound answers ($\chi^2_{(1,131)}=41.75$; $p < 0.01$).

3.6. Phases of the Moon

The following question was asked to discover what the conceptions of students were about the phases of the Moon: "The (**See Figure 1.**) diagrams given below show the Moon's appearance on any one night and a couple of nights after that night. What do you think could be the reason for this change?" Table 14 presents students' conceptions on the phases of the Moon before and after instruction.

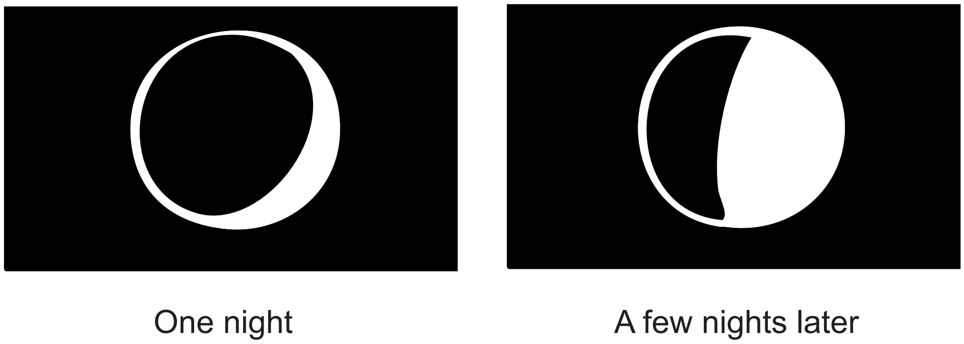


Figure 1. Diagrams used at question about the phases of the Moon.

Table 14. Conceptions related to the phases of the Moon ($n=131$)

Conceptions	Before Instruction *f* (%)	After Instruction *f* (%)
The Moon revolves around the Earth—SU	8 (6.11)	63 (48.09)
Phases of the Moon confused with the Moon eclipse	48 (36.64)	23 (17.56)
The four phases of the Moon were explained	14 (10.69)	20 (15.27)
The Sun is in front of the Moon; when the Sun recedes, the Moon is better seen	7 (5.34)	1 (0.76)
The Sun drawing close to the Moon	4 (3.05)	—
Weather conditions (clouds or fog)	4 (3.05)	1 (0.76)
Uncodable	6 (4.58)	6 (4.58)
No explanation	40 (30.53)	17 (12.98)

Note: Scientific understanding: SU, the others are nonscientific understanding.

As can be seen in the table, 6.11% of the students before instruction offered scientifically acceptable explanations in the category of "the Moon revolves around the Earth." Student explanations in this category were mostly, "*phases of the Moon occur because it revolves around the Earth.*"

Among the incorrect responses, the highest ratio was seen to be in the category of "the phases of the Moon are confused with the eclipse of the Moon" (36.64%). Student explanations offered in this category were mostly, "*The Earth is between the Sun and the Moon, it moves out and away with time and more of the Moon is seen*" or "*An eclipse of the Moon has occurred, a few nights later the Earth has moved out from in-between and more of the Moon is seen.*" Because students did not know that the eclipse of the Moon would take a few hours in one night, they said that the reason for the change in the appearance of the Moon was that the Earth moved away and its shadow therefore got smaller. This notion is frequently reported as a misconception in literature (Baxter 1989; Dunlop 2000; Trumper 2001a; Barnett and Morran 2002; Trundle *et al.* 2007).
In the category, "The four phases of the Moon were explained," most of the students thought that the reason the appearance of the Moon changed was because it was an actual change in the Moon, so that their explanation was: "*The Moon has phases—the new Moon, the full Moon, and the first quarter and last quarter it's a crescent—and the Moon appears in these phases every month.*" In the category of "the Sun is in front of the Moon; when the Sun recedes, the Moon is better seen," the students pointed to the Sun as the reason for the change in the Moon's appearance, stating that because the Sun was between the Moon and the Earth, it could not be seen and when it did recede, a bigger portion of the Moon could be seen. This conception has been reported as well in the work of Baxter (1989) and Trumper (2001a). In the category of "the Sun drawing close to the Moon" students said, as a reason for the increase in the bright parts of the Moon, that the Sun was nearing the Moon. Explanations were mostly along the line of: "*The Sun is coming close to the Moon so it radiates more of its beams on the Moon and reflects more light.*" In the "weather conditions (clouds or fog)" category, the clouds or fog was stated to be the reason for the change in the appearance of the Moon. Such a conception was also reported in a study by Baxter (1989), Sharp (1996), and Dunlop (2000).

As far as we know, the conceptions of "the Sun's approaching the Moon" and "the four phases of the Moon were explained" have not been encountered in other studies conducted with elementary school children.

About 48% of the students offered correct explanations after instruction, and the increase in these correct explanations compared to the situation prior to the instruction was 42%. While there were noticeable decreases in the categories of "the phases of the Moon are confused with the lunar eclipse," "the Sun is in front of the Moon; when the Sun recedes, more of the Moon appears," and "weather conditions (clouds or fog)," the category of "the Sun nearing the Moon" was not encountered at all after instruction. The fact that about half of the students were able to offer correct explanations following the instruction shows that the instruction (3D modeling) was in fact effective. All of the students interviewed said that before the instruction they had thought that the shadow over the Moon stemmed from the Earth but that following instruction, 3D modeling allowed them to see that the change in the appearance of the Moon was a result of the Moon's revolving around the Earth. An interview with Student 4 in this context has been presented below.

> **Student 4:** I had really thought when I saw the figure that it was because of the Earth's shadow. But there was a film we saw in class—there was just the Moon on one side and on the other, there was both the Earth and the Moon. We had watched that a couple of times. We later discussed it in class and in the end, the Moon's appearance changes because it revolves around the Earth.

As can be seen, the interview carried out with Student 4 and others showed that the conceptual changes that came about stemmed from the 3D modeling displayed in class and the class discussions.

Frequencies and results of the χ^2-test of students' scientific and nonscientific understandings in pre- and post-tests about phases of the Moon are given in Table 15.

Table 15. χ^2-results about phases of the Moon

	Pretest (f)	Post-test (f)	χ^2	p
Scientific understanding	8	63	56.34	0.00001[a]
Nonscientific understanding	123	68		

[a] $p < 0.01$.

As could be seen in Table 15, there is a statistically significant difference between the frequencies of those who gave scientific and nonscientific answers before and after teaching favoring those who gave scientifically sound answers ($\chi^2_{(1,131)} = 56.34$; $p < 0.01$).

4. CONCLUSIONS AND DISCUSSION

This study first established what conceptions students had about certain phenomena and concepts in astronomy and then examined the effects on conceptual change and learning of POE strategy-supported 3D modeling and observations. It can generally be said that most of the misconceptions established before instruction were similar to those reported in literature and that according to quality and quantity findings, the POE tasks based on 3D computer modeling and observations had been noticeably effective in achieving conceptual change and learning. In the interviews held with the students following the instruction, the children stated that the modeling used in the instruction as well as the observations had been effective in causing a change in their conceptions. For example, in the phenomenon of the four phases of the Moon, the students generally confused this with a lunar eclipse, but the modeling used in the instruction led to their defining the reason for the phases as the fact that the Moon was revolving around the Earth. Findings correspond with those of other studies that have used 3D computer models (Bakas and Mikropoulos 2003; Barnett and Morran 2002; Hansen, Barnett, and MaKinster 2004; Küçüközer 2008) and observation (Trundle, Atwood, and Christopher 2007) for teaching astronomical phenomena.

The conceptual change theory developed by Posner *et al.* (1982) defines stages in conceptual change as *dissatisfaction, intelligibility, plausibility, and fruitfulness*. Teaching strategies that find support from this theory and have been accepted by many science educators (Scott *et al.* 1992) encompass supported activities in an environment in which students are aware of the differences in their ideas through group and class discussions and in which they are allowed to reevaluate these ideas. This environment is facilitated when students are provided meaningful activities that are related to their personal experiences (Barnett and Morran 2002). The

criticisms of the conceptual change theory developed by Posner *et al.* (1982) have been generally to the effect that this theory ignores effective and social aspects and pays too much attention to plausibility (Strike and Posner 1992). Pintrich, Marx, and Boyle (1993) state that effective and social aspects of learning, particularly students' motivational beliefs, might affect the process of conceptual change, and the four necessities of conceptual change are depicted as if they operate in a cold, rational manner that ignores the influence that motivation might play regarding whether these four conditions for conceptual change might be met. On the other hand, Hynd, Alvermann, and Qian (1997) argue that the possibility of conceptual change in a motivated student is quite high. Dole and Sinatra (1998) confirm that dissatisfaction with an existing conception, motivation of the student, social context, and personal interests affect conceptual change. Duit and Treagust (1998) say that conceptual change should be placed in conditions that support conceptual change, which includes teachers' and students' beliefs, interests, and motivation. All of these criticisms essentially state that social environment and motivation are not being taken into consideration within the framework of conceptual change theory.
In our study, besides using the POE strategy for conceptual change, at the same time the strategy was also a technique that allowed students to work on tasks collaboratively in pairs (Tao and Gunstone 1999). In this respect, this technique has an important role in terms of creating a social environment that supports conceptual change in the learning environment. The observations and 3D computer modeling, which we used as part of the POE strategy not only facilitate learning but are also effective in motivating students (Bakas and Mikropoulos 2003). In literature, the number of studies using POE-supported observations and modeling in teaching is negligibly small. This study has shown that 3D modeling based on POE strategy and observations has a beneficial effect on conceptual change and learning/understanding.

Acknowledgments

We would like to thank Neset Demirici and Erol Asker for their valuable contributions. This study was sponsored by the Balikesir University Scientific Research Projects Department.

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