The effects of 3D computer modelling on conceptual change about seasons and phases of the Moon

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The effects of 3D computer modelling on conceptual change about seasons and phases of the Moon

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Abstract

In this study, prospective science teachers' misconceptions about the seasons and the phases of the Moon were determined, and then the effects of 3D computer modelling on their conceptual changes were investigated. The topics were covered in two classes with a total of 76 students using a predict–observe–explain strategy supported by 3D computer modelling. The results of the study suggest that, prior to teaching, the subjects had misconceptions regarding both phenomena, and that the teaching was quite effective regarding conceptual change.

S Supplementary data are available from stacks.iop.org/physed/43/632

Introduction

Students come into science classes with their own ideas about the natural world. These ideas are sometimes non-scientific, although they may make sense to the students. Non-scientific ideas such as terminological misconceptions and alternative frameworks often go unaddressed and unchanged in the science classroom [1]. Researchers have done studies on developing teaching strategies and activities to achieve conceptual change from misconceptions towards scientific conceptions. Scott *et al* [2] have identified two main groups of special teaching strategies to promote conceptual change. The first group is based upon cognitive conflict and the resolution of conflicting perspectives, and 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 [3] is based upon the assertions of constructivism, using a predict–observe–explain (POE) strategy 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. POE is a technique that also allows students to work on tasks collaboratively in pairs [4]. The use of POE tasks within a computer environment has been little reported in the literature. Tao and Gunstone [4] developed computer-supported POE tasks to confront students' misconceptions in mechanics.

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Table 1. A teaching activity about the phases of the Moon.

Predict

Students were asked to predict the cause of the phases of the Moon.

Observe

The 3D modelling below was shown to the students. The 3D modelling employed two cameras to simultaneously show both the Moon from the Earth, and the position of the Moon on 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 modelling a few times, the different phases of the Moon 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 learning astronomy, two of the topics students have difficulty with most, and about which they possess many misconceptions, are the seasons and the phases of the Moon. Although there are a number of studies that point out both students' and teachers' misconceptions, very few of them deal with the conceptual change of those misconceptions. Recently, three-dimensional (3D) computer modelling has been used to engender conceptual change about the seasons [5–7] and the phases of the Moon [7, 8]. 3D computer modelling technology is particularly valuable for the teaching and learning of astronomy because it helps students understand abstract concepts and phenomena. Moreover, it could be used to support students in developing scientific understanding of astronomical phenomena [8].

In this study, the effects of POE tasks embedded 3D computer modelling supported teaching on conceptual change about both the seasons and the phases of the Moon were investigated.

Methodology and teaching activities

The sample group of 76 participants, ranging in age from 19 to 21, consisted of prospective science teachers attending the 'Physics III (Astronomy)' course at the University of Balıkesir (Turkey). In this study, an open-ended questionnaire consisting of eight questions (available in the online version of the journal at stacks.iop.org/physed/43/632) was used together with interviews to understand and describe students' understanding of astronomical concepts and phenomena before and after instruction. The activities and results regarding the cause of seasons and the phases of the Moon are reported.

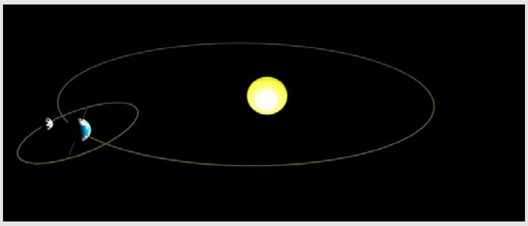
The questionnaire derived from three different sources: Barnett and Morran [5], Trumper [9], and Zeilik *et al* [10]. Six experts in physics education, two experts in physics, and two experts in astronomy judged the content validity of the questionnaire and, after pilot implementation (10 students), the questionnaire was finalized.

Before and after instruction, 15 volunteer students were each interviewed for between 20 and 35 min. Individual interviews were conducted in order to clarify the nature of their response to the open-ended questionnaire. In addition, the questions were used to clarify the reasons for differences (if any) between the ideas held by the students before and after instruction, and the reasons why they did not maintain their previously held ideas. Before and after instruction,

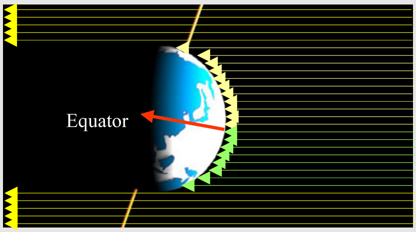
Table 2. A teaching activity about the seasons.

Predict
Why do the seasons occur?

Observe
The 3D modelling below, depicting the Sun, the Earth and the Moon and their orbits, was shown to the students.

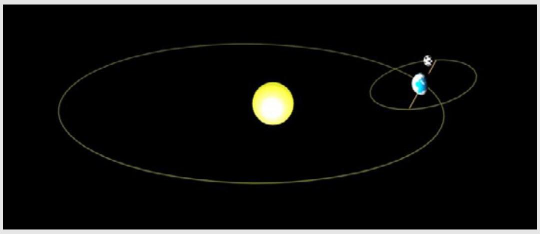


The 3D modelling was paused when it reached the position shown in the above figure, and the students were asked which season it would be in each hemisphere. After discussion, the representation in the figure below was shown.

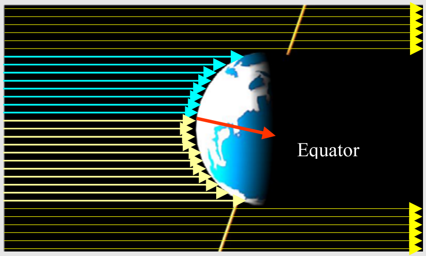


As seen in the figure, arrows are used to show the amount of sunlight that each hemisphere is receiving, the gaps between each line being the same. Using this representation, it was expected that the students would become aware of the fact that the number of beams on each hemisphere were different, and that the reason for this was the tilt of the Earth's axis; thus, it would be summer in the northern hemisphere while it was winter in the southern hemisphere.

The 3D modelling was restarted to show winter in the northern hemisphere. It was paused when it showed the position seen in the figure below, and the students were asked what season it would be in each hemisphere.



After discussion, the representation in the figure below was presented. As in the previous representations, students were expected to notice that the number of beams received by each hemisphere were different, and that, this time, the situation was reversed (i.e., the southern hemisphere was receiving more beams than the northern; therefore, while it was summer in the southern hemisphere, it was winter in the northern hemisphere).



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

Table 3. Prospective science teachers' conceptions about the seasons and the phases of the Moon before and after instruction (C: correct, MC: misconception).

	Conceptions	Before instruction (%)	After instruction (%)
Seasons	The tilt of the Earth's axis (C)	35	93
	The Earth revolves around the Sun (MC)	30	7
	Change in distance between the Earth and the Sun (MC)	24	—
	The rotation of the Earth on its own axis (MC)	4	—
	Uncodable	5	—
	No explanation	2	—
Phases of the Moon	The Moon revolves around the Earth (C)	25	90
	Phases of the Moon confused with the lunar eclipse (MC)	32	5
	The Moon revolves around the Sun (MC)	9	—
	The rotation of the Moon on its own axis (MC)	4	—
	Any planet enters between the Moon and the Earth (MC)	4	—
	Black clouds enter between the Moon and the Earth (MC)	4	—
	Uncodable	10	3
	No explanation	12	2

prospective science teachers' explanations were evaluated by analysing their responses in the open-ended questionnaire, and the data were gathered through interviews. The methodology used in analysing the data was a grouped categorization of those responses construed as having similar intended meanings.

In the teaching, the students' misconceptions were taken into consideration, and POE tasks were provided to help students change their misconceptions. First, in the predict phase, questions revealing the students' ideas were asked, and then students 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 modelling was used showing the phenomena of the phases of the Moon (table 1), and the seasons (table 2), and students were again asked to discuss them. Finally, in the explain phase, students were asked to compare and discuss their predictions and the results of their observations.

In our study, 3D computer modelling was 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 modelling software package used mostly by design visualization specialists, game developers, and visual effects artists. After the Sun is defined as the source of the 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 radii.

Before the activities, a correctly scaled representation of the Sun, the Earth and the Moon was shown to the students 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 were scaled proportionately smaller or larger by a certain amount.

Results

Table 3 presents the prospective science teachers' ideas on the seasons and the phases of the Moon before and after instruction. Before instruction, they held a series of misconceptions on these phenomena. The most frequent misconceptions encountered in the students' ideas about the cause of the seasons are the 'change of the distance between the Earth and the Sun—the Earth revolves around the Sun in an elliptic orbit: when the Earth goes nearer to the Sun summer occurs, and when it wanders away winter takes place', and 'the Earth revolves around the Sun—besides the occurrences of the seasons the season changes were also attributed only to the revolution of the Earth around the Sun'. Concerning the phases of the Moon, common misconceptions were 'the phases of the Moon were confused with the lunar eclipse—the phases of the Moon are caused by the shadow of the Earth on the Moon'. After instruction, almost all of the students gave scientifically sound explanations about both of these topics.

In the interviews, the students stressed the effectiveness of the class discussions (POE tasks) and 3D computer modelling on changing their previously held ideas about both phenomena.

Exemplifying this are the thoughts of a student who had previously thought the seasons occurred because of the revolution of the Earth around the Sun, and who, after instruction, said that it is because of the tilt of the Earth's axis: 'Well you know it remains in the mind, it is being mentioned at school, I mean something like its rotation around the Sun. But now we discussed in the lesson, moreover we had counted the beams on Earth after the animation. It was coming out different on Southern and Northern hemispheres. I mean because of the tilt of the axis the seasons occur. It is because of the amount of the beams received by both hemispheres is becoming different. Really now this knowledge I newly acquired are more logical besides the diagrams shown has been very effective in changing my opinion.' Similar to this are the thoughts of a student who confused the phases of the Moon with the lunar eclipse before instruction, but subsequently changed this idea to the revolution of the Moon around the Earth: 'Beams coming from the Sun, well this appearance differences were results of orbiting of the Moon around the Earth it is said. What now, when I took this test previously I did not have too much information that is why I had told by using logic that it might be the shadow of the Earth. I mean I confused the issue with the lunar eclipse, lunar eclipse lasts a couple of hours but the phases of the Moon for example the full Moon is seen a couple of days, the others too of course. In the double view animation shown during the lesson, well you see the Moon was orbiting the Earth; there was just appearance of the Moon and changing in the other. I can tell that that animation was effective in changing my opinion.'

Conclusion

The data obtained by means of the questionnaire and interviews after instruction show that 3D computer modelling used during the instruction had been quite effective in achieving conceptual change. Such findings correspond with those of other studies that used 3D computer models for teaching astronomical subjects [5, 6, 8]. With this study, it was demonstrated that POE-supported 3D computer models—which were not used in other studies about astronomy teaching—made a considerable contribution to learning.

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