Computers & Education 68 (2013) 482–494

Contents lists available at SciVerse ScienceDirect

Computers & Education

journal homepage: www.elsevier.com/locate/compedu

Designing a powerful learning environment to promote durable conceptual change

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ARTICLE INFO

Article history:
Received 10 January 2013
Received in revised form
15 June 2013
Accepted 24 June 2013

Keywords:
Interactive learning environments
Post-secondary education
Lunar phases and eclipses
3D computer modeling
Conceptual change

ABSTRACT

The purpose of this study was to investigate the long-term effectiveness of a three-dimensional (3D) computer modeling supported predict–observe–explain (POE) strategy on pre-service science teachers' understanding of lunar concepts. Thirty-three preservice teachers participated in the study. A questionnaire was used to assess participants' understanding of the phases of the Moon and eclipses before, after, and 22 months after the instruction. Semi-structured interviews were conducted with six participants before and after the instruction. The results demonstrated that few participants had a scientific understanding about the targeted lunar concepts before the instruction. However, the majority of the participants had a scientific understanding after the instruction indicating that the instructional intervention was quite effective in facilitating conceptual change. The results also demonstrated that twenty-two months after the instruction most participants maintained their scientific conceptual understanding suggesting that the powerful learning environment designed for this study was effective in promoting a durable conceptual change.

1. Introduction

Students enter science classrooms with preconceived ideas that are usually contrary to scientific concepts. These preconceived notions are usually labeled as "misconceptions" or "alternative ideas" in the science education literature. A large number of studies have been conducted on children's and adults' conceptual understanding of various scientific phenomena (Duit, 2009). The findings of these studies demonstrated that these preconceived notions tend to be resistant to formal instructions. Astronomy is one of the most prolific domains where a great number of studies have been produced. Pioneering studies on the basic concepts of astronomy targeted primary school students' conceptions of the Earth (Nussbaum, 1979; Nussbaum & Novak, 1976). Subsequently, the conceptions of pre-school students (Valanides, Gritsi, Kampeza, & Ravanis, 2000), junior high school students (Dove, 2002; Küçüközer, Küçüközer, Yürümezoğlu, & Korkusuz, 2010; Sharp, 1996; Trumper, 2001a; Vosniadou & Brewer, 1992), senior high school students (Baxter, 1989; Lightman & Sadler, 1993; Trumper, 2001b), university students (Lemmer, Lemmer, & Smit, 2003; Trumper, 2000; Ünsal, Güneş, & Ergin, 2001) pre-service teachers (Bekiroğlu, 2007; Küçüközer, 2007; Parker & Heywood, 1998; Trumper, 2001c; Trundle, Atwood, & Christopher, 2002, 2010) and in-service teachers (Lightman & Sadler, 1993; Mant & Summers, 1993; Parker & Heywood, 1998; Saçkes, Trundle, & Krissek, 2011) were investigated. The findings of these studies indicated that grownups and the younger generations have similar misconceptions about astronomical phenomena. For example, "the shadow of the Earth causes the phases of the Moon" has been reported as the most common misconception regarding the cause of the moon phases (Barnett & Morran, 2002; Baxter, 1989; Küçüközer, 2007; Küçüközer et al., 2010; Parker & Heywood, 1998; Sharp, 1996; Trumper, 2000; Trumper, 2001a, 2001b, 2001c; Trundle et al., 2002). Common misconceptions regarding the e*clipse* phenomenon include "during the solar eclipse the Moon is always in its full Moon phase" (Trumper, 2000; Trumper, 2001a, 2001b, 2001c) and "the Sun goes between the Earth and the Moon, and the Moon is left behind the Sun, for this reason the Moon cannot be seen" (Bakas & Mikropoulos, 2003; Küçüközer, 2007; Küçüközer et al., 2010).

As a matter of fact, Trumper (2006) states that "*Future elementary teachers have more alternative conceptions about basic astronomy concepts than typical junior high school students.*" His remarks underline the importance of future research on pre-service teachers'

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0360-1315/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.compedu.2013.06.012

conceptual understanding's of basic astronomy concepts. Particularly, more studies that go beyond the identification of specific misconceptions pre-service teachers hold are need (Trundle et al., 2002).

Studies have demonstrated that misconceptions usually remain as they are even after formal instructions. There is a great need for effective teaching activities that help students in restructuring and changing their existing conceptual understanding (Trundle, Atwood, & Christopher, 2007). The findings of the conceptual change studies that targeted lunar phases and eclipse phenomena suggest that conceptual change oriented (Trundle et al., 2002, 2006, 2007) and technology supported instructional interventions (Bell & Trundle, 2008; Keating, Barnett, Barab, & Hay, 2002; Küçüközer, 2008; Trumper, 2006; Trundle & Bell, 2010; Zeilik, Schau, & Mattern, 1999) have potential to promote scientific conceptual understandings even with middle school students and younger children (Hobson, Trundle, & Saçkes, 2010; Trundle, Atwood, Christopher, & Saçkes, 2010). The study conducted by Trundle and Bell (2010) has a unique place in this line of research literature. In this study researchers compared the effectiveness of three instructional interventions in promoting conceptual change with pre-service early childhood teachers regarding the shapes and sequences of the moon, and the cause of the phases of the moon. The first group used the planetarium software program Starry Night, the second used observations of nature plus Starry Night, while the third group used observations of nature alone in the instruction. The "Starry Night only" treatment demonstrated statistically greater gains for sequencing moon phases than the other two treatments. There was no difference among the treatment groups regarding the cause of the phases of the moon.

The only longitudinal study is also conducted with Trundle et al. (2007). In this longitudinal study researchers investigated 12 female primary school pre-service teachers' conceptual understanding about the phases of the moon. Before the instruction, their misconceptions were categorized as, "The phases of the Moon occur because the Earth is blocking the Moon," "The phases of the Moon occur due to the tilting of the Earth's axis and the spinning of the Sun and the Earth around the Moon." Three weeks after the inquiry-based instruction, all participants constructed scientifically acceptable explanations. Six months or more after the instruction, nine of the participants showed evidence of continuing to hold some kind of scientific understanding suggesting that the change in their conceptual understanding was durable over time. However, two participants utilized two or more misconceptions in their explanations of the cause of the lunar phases and a third one used a single alternative explanation indicating that these participants regressed in their conceptual understanding.

2. Theoretical framework

The theory of conceptual change forms the basis for this study (Hewson, 1982; Hewson & Hewson, 1992; Posner, Strike, Hewson, & Gertzog, 1982). During the last thirty years, many theoretical approaches to conceptual change have been developed (Tyson, Venville, Harrison, & Treagust, 1997). The most influential theory about conceptual change was developed by Posner et al. (Duit & Treagust, 1998). Posner et al. (1982) proposed four conditions for 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*. The theory was later expanded by authors such as Hewson (1982), and Hewson and Hewson (1992). They emphasize that it is the status of the concept that determines whether there will be conceptual change. More specifically, when a new conception has met the respective conditions of intelligibility, plausibility, and fruitfulness, it is elevated in status and it is only when all three conditions have been fulfilled that there will be *dissatisfaction* with the existing conception and the status of the existing conception will be lowered. Hewson and Hewson (1984) suggested using the conceptual conflict strategy to lower the status of existing concepts and raise the status of the new concepts.

The criticisms of the conceptual change theory developed by Posner et al. (1982) have suggested that this theory ignores effective and social aspects and pays too much attention to plausibility (Strike & 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. Dole and Sinatra (1998) suggest that dissatisfaction with an existing conception, motivation of the student, social context, and personal interests affect conceptual change. Duit and Treagust (1998) argue 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 Posner et al.'s conceptual change theory. Therefore, the current study utilized a conceptual change oriented instructional intervention that emphasizes students' interaction and motivation and the use of cognitive conflict strategy.

2.1. POE and 3D computer modelings

Various instructional strategies have been proposed to induce conceptual change in the literature (Scott, Asoko, & Driver, 1992; White & Gunstone, 1992). The Predict–Observe–Explain (POE) strategy is one of these strategies (White & Gunstone, 1992), which facilitate conceptual change by creating cognitive conflict. 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, students are asked to explain the similarities or differences between their predictions and the observations.

In this study, the POE strategy was used to induce conceptual change and to promote interaction among the participants by encouraging participants to work on tasks collaboratively in pairs (Tao & Gunstone, 1999). Also, the POE strategy has a potential to promote conceptual change that is durable (Georghiades, 2000). Although the use of POE strategy has been reported extensively in the literature, the number of studies that used computer-supported POE strategy is quite limited (Kearney & Treagust, 2000). Examples of these are only seen in Kearney and Treagust's (2000) use of digital videos about force and motion within a POE framework, Tao and Gunstone's (1999) use of computer simulations to support POE strategy in mechanics, and Küçüközer (2008) and Küçüközer, Korkusuz, Küçüközer, and Yürümezoğlu (2009) use of 3D computer modeling to support POE tasks in some astronomical phenomena. The POE-supported videos, simulation and 3D computer modeling used in these studies have been reported to have had a positive effect on students' learning and conceptual change. The 3D computer modelings appear to reduce the cognitive load and foster motivation thereby can enhance the efficacy of the POE strategy in helping learners comprehend difficult science concepts (Hobson et al., 2010; Merchant et al., 2012; Rutten, van Joolingen, & van der Veen, 2012).

Recently in studies conducted particularly with primary school students, 3D computer models have been used to promote conceptual change. Several studies about astronomical events and concepts have reported the effectiveness of 3D computer models in fostering conceptual change (Bakas & Mikropoulos, 2003; Barnett & Morran, 2002; Hansen, Barnett, & MaKinster, 2004a, 2004b; Küçüközer et al., 2009). There are two different ways 3D computer modeling has been used in such studies. In some studies, researchers used models during the instruction that they themselves had prepared beforehand (Bakas & Mikropoulos, 2003; Barnett & Morran, 2002; Küçüközer et al., 2009). In other studies, students were given specific tasks and asked to prepare models by using a computer software (on topics such as "What causes the seasons of the Earth?" and "Draw a diagram that shows the different seasons") (Hansen et al., 2004a, 2004b; Keating et al., 2002). Researchers report that 3D modeling helps students in understanding the phenomena that cannot be otherwise understood through experience and observations (Bakas & Mikropoulos, 2003); it supports the students' ability to visualize astronomical phenomena (such as the phases of the Moon and the seasons) and abstract concepts (such as the line of nodes and the Moon's orbital tilt relative to the Earth) (Keating et al., 2002), and develops spatial reasoning and visualization (Hansen et al., 2004a).

2.2. The powerful learning environment for conceptual change

In the present study the 3D computer modeling supported POE strategy was used to facilitate conceptual change. This kind of settings may provide a powerful learning environment for students where they have opportunities to construct scientific conceptual understanding that is durable over time (de Jong, 2005). The instructional intervention employed in the current study was designed based on the principles of the powerful learning environment (PLE) delineated by de Jong (2005). The principles of the PLE include: i) Increasing the engagement of learners, ii) Realizing the situatedness of learning, iii) Improving the quality of collaboration in learning, iv) Enabling students to express their knowledge, and v) Giving students opportunities to engage in key learning processes.

The 3D computer modeling-supported POE strategy aligns well with the principles of PLE and it has a potential to promote conceptual change and understanding that is durable over time. The following points provide a detailed description of the connection between the 3D computer modeling-supported POE strategy and the principles of PLE:

- *Increasing the engagement of learners*: POE is effective in motivating students and developing their metacognitive skills: POE helps students to plan their learning and thinking processes during the activities, thus promote the use of self-regulatory skills and students' motivation (Klangmanee & Sumranwanich, 2009; Küçüközer et al., 2009; Vosniadou, 2005).
- *Realizing the situatedness of learning*: The tool of 3D computer modeling presents us with a three-dimensional, spatial representation of phenomena in the world or in the sky that we cannot touch or experiment with – for example, the cycles of day and night, the phases of the moon, eclipses, the occurrence of the seasons, etc. – (Keating et al., 2002).
- *Improving the quality of collaboration in learning*: POE allows students to work on tasks collaboratively in pairs. Thus, it supports a cooperative learning environment where students can share their knowledge in discussions and talks with others in their group (Küçüközer, 2008; Tao & Gunstone, 1999).
- *Enabling students to express their knowledge*: POE gives students opportunities to become aware of their own ideas through discussions that take place at every stage of POE and facilitates the construction of new concepts based on their existing ideas, thereby paving the way for conceptual change (Kearney & Treagust, 2000; Küçüközer, 2008).
- *Giving students opportunities to engage in key learning processes:* 3D computer modeling and illustrations is a powerful tool that may reduce the cognitive load via helping the students in conceptualizing and visualizing the relationship between 3D objects. Conceptual understanding of the cause of the lunar phases requires students to be able to entertain the Earth and Space as reference frameworks, which might be a challenging task for many learners. 3D computer modeling may facilitate conceptual change by providing students a multiple referential framework for astronomical phenomena and opportunities for changing their perspective during the instruction (Hobson et al., 2010; Korakakis, Pavlatou, Palyvos, & Spyrellis, 2009; Merchant et al., 2012; Rutten et al., 2012).

3. The present study

Most studies have examined the short term effect of instructional strategies in achieving conceptual change using pre-test–post-test designs about the moon phases and eclipses (Barnett & Morran, 2002; Hansen et al., 2004a, 2004b; Küçüközer, 2008; Küçüközer et al., 2009; Trundle et al., 2002, 2006; Trundle & Bell, 2010). In the majority of these studies post-tests were implemented immediately after the instruction (Barnett & Morran, 2002; Hansen et al., 2004a, 2004b; Küçüközer, 2008; Küçüközer et al., 2009; Zeilik et al., 1999). Only in few studies post-tests were implemented several weeks after the instruction (Trundle & Bell, 2010; Trundle et al., 2006). About Moon phases or eclipses, few longitudinal studies have investigated the durability of the change after a long period following an instructional intervention (Trundle et al., 2007). Only longitudinal studies conducted over a long period of time can show us whether in fact conceptual change has occurred. Therefore, it is important that more of these types of studies are undertaken to assess the effectiveness of teaching activities in helping pre-service teachers construct scientific conceptual understanding that is durable over time.

A review of the literature revealed that most previous studies concerning astronomical phenomena and concepts have focused on the conceptual understanding of elementary and high school students. Some studies have included university students but only few studies have focused on pre-service science teachers (Küçüközer, 2008). Moreover, there is only one long-term research study with pre-service classroom teachers that was carried out to determine how effective programs of instruction was in promoting conceptual change (Trundle et al., 2007). In the present study, therefore, our focus was on pre-service science teachers' conceptions about astronomical phenomena before and after instruction and also two years after the instruction.

There are very few studies that have used 3D computer modeling or simulations based on POE strategy in teaching astronomical phenomena and concepts. It is therefore apparent that such studies are needed at this level (Küçüközer, 2008). In this context, the purpose of the present study was to probe into the conceptions of pre-service science teachers about the moon phases and eclipses before and after instruction and to determine the effect of 3D computer models based on POE on conceptual change. To address this objective, answers to the following research questions were sought: what are the conceptions held by pre-service science teachers about astronomical phenomena before and after instruction, and 22 months after the instruction? What do the pre-service science teachers think about the changes in their ideas (if any) and the teaching activities after the instruction?

4. Methodology

A qualitative approach was used in this study to understand and describe pre-service science teachers' understanding about the Moon's phases and eclipses. Qualitative methods provide rich data that offer the possibility of better understanding and describing pre-service science teachers' perceptions of phenomena and concepts. This study includes four parts: i) pre-test and interviews, ii) instruction iii) post-test and interviews and iv) delayed post-test.

4.1. Participants

The sample of the present study consisted of pre-service science teachers at the Department of Science Education at a state university in western Turkey. A total of 33 preservice teachers participated in the study with an age range between 20 and 21 years old. The subjects had not taken any astronomy courses at the university level before this course. A pre-test and interviews were conducted at the beginning of the semester followed by the instruction and then a post-test and interviews were administered. Approximately two years later (22 months), a delayed post-test was administered.

4.2. Instructional context

The study was conducted during an astronomy course in the department of science education. The topics covered during the astronomy course were stars, black holes, space energy, galaxies, the solar system (including eclipses), the phases of the Moon, Kepler's laws, relativity, motion in space, space time, communication satellites and their working principles, and distance determination in the space. The astronomy course lasted 12 weeks with two lessons back-to-back and each lesson lasting 45 min. The Moon phases and eclipses were introduced and evaluated within the scope of this study. Instruction on these concepts was carried out for a total of two weeks, in four class hours (180 min).

In the instruction, the pre-service science teachers' misconceptions were reviewed and POE tasks were introduced that would help pre-service science teachers change their misconceptions. In the "predict" phase of POE tasks, questions were asked that would reveal the pre-service science teachers' ideas, and then pre-service science teachers were given some time to discuss the issue within their groups before being expected to reach a conclusion of their own. In the "observe" phase, 3D computer modeling and images were used to show the astronomical phenomena of the Lunar eclipse and the phases of the Moon, and pre-service science teachers were again asked to discuss these events. Finally, in the "explain" phase, pre-service science teachers were asked to compare and discuss their predictions and the results of their observations (Fig. 1 presents an example of POE tasks concerning eclipses).

In this study, 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. Thorough 3D Studio MAX software 3 dimensional representations of astronomy phenomena can be created. These phenomena can be observed from different point of views (Merchant et al., 2012). For example, in the current study phases of the moon are modeled from two points of views. 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 (Küçüközer et al., 2009).

After the Sun is defined as the source of light, the illumination of the Moon and the Earth is accurately calculated by the program, and, in the same way, the objects' shadows can be accurately produced with respect to their distances to the source of the light and their radiuses.

Before the activities, a correctly scaled representation of the Sun, the Earth, and the Moon was shown to the pre-service science teachers to explain the difficulty of working with such proportions. It was shown that, if the Earth were scaled smaller relative to a smaller scaled Sun, it would be too small on the screen. It was stated that, because of such difficulties, the sizes of the Earth and the Moon could be scaled proportionately smaller or larger by a certain amount. After the POE activities, since it was not possible to reduce the sizes of the Sun, Earth and Moon in the same proportions so that we could make an accurate demonstration, another activity was conducted where the pre-service science teachers were shown drawings of the topic. In this activity, the pre-service science teachers were asked how we could have shown the eclipse of the Moon if we had proportionately reduced the dimensions. The pre-service science teachers first had a discussion within their own group and then a classroom discussion was held where the pre-service science teachers were asked to develop suggestions for a drawing.

4.3. Data collection and analysis

Two data collection techniques were used in the current study. An open-ended questionnaire was used to determine the pre-service science teachers' conceptions about the phenomena of the moon's phases and eclipses. Semi-structured interviews were used to gain a deeper understanding of the conceptions of the participants about the targeted phenomena as well as their perceptions of the instructional strategies implemented in the study.

4.3.1. The open-ended questionnaire

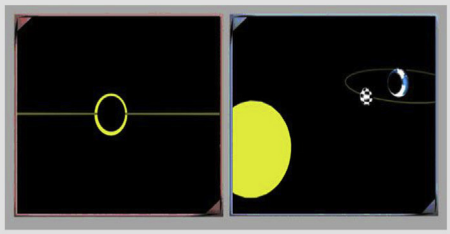
The questionnaire was composed of three open-ended questions taken from three different sources: Keating et al. (2002), Küçüközer (2007) and Trumper (2000). Two experts in science education judged the content validity of the questionnaire and the questionnaire was finalized after a pilot implementation with 10 pre-service science teachers. The questionnaire was administered to the 33 participants before and after instruction and then 22 months later, during normal class hours. Even though there was no time limit imposed, the questionnaire was completed within about 15 min.

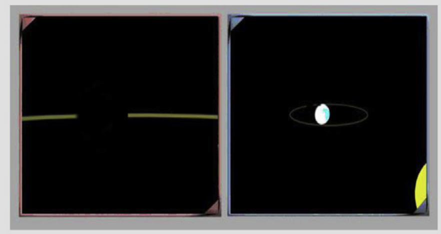
Predict

- Pre-service science teachers were asked to predict why solar and lunar eclipses take place. They discussed the topic first in their own groups and then an inter-group discussion took place.

Observe

- The 3D modelling below was shown to the pre-service science teachers (The 3D model employed two cameras simultaneously 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 Sun, the Moon and the Earth as viewed from space). The 3D modelling was stopped when it showed the positions given below and the pre-service science teachers were asked to describe what they saw and to discuss it.





Explain

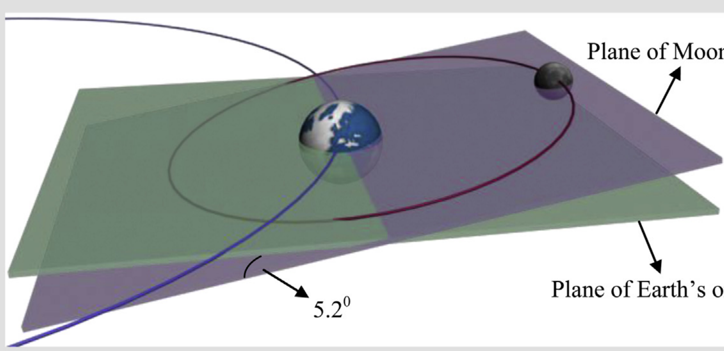
- Pre-service science teachers were asked to explain the similarities or differences between their predictions and observations.

Predict

- While the pre-service science teachers were watching the 3D modelling they were expected to notice that during the Solar eclipse, the shadow of the Moon is not cast on Earth every month. Pre-service science teachers were allowed to have a discussion after they were asked why eclipses did not happen every month.

Observe

The Figure below was prepared by using the 3D Studio MAX 8 program and clearly shows the 5.2^0 difference between the orbital planes (The pre-service science teachers were then asked to have another discussion. With this figure they were expected to realize that eclipses do not happen every month due to the difference between the orbital planes of the Earth and the Moon.)



Explain

- Pre-service science teachers were asked to explain the similarities or differences between their predictions and observations.

Fig. 1. A POE activity about eclipses and why eclipses don't occur every month.

The questionnaire on eclipses and the phases of the moon in the study were as follows:

- The diagrams given below show the Moon's appearance on any one night and a few nights later. What do you think could be the reason for this change?

One night A few nights later

- Why don't lunar and solar eclipses happen every month?
- What do you understand from "an eclipse of the Moon" – please explain it with a diagram.

4.3.2. Semi-structured interviews

Before and after the instruction, semi-structured interviews were conducted with six out of the 33 participants who volunteered to be interviewed. Twenty-two months later, these six pre-service science teachers excused themselves from the interviews, telling us that they were very busy with studying for their courses and preparing for the KPSS test (a national exam that Education College graduates must pass to become teachers). The interviews lasted 20–25 min and were of the "non-technical interview" type (Hewson & Hewson, 1992). The interviews conducted before the instruction were carried out with the aim of clarifying the pre-service science teachers' responses to the open-ended questionnaire. At the sessions before the instruction pre-service science teachers were asked, "Could you please clarify the response you gave to the question… What did you mean here?" and then "How did you get this idea?" Other questions were added depending upon the pre-service science teacher's responses over the course of the interview. In the interview after the instruction, pre-service science teachers who had differing ideas before and after the instruction (most pre-service science teachers did—the misconceptions most pre-service science teachers had before the instruction turned into scientific ideas after the instruction) were asked why they changed their minds (conceptual change), the general objective here being to make an evaluation of the instruction. The questions asked after the instruction were: "What kind of differences are there between your ideas before and after the instruction?" and "What do you think about the 3D models you used in the instruction and how the topic was taught in general (POE)?" The interviews were recorded and then transcribed. The excerpts from the interviews are presented in the results section of the article, with scientific explanations emphasized and underlined in bold letters. The misconceptions are labeled in bold letters and the statements illustrating the pre-service science teachers' change in their conceptual understandings are labeled in bold italics.

4.4. Analysis

The conceptions of the pre-service science teachers were assessed before and after the instruction and about two years later by analyzing their responses to the open-ended questionnaire and the data gathered in the interviews. The methodology used in the analysis of the data was a categorization of the responses that were construed to have similar intended meanings (Driver & Bell, 1986). For example, the following response was put into the category of the scientific explanation "*The moon reflects the light from the sun and orbits around the Earth at the same time and this is why its position changes from day to day and is perceived as the phases of the moon*" and the category is labeled as "The Moon revolves around the Earth". Responses such as "*The reason for the change in the appearance of the Moon is the shadow of the Earth; the Earth gets out of the way and the Moon is more visible*" was put in the category of misconception and labeled as "Phases of the Moon confused with a Lunar eclipse." The categorizations of the misconceptions were made based on commonly identified misconceptions reported in previous studies (Keating et al., 2002; Küçüközer, 2007; Trumper, 2006; Trundle et al., 2002, 2006, 2007). Another science educator independently coded the entire data set to establish inter-rater reliability. The percentage of agreement between the two coders was 94%. To examine the effectiveness of the instructional intervention participants' responses (grouped as scientific and nonscientific) to the open-ended questions were analyzed using the Chi Square analysis. Yates' correction was used when the observed frequency was less than five.

5. Results and discussion

5.1. Phases of the moon

Table 1 presents the conceptions of the pre-service science teachers about the phases of the Moon before and after instruction, and two years later. A look into the pre-service teachers' ideas before the instruction shows that only a small percentage of pre-service science teachers (15%) provided scientifically acceptable answers while the large majority failed to give the scientific response.

Among the alternative responses, the one that had the highest percentage (61%) was the category of "Phases of the Moon confused with a Lunar eclipse." Ideas in this category are the most frequently encountered misconceptions in the literature (Küçüközer, 2007, 2008; Trundle et al., 2002, 2006, 2007; Trundle & Bell, 2010). Pre-service science teachers falling into this category generally confuse the reasons for the phases of the moon with the reasons for eclipses, stating that the phases are caused by the shadow of the Earth and that when the Earth gets out of the way, the visible portion of the Moon gets bigger. All of the pre-service science teachers interviewed offered explanations similar to this. The following transcript is an excerpt from the pre-instruction interview with Participant6:

> **Participant6**: The Earth is moving aside in my opinion. As the Moon is left behind the Earth, it can't receive the light. For this reason … when we look at these two diagrams, they show that the **Moon is moving away from the shadow of the Earth**. These diagrams, … Hmmm, yes … in other words, I think these are positions after the lunar eclipse.

Table 1
Pre-service science teachers' conceptions about the phases of the Moon.

Conceptions	Pre-test *f* (%)	Post-test *f* (%)	Delayed post-test *f* (%)
- The Moon revolves around the Earth[a]	5 (15)	28 (85)	23 (70)
- Phases of the Moon confused with a lunar eclipse[b]	20 (61)	3 (9)	8 (24)
- The Moon revolves around the Sun[b]	2 (6)	–	–
- The rotation of the Moon is on its own axis[b]	2 (6)	–	–
- The sun nearing the Moon[b]	2 (6)	–	–
- Uncoded responses	1 (3)	1 (3)	1 (3)
- No response	1(3)	1 (3)	1 (3)

[a] Scientific.
[b] Misconception.

As can be seen in the excerpt above, Participant6 has stated that this is a lunar eclipse and that the Moon has come out of the shadow of the Earth.

Results demonstrated that after the instruction, a large majority of the pre-service science teachers (85%) were able to provide scientifically acceptable explanations. Of the 20 pre-service science teachers whose responses fell into the Lunar Eclipse category before the instruction, only 3 maintained their previous ideas even after the instruction. For these three pre-service science teachers, the misconception was very firmly established and showed resistance to change. All of the pre-service science teachers interviewed after the instruction, however, offered explanations that were scientifically acceptable. Participant6, for example, said the following in the interview after the instruction:

> **Participant6**: I seem to have said that this question is related to the phases of the moon… Why? Because the diagrams say that this is the view of the Moon on a particular night and then a few nights later. Now this could have been a lunar eclipse too. Then the captions in the diagrams should have said… Hmm, one of them should have said any time in the night, 9:00 PM, for example, and the other should have read 9:30 PM. Then I would have called this an eclipse. But this is different, since it says "a few nights later," this can't be an eclipse. That's why I had said that this had to do with the phases of the Moon. The reason for that was that **the Moon orbits around the Earth**. If there was not a lunar eclipse, **the moon will always be lit up by the sun**. In other words, it would reflect the light a**nd relative to its position around the Earth, the part seen from the Earth will always change**.

As is seen in the excerpt above, participant6 became aware that this event was not an eclipse and therefore stated that the Moon reflected the light from the Sun and because it was orbiting around the Earth, this was what caused the phases of the moon. The excerpt, particularly the underlined bold parts, demonstrates that participant6 revised his conceptual understanding and constructed scientific understanding of the cause of moon phases. In Trundle et al. (2007) study all 12 participants provided scientific explanations three weeks after the instruction. Likewise, in the present study all six interviewed participants provided scientific explanations.

In the delayed post-test that was administered two years later, the majority of the pre-service science teachers (70%) offered the scientific explanation. For example, in the delayed post-test Participant6 again provided the scientific response, stating, "These diagrams refer to the phases of the Moon. The Moon reflects the light from the Sun, at the same time orbiting around the Earth, and this is how the phases of the moon occur." These responses suggest that even two years after the instruction Participant6 maintained a scientific conceptual understanding. It appears that the pre-service science teachers who offered the scientific explanation in the post-test and in the delayed post-test have experienced conceptual change and constructed scientific conceptual understanding that is durable (Georghiades, 2000). It is likely that through the instructional intervention scientific explanation gained a higher status in some participants' conceptual ecology (Hewson, 1982; Hewson & Hewson, 1992).

The responses of eight of the pre-service science teachers were in the category of "phases of the moon confused with a lunar eclipse" before the instruction. After the instruction, five of these eight pre-service science teachers' provided scientific explanation. Two years after the instruction, however, these five pre-service science teachers returned back to their alternative conceptual understanding. Georghiades (2000) described this phenomenon as conceptual decay where learners exhibit regression to their initial conceptions. It appears that the alternative conceptual understanding held by these five pre-service science teachers before the instruction regained a higher status than the scientific explanation two years after the instruction (Hewson & Hewson, 1992). Trundle et al. (2007) reported similar results. In their study with pre-service teachers all of the 12 participants provided a scientific explanation immediately after the instruction but several months later, three participants had returned to their ideas prior to the instruction.

5.2. Eclipses

Table 2 presents the pre-service science teachers' conceptions about "why eclipses do not happen every month?" before, after, and about two years after the instruction.

A look into pre-service science teachers' concepts before the instruction shows that none of the pre-service science teachers were able to provide a scientifically acceptable response. Approximately two-thirds of the pre-service science teachers explained the event according to misconceptions and one-third gave no response at all. Among the alternative responses, the one with the highest percentage (55%) was the category of "Because of the difference between the Earth and Moon's speeds or the completion times of their cycles." The response in this category of Participant1 in the interview before the instruction was as follows:

> **Participant1**: The speeds of the Earth and the Moon are different so when we think of them together with the Sun, the three of them aren't aligned every month. **In other words, their speeds or their orbiting periods are different so they don't get aligned and that's why an eclipse doesn't happen**—how can it when their speeds are different?

Three of the other pre-service science teachers expressed similar thoughts to those of participant1 in their interviews. For the explanation to why an eclipse does not happen every month, they offered as the reason the inequality in the orbiting speeds or periods of the

Table 2
Pre-service science teachers' conceptions about "Why don't eclipses happen every month?".

Conceptions	Pre-test f (%)	Post-test f (%)	Delayed post-test f (%)
- The Earth and Moon's revolving planes are not the same (5.2^0)[a]	–	33 (100)	29 (88)
- Because of the difference between the Earth and Moon's speeds or the completion times of their cycles[b]	18 (55)	–	3 (9)
- Because of the different positions of the Earth and the Moon[b]	3 (9)	–	–
- The tilt of the Earth's axis[b]	1 (3)	–	–
- Order of the universe[b]	1 (3)	–	–
- No response	10 (30)	–	1 (3)

[a] Scientific.
[b] Misconception.

Moon and the Earth. This kind of misconception is encountered in the literature (Küçüközer, 2007). The other two pre-service science teachers who were interviewed stated that they had no idea about the subject.

After the instruction, all of the pre-service science teachers offered explanations that were acceptable scientific responses, stating that an eclipse did not occur every month because there was a 5.2° angle between the orbiting planes of the Earth and the Moon. In the interview with participant1 after the instruction, this pre-service science teacher stated the following as an explanation.

> **Participant1**: Well, I had said hmm... What did I say? The Sun, Earth and Moon have to be aligned for an eclipse to occur. **This alignment doesn't happen every month because of the 5.2° difference between the orbiting planes of the Earth and Moon**.

The other participants interviewed also provided similar explanations as to why eclipses did not occur every month, stating that this was because of the 5.2° difference between the orbiting planes of the Moon and Earth.

Almost all of the participants (88%) that took the delayed post-test two years after the instruction provided scientifically acceptable explanations. Participant1 (and the remaining 5) provided the scientific explanation in their explanations at the delayed post-test that "Eclipses don't occur every month because of the difference in the orbiting planes of the Moon and Earth." Participants who provided the scientific explanation had undergone durable conceptual changes (Georghiades, 2000). Using the terminology of Hewson and Hewson (1992) the *high status* that the scientific explanation had gained as a result of the instructional intervention appeared to be sustained even 22 months after the instruction. However, three participants had returned to their ideas before the instruction that "orbiting speeds and periods are different" indicating that these preservice teachers have experienced conceptual decay (Georghiades, 2000). While the status of the misconception rose, that of the scientific notion fell for these participants. The change observed in these participants' conceptual understanding from pre- to post-test was not durable.

5.3. Lunar eclipse

5.3.1. Explanations

Table 3 presents conceptions of the pre-service science teachers about lunar eclipses in response to the question "What do you understand from a 'lunar eclipse'? Please explain it with a diagram." This question was asked before and after the instruction and then two years later. It was observed that a large majority of the participants (79%) offered the scientific explanation before the instruction. Participant8's response was, "The Sun, Earth and the Moon are aligned in certain periods of the year and the Earth comes in-between the Moon and the Sun. The cluster of rays coming from the Sun fall upon the Earth. Right at that moment, when the moon cannot receive the rays of the sun because it is behind the earth, it will be in shadow. Its appearance is a lunar eclipse." The other participants generally offered explanations similar to that of Participant8. These participants knew that lunar eclipses occurred when the Sun, Earth and the Moon were aligned together and the Moon was in the shadow of the Earth since it could not get the light from the Sun. Of the participants, 18% confused lunar eclipses with solar eclipses. Before the instruction one participant stated that during the lunar eclipse the Sun moves between the Earth and the Moon and the moon could not be seen from the Earth. This type of misconception has been reported in previous studies conducted with elementary school children (Bakas & Mikropoulos, 2003; Küçüközer et al., (2010). All of the participants offered the scientific explanation after the instruction but two years later, only two participants confused the lunar and solar eclipses while the rest provided the scientific explanation.

5.3.2. Diagrams

The diagrams of the pre-service science teachers of lunar eclipses before, after and two years after the instruction are presented in Table 3. It was seen that before the instruction, a large majority of the pre-service science teachers made a correct alignment in the diagram, drawing the Sun-Earth-Moon in the right order. However, the sizes and the distances were not correctly drawn. Participant3 mentioned this limitation of his diagram in the interview before the instruction:

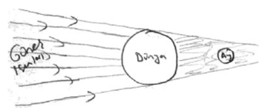
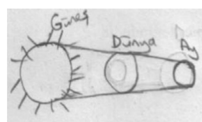
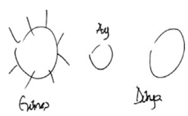
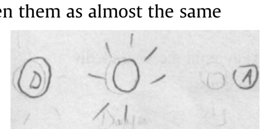
> **Participant3**: I didn't make such a good drawing but in the end, when the three are aligned with each other, there's a lunar eclipse. **I mean, that's what they generally say in the textbooks. In my drawing, though, it's like the Sun and the Earth are the same size**… **Usually in books, the Sun is drawn a bit bigger, and then the next biggest is the Earth and the Moon is the smallest**.
>
> **R**: And if I asked you to draw it again, what would you do?.
>
> **Participant3:** I'd make the sun a little bigger. A few times the size of the Earth. And if the Earth was a few times the size of the Moon, it would be like in the books. Our previous teachers drew it like this.

As can be seen in the interview transcripts, participant3 was aware of getting the order right in the drawing but unaware that the sizes and distances were incorrect. The participant3 stated that books and previous teachers in elementary school and high school would make drawings of this kind. Küçüközer (2007), in a study with pre-service science teachers and Küçüközer et al. (2010) in a study with elementary school pre-service science teachers, reported similar explanations. The studies displayed sample drawings from textbooks and emphasized that the sizes and distances were actually not in fact authentically shown. The same observation was noted by Bakas and Mikropoulos (2003) in their study, in which they pointed to the same characteristics in Greek textbooks.

After the instruction, however, almost all of the pre-service science teachers had the right order (Sun–Earth–Moon) and their drawings displayed the correct distances and sizes. While six pre-service science teachers' drawings were categorized as "The alignment correct but showing the distances and sizes of the Sun, the Earth and the Moon as almost the same" before the instruction, these participants' drawings were categorized as scientific after the instruction. These six participants produced very similar drawings. The following excerpt illustrates a typical example of the explanations participants provided regarding their post-instructional drawings.

> **Participant3**: Actually, I had the right order from the beginning but now, that is, after the lesson … We'd discussed in class how we could make a correct drawing. At the end, the class decided on a drawing like this. So, in other words, the Sun is much, much bigger than either the Earth or the Moon so when you draw it on the page, the others are too small to see if they're drawn to scale. **That's why we depicted the sun with its rays**. I think this is a much better idea. I will take care to draw it in this way when I become a teacher.

Table 3
Conceptions of pre-service science teachers about lunar eclipses.

	Conceptions	Pre-test f (%)	Post-test f (%)	Delayed post-test f (%)
Lunar eclipse	- The disappearance of the Moon from sight as it orbits around the Earth, and the Sun, Earth and Moon become aligned[a]	26 (79)	33 (100)	31 (94)
	- Confusion with a solar eclipse	6 (18)	–	2 (6)
	- Moon disappearing from sight from Earth as a result of the Sun coming in-between the Earth and the Moon[b]	1 (3)	–	–
Diagrams of a lunar eclipse	- The alignment, distances and sizes of the Earth and the Moon correctly shown 	–	30 (91)	25 (76)
	- The alignment correct but showing the distances and sizes of the Sun, the Earth and the Moon as almost the same 	26 (79)	3 (9)	8 (24)
	- The lunar eclipse is confused with the solar eclipse and the distances and sizes of the Sun, the Earth and the Moon are almost the same 	6 (18)	–	–
	- The Sun between the Earth and the Moon. While they used non-proportional models of the Sun, the Earth and the Moon, the pre-service science teachers also showed the distances between them as almost the same 	1 (3)	–	–

[a] Scientific.
[b] Misconception.

Again, a large majority of the pre-service science teachers (76%), including those six participants who shifted from alternative to scientific drawings from pre- to post-test, drew the same order, sizes and distances 22 months after the instruction. Eight pre-service science teachers made drawings similar to those they made before the instruction, with the order right but with incorrect sizes and distances. All of these eight pre-service science teachers had made the same type of drawing before the instruction as well.

5.4. Statistical analysis of the responses to the open-ended questionnaire

The change in participants' responses to the open-ended questions from pre to post and from post to delayed post-test was examined using the Chi Square analysis. The results of the Chi Square analysis indicated that significantly more participants provided scientific responses to the questions about the moon phases ($\chi^2 = 32\ 06$, $p < 0.001$) and the eclipse phenomenon (Yates' $\chi^2 = 62.01$, $p < 0.001$), and draw a scientific representation of the lunar eclipse (Yates' $\chi^2 = 48\ 49$, $p < 0.001$) in the post test than the pretest. The difference between the post-test and delayed post-test responses for the moon phases ($\chi^2 = 1.12$, $p = 0.29$), the eclipse phenomenon (Yates' $\chi^2 = 2.02$, $p = 0.12$), and the drawing task (Yates' $\chi^2 = 1.74$, $p = 0.19$), on the other hand, was not statistically significant. The overall findings of the Chi Square analyzes demonstrated that the instructional intervention was effective in helping pre-service science teachers develop and retain scientific conceptual understanding from pre to post test and from post to delayed post-test.

5.5. Participants' views on the change in their conceptual understandings and the instruction

This section describes the views of the six pre-service science teachers regarding the change in their conceptual understanding of the cause of the lunar phases and eclipses and the efficacy of the instructional intervention.

5.5.1. Moon Phases

Prior to the instructional intervention all six participants who were interviewed held the alternative eclipse model regarding the cause of the lunar phases. After the instruction, all six participants provided a scientific explanation for the cause of the moon phases. Participants provided similar in describing the change in their conceptual understanding during the instructional intervention. The following excerpt illustrates one participant's description.

R: You gave us an explanation based on the shadow of the Earth before the instruction. After the instruction, you gave us another explanation. Why did you change your mind?

Participant6: Because before, Hmmm, I thought, er… It was like a lunar eclipse and that's why I had connected it to the shadow of the Earth. ***But in the classroom discussions and in the animation, I understood that I had been wrong. When I thought about it, both explanations seemed reasonable but as I said a little while ago, when I understood the logic behind the phenomena, I can now differentiate between an eclipse and the phases of the moon. The animation was really very helpful***.

As the excerpt illustrates Participant6 (like other five participants) stated that the animation (3D computer modeling) and the class discussions were effective in helping them restructure their conceptual understanding. There is evidence of conceptual change in this interview transcript. Participant6 became aware that his ideas were unfruitful before the instruction. POE strategy supported with 3D computer modeling was effective in providing participants opportunities to discuss and revise their alternative explanations and in helping them constructing scientific understanding (Hewson & Hewson, 1984, 1992; Posner et al., 1982). Participants stressed that scientific explanation begins to seem more logical after the instruction which indicates that the scientific explanation of the cause of the lunar phases gained a higher status in comparison to alternative explanations. All six participants who were interviewed continued to provide scientific explanation 22 months after the instruction. These findings suggest that the powerful learning environment provided in this study was also effective in helping participants in retaining their scientific conceptual understanding almost two years after the instruction.

5.5.2. Eclipse

Four of six pre-service science teachers provided alternative explanations to the question "why eclipses do not happen every month?" indicating that "…Earth and Moon's speeds or the completion times of their cycles" cause the eclipses. Two pre-service teachers did not respond to this question. After the instruction all six participants indicated that "an eclipse did not occur every month because there was a 5.2° angle between the orbiting planes of the Earth and the Moon" suggesting that they constructed scientific understanding regarding the eclipse phenomenon. All six participants stressed the importance of classroom discussions and 3D modeling in helping them revising their alternative understandings and developing scientific understanding. The following excerpt illustrates one participant's explanation of the reasons he revised his pre-instructional explanation for the eclipse phenomenon.

R: You had said before the instruction that the orbiting speeds were not the same and that's why they weren't aligned. You gave another explanation after the instruction. Why did you change your mind?

Participant1: I really did not know the reason, I used logic, that in the end they should not be on the same line, therefore I thought **that their speeds or periods should be different**. There was an animation in class about this subject; we had had a discussion before the animation. We had then stated our previous ideas too. ***Our discussion during the lesson and the animation about the concepts were effective in changing my ideas. This information, I mean, the difference of the angle (5.2) is really logical. And seeing these with pictures and animations is much better. I don't think I'll ever forget this from now on***.

Participiant1 indicated that classroom discussions and the 3D modeling promoted his conceptual understanding of the phenomenon. Through the instructional intervention the scientific explanation appears to gain a higher status and become intelligible for the participant (Hewson & Hewson, 1984, 1992; Posner et al., 1982). The influence of the learning environment on participants' conceptual understanding was long lasting. Even 22 months after the instruction these participants were able to provide scientific explanation for the eclipse phenomenon.

5.5.3. Diagrams

All six participants produced drawings that fail to take the size and the distance into account before the instruction. However, after the instruction all participants' drawings included scientific perspective. The following excerpt illustrates one participant's comparison of his pre- and post-instructional drawings.

Participant3: …That's why we depicted the sun with its rays. I think this is a much better idea…

R: I know you explained it a little, but could you tell us why you changed the drawing?

Participant3: As I said before, my previous drawing was…Like what I remember from the textbooks, like our teachers used to draw. ***But in reality, in explaining the event, we've been drawing the distances and sizes all wrong. Our class discussions were very effective and then, when someone made the drawings on the board, attempting to reduce the sizes proportionately, the Earth and the Moon almost became invisible. That's why I changed my drawing***.

Participant3 indicated that the discussion of the proportional representation of the sun, earth and the moon helped them in developing a scientific representation of the phenomena. Even 22 months after the instructional intervention participants were able to draw scientific representation of the eclipse phenomena suggesting that classroom discussion was effective enough to produce long term change in participants' representational skills.

5.5.4. Instruction

During the interviews pre-service science teachers were also asked to evaluate the instruction. Participants indicated that they had learned something new and they realized that their preconceptions about basic astronomical phenomena were wrong. Moreover, participants asserted that the 3D models used during the instruction had been effective in helping them understand the concepts. Participant4's words can be given as an example of the views of the participants concerning their own learning process.

Participant4: ….. Before the instruction and …. after it,…, I can say that right now, I've learned many things about astronomy, about, for example, the stars, the galaxies, the universe, the Big Bang, and space exploration. There's one more thing– **I've learned that many things I used to know about astronomy were wrong. You know I had some ideas but many of them were wrong**… So the course was very useful in this respect. ***Now my ideas are much clearer, I mean, they're more correct. One more thing, now when I go online, I mostly visit sites about astronomy. I tell people everything I have learned from the course***.

As seen above, the instructional intervention allowed participant4 to realize that some of her previous ideas were not accurate. Additionally, participant4 stated that she mostly visits astronomical sites when she goes online suggesting the instructional intervention might caused behavioral changes as well.

5.5.5. 3D models

All of the pre-service science teachers interviewed confirmed that 3D models used during the instruction helped and improved their learning, that they were able to comprehend the concepts more easily with this technique, and that they had no difficulties in developing a mental picture in their minds about the phenomena. As an example of this, the thoughts of Participant1 were as follows:

Participant1: My thoughts towards the course are absolutely positive. ***The animations (3D models) and pictures used during the instruction will always stay in my mind. I mean the images will stay– for example, the animations that you showed during the lesson about the eclipses and why they don't happen every month, and the order of the Moon, the Earth and the Sun during the eclipses. Whenever I see a question about eclipses, the animations and images come to my mind and I answer questions easily. Visual effects in fact are very important. For example, I will never forget the tilt of 5.2° from now on. I can tell that these sorts of things made it much easier for me to learn. For example, if you had just lectured, I guess nothing would have stayed in my mind, I would not have been able to remember anything.***

Participant1 states that the 3D models and pictures made it easier for her to learn and because of this, she will not forget the concepts that she learned. She gives the example of how she feels she will always remember the 5.2° tilt of the axis and she asserts that she would not have been able to remember this information in the future if the knowledge had just been presented through a lecture.

These findings suggest that the 3D modeling used in the instructional intervention reduced participants' cognitive load (Sweller, 1988), thus making it easier for pre-service science teachers to understand the targeted phenomena (Hobson et al., 2010). In a similar study with young children, Hobson et al.'s (2010) demonstrated that a planetarium software acted as an extension of learners' cognition thereby freed some of the cognitive processing capacities, which in turn, facilitated children's construction of a scientific understanding of the cause of the moon phases.

6. Conclusion and implications

In this study, the conceptions of pre-service science teachers about the phases of the moon and eclipses were examined before and after an instructional intervention and approximately two years later. The instruction consisted of 3D computer models based on POE strategy. Results demonstrated that before the instruction, pre-service science teachers had some misconceptions about the phases of the Moon and eclipses. Most of these misconceptions had been previously reported in many studies on teacher candidates (literature (Bell & Trundle, 2008; Keating et al. 2002; Küçüközer, 2007; Küçüközer, 2007, 2008; Trundle et al., 2002, 2006, 2007; Zeilik et al., 1999).) and learners from various levels (Barnett & Morran, 2002; Baxter, 1989; Küçüközer et al., 2010; Parker & Heywood, 1998; Sharp, 1996; Trumper, 2000, 2001a, 2001b, 2001c) in the literature. The most common misconceptions discovered before the instruction were the following: concerning the phases of the Moon, "Phases of the Moon confused with a Lunar eclipse"; concerning why eclipses do not happen every month, "Because of the difference between the speeds of the Earth and Moon or the completion times of their cycles". In the participants' drawings of the lunar eclipse, the participants generally drew the images in the right order but the sizes of the Sun, Earth and Moon as well as their distances to each other were out of proportion.

After the instruction most pre-service science teachers were able to make scientifically acceptable statements about the phases of the Moon and eclipses. The misconception "Phases of the Moon confused with a lunar eclipse" was somewhat resistant to change. In their depictions of a lunar eclipse most pre-service science teachers drew the celestial bodies in the right order and were also able to depict the distances and sizes correctly. Only three pre-service science teachers did not consider proportional distances or sizes in their drawings after the instruction. Twenty-two months after the instruction, again, most pre-service science teachers were able to make scientifically acceptable statements. As regards the phases of the moon, while 28 pre-service science teachers had offered correct explanations after the instruction, 22 months later, the number of pre-service science teachers providing scientific explanations fell to 23. Five pre-service science teachers' explanations included the same misconceptions they had before the instruction (in the category of confusing the phases of the Moon with a solar eclipse). Concerning the reason eclipses do not happen every month, 33 pre-service science teachers offered scientific explanations after the instruction. However 22 months later this number fell to 29. Three pre-service science teachers provided explanations including the same misconceptions they had before the instruction (in the category of stating that the reason lay in the difference between the speeds of the Earth and Moon or the completion time of their cycles). In the drawings of a Lunar eclipse, 30 pre-service science teachers produced a scientifically acceptable drawing but 22 months later, only 25 produced scientifically acceptable drawings. Five pre-service science teachers (different from those participants who regressed in their conceptual understanding of the cause of the lunar phases) produced diagrams that were similar to what they drew before the instruction (diagrams in which distances and sizes were disregarded).

The data obtained through the questionnaire and interviews after the instruction and statistical analysis showed that the teaching activities used during the instruction were quite effective in facilitating conceptual change. Moreover, the pre-service science teachers stated clearly that they liked the teaching activities and that the activities helped them in understanding the targeted concepts. In respect to conceptual change, our results are consistent with other studies on this subject in the literature (Keating et al., 2002; Küçüközer, 2008; Parker & Heywood, 1998; Trumper, 2006; Trundle et al., 2002, 2006; Zeilik et al., 1999). The findings of the present study are congruent with the results of the studies that used computer-supported POE strategy (Kearney & Treagust, 2000; Küçüközer, 2008; Küçüközer et al., 2009; Tao & Gunstone, 1999).

The findings of the study show that the 3D computer modeling-supported POE strategy was considerably effective in bringing about durable conceptual change. This was indicated by the fact that a large majority of the pre-service science teachers were able to present scientifically correct and acceptable statements about the phases of the Moon and eclipses approximately two years after the instruction. Studies that investigate the long-term impact of instructional intervention are very limited. The only long-term study concerning the phases of the Moon in this context is that of Trundle et al. (2007) where the participants' conceptual understanding were assessed about six months after the post-interview. The findings of Trundle et al. (2007) study are consistent with the findings of the present study in that nine pre-service elementary teachers' explanations "durable" over six months or more after the instruction, whereas three pre-service elementary teachers "conceptual decay". In the present study, participants were assessed about 22 months after the post-interviews and 3D computer modelings designed by 3D Studio Max software was used. The current study is the first to demonstrate the effectiveness of using a 3D computer modeling-supported POE strategy to achieve durable conceptual change.

3D computer modelings used in the present study allow participants to observe the targeted phenomena from multiple perspectives and facilitate the construction of scientific mental models (Keating et al., 2002). Vosniadou (2005) asserts that a computer-supported learning environment in which students freely express and discuss their ideas facilitates students' metaconceptual awareness, which is associated with durable conceptual understanding. The findings of the present study demonstrated that the 3D computer modeling-supported POE strategy provided a powerful learning environment where the participants develop scientific conceptual understanding that is durable over time. The efficacy of this type of instructional intervention should be tested with young learners.

Three participants did not change their conceptual understanding of the cause of the moon phases after the instruction and five participants returned their alternative conceptual understanding 22 months after the instruction. It appears that the 3D computer modeling supported instructional intervention was not effective in helping some participants restructure their conceptual understanding and others retain their scientific conceptual understanding. The instruction failed to create a state of *dissatisfaction* with the current conception and make the scientific concept *intelligible*, *plausible*, and *fruitful* for these participants. Therefore, the status of alternative conceptions remained stable for some participants after the instruction and the status of scientific conception temporarily elevated for participants with conceptual decay (Hewson, 1982; Hewson & Hewson, 1992). Participants who did not benefit from the instructional intervention might have a limited metacognitive awareness of their conceptual understanding of the cause of the lunar phases (Trundle et al., 2007) or they might be responsive to other forms of learning environments. Future studies should examine how participants' level of metacognitive awareness and their learning styles interact with the learning environment.

The present study demonstrated that 3D modeling-supported POE strategies promote motivation and the social environment. The POE strategy allows students to express and discuss their ideas in a social environment and 3D models, because they are engaging, are effective in stimulating motivation (Bakas & Mikropoulos, 2003; Merchant et al., 2012). In understanding complex science concepts learners frequently experience difficulty which results in declining motivation to learn. Learning environments that reduce cognitive load and support comprehension and understanding of complex science concepts have potentials to promote learners' motivation. The conceptual change oriented learning environment used in the present study takes the social and motivational factors into account and addresses the limitations of Posner et al. (1982) model of conceptual change (Dole & Sinatra, 1998; Pintrich et al., 1993; Strike & Posner, 1992). Future studies should investigate the effectiveness of the 3D computer modeling-supported POE strategy designed based on the principles of PLE on learners' conceptual understanding of other science concepts. Studies should also focus on how this type of learning environment influence or interact with learners' levels of motivation.

Researchers suggest that 3D computer modeling or simulations might reduce pre-service science teachers' cognitive load thereby facilitates learning (Hobson et al., 2010; Merchant et al., 2012; Rutten et al., 2012; Sweller, 1988). The 3D models used in the instructional intervention may have been the catalyst in achieving durable conceptual change in the present study. Future studies should focus on demonstrating more concretely the relationship between factors that reduce cognitive load and conceptual change. There are several limitations of the present study. The major limitation of this study is its sample size. Further studies should be conducted with larger sample sizes to extend the results of the current study to the population of preservice science teachers. The open-ended questionnaire was the main data collection instrument in this study and in-depth interviews were conducted only with six participants in the delayed-post test. Future studies should conduct interviews with all participants in all data collection points.

When we look at the POE-supported 3D modeling activities in the study in terms of the powerful learning environment that de jong (2005) described, we can state that the instructional activities are highly motivating in enlisting student participation. The fact that the change in most preservice teachers' conceptual understanding of the phases of the moon and eclipses was durable almost two years after the instruction shows that the learning environment used in the present study was effective in helping preservice teachers retaining their conceptual understanding in their long-term memory. POE strategies are suitable for use in cooperative environments where students have the opportunity to freely express their thoughts at every stage of the learning process, and are thus effective in allowing students to be aware of their own ideas and the ideas of their classmates. The technique, for all these reasons, provides a powerful learning environment. Future research should probe into the efficacy of instructional interventions that are based on the principles of the powerful learning environment in promoting conceptual change in other science concepts.

Acknowledgements

Thanks to Mesut Saçkes and Asuman Küçüközer for their helpful comments on an earlier version of this paper and Ayberk Sarıoğlan for her help in the collection of delayed-post test data.

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