

Teaching future teachers basic astronomy concepts – Sun-Earth-Moon relative movements – at a time of reform in science education

Ricardo Trumper*
Haifa University, Israel

In view of students' alternative conceptions about basic concepts in astronomy, we conducted a series of constructivist activities with future elementary and junior high school teachers aimed at changing their conceptions about the cause of seasonal changes, and of several characteristics of the Sun-Earth-Moon relative movements like Moon phases, Sun and Moon eclipses, and others. The activities concerning the characteristics of the Sun-Earth-Moon relative movements and their results are reported. The experimental class as well as the control groups improved their grasp of basic astronomy concepts at a statistically significant level. Regarding subjects relevant to this study (Sun-Earth-Moon relative movements), only the experimental class and one of the control groups showed a statistically significant improvement, and in both cases the experimental class made the most impressive progress of all.

Introduction

The Israeli education system experienced a long period of change as a result of the recommendations of the Tomorrow 98 Report (1992). Among the reforms proposed are the revision of mathematics, science and technology curricula, and the 'implementation of a comprehensive program for the pre-service and in-service training' (p. 29) of schoolteachers.

Similar initiatives on curriculum reform in several countries have set ambitious goals to increase scientific literacy among the population. The impetus for reform and the achievement of scientific literacy appears related to such issues as the number and quality of scientists, engineers and technicians; the technical illiteracy of most high school and college graduates; a worsening shortage of qualified high school science teachers; and declining test scores in science. Such developments have been reported

*Kibbutz Hahoterim, Doar Na Hof Hacarmel 30870, Israel. Email: rtrumper@research.haifa.ac.il

by the USA (American Association for the Advancement of Science, 1993; National Research Council, 1996), Canada (Orpwood & Souque, 1985), Australia (Department of Employment, Education and Training, 1989), the UK (Goldsworthy, 1997) and Italy (Borghi *et al.*, 1991).

The limited impact of the reforms made in science teaching over the past two decades in different parts of the world has attracted considerable interest. Wallace and Louden (1992, p. 519) concluded that the reform of classrooms must be understood through the ‘view of the central place of teacher’s knowledge in teacher’s work’. Several recent studies analysing the results of the reforms in science education in American schools have reached the following conclusions (Yager *et al.*, 1996; Dana *et al.*, 1997; Radford, 1998):

1. Instituting reform in science education requires teachers who are knowledgeable in science content, process and inquiry pedagogy.
2. Most teachers need training in order to be able to teach reform-based science.
3. Standards for both teaching and learning science must take into account recent research into constructivist theory and its implementation in the classroom.

According to these premises, a new ‘Science and Technology’ programme was proposed here in Israel from elementary to senior high school. One of the new topics is ‘The Earth and the Universe’, the core subject of which is astronomy.

Despite the historical and scientific significance of the study of astronomy, the subject is rarely taught today in Israel, even at the high school level. There are good reasons for introducing astronomy into the curriculum:

1. New discoveries in astronomy create interest and can be exploited to increase students’ motivation to learn science.
2. The study of astronomy can demonstrate the growth of knowledge as a process of developing, discarding and replacing explanatory models.

Students’ conceptions of basic astronomy concepts

High school, college and university students’ notions of astronomy concepts have been investigated far less than those of elementary school students, which have been researched extensively during the last 30 years (e.g., Nussbaum & Novak, 1976; Nussbaum, 1979; Klein, 1982; Sneider & Pulos, 1983; Jones *et al.*, 1987; Baxter 1989; Vosniadou, 1992; Vosniadou & Brewer, 1992, 1994; Sharp, 1996).

Lightman and Sadler (1993) found that students in grades eight to 12 shared some of the conceptions held by elementary school children. Though more than 60% of the students held the accepted scientific concept about the day-night cycle, less than 40% knew the correct characteristics of the Moon’s revolution. Furthermore, less than 30% had the right conception about the phases of the Moon, the Sun overhead and the Earth’s diameter, and only 10% knew the reason for the change of seasons. Zeilik *et al.* (1998) obtained similar results among university majors: they found that only 10% of the students held the correct view of the Moon’s rotation, 23% had the right

conception of the Sun overhead, and about 30% knew the accepted scientific explanation of the solar eclipse and the phases of the Moon.

Very few studies investigating teachers' astronomy conceptions have been carried out. Taylor tells of:

a junior high school teacher with a keen interest in teaching science who once told me that the phases of the Moon are caused by 'the shadows that the Earth casts on it.' Other teachers in the same school could offer no explanation at all for the phases of the Moon. Yet they have all been taught [through a traditional textbook approach] the topic when they were in school, and all of them had taught it to their classes. (Taylor, 1996, p. 39)

Trumper (2001) assessed students' basic astronomy conceptions from junior high school through university. He summarized the most widespread misconceptions at all educational levels, as can be seen in Table 1.

Table 1. Most widespread astronomy misconceptions by groups (%)

Subject	Misconception	Junior high school	Senior high school	Future primary teachers	Future high school teachers	Non-science university
<i>Day-night cycle</i>	Earth moves around the Sun	36	30	51	37	34
<i>Moon's phases</i>	Moon moves into Earth's shadow	19	27	16	25	29
	Moon moves into Sun's shadow	25	17	29	23	16
<i>Reason for seasons</i>	Earth closer to Sun in summer	45	33	37	32	32
<i>Reason for it being hotter in summer than in winter</i>	Earth closer to Sun in summer	36	28	20	19	22
	Earth's rotational axis flips back and forth	20	23	31	29	23
<i>Sun overhead at noon</i>	Every day	35	36	48	44	42
<i>Moon's phase in solar eclipse</i>	Full phase	74	77	71	75	70
<i>Moon's rotation – same side visible</i>	Moon does not rotate on its axis	54	57	51	47	50

Moreover, he found that future elementary school teachers got the lowest correct response rate (32%), even lower than that scored by junior high school students (36%). This suggests that future elementary teachers have more alternative conceptions about basic astronomy concepts than typical junior high school students.

Constructivist attempts in teaching astronomy

Public interest in astronomy seems to have grown since the upsurge of media reports on the different satellites and shuttles taking part in space research. In parallel, astronomy is being increasingly introduced into the school curriculum in different countries, including Israel. Nevertheless, very few teachers venture to teach astronomy since they lack the necessary knowledge and training for it; the majority of elementary and junior high school teachers did not study astronomy at school or at college. Moreover, learning astronomy demands abstraction capabilities and a high understanding of space and time concepts, or alternatively, ways of teaching that explain phenomena as concretely as possible. These requirements increase teachers' lack of confidence and reluctance to teach astronomy.

According to a constructivist perspective, humans are seen as subjects who actively construct understanding from experiences using their already existing conceptual frameworks (Vosniadou, 1991; Wubbels, 1992). A constructivist way of teaching assumes the existence of learners' conceptual schemata and their active application of these when responding to and making sense of new situations. What a student learns, therefore, results from the interaction between what is brought to the learning situation and what is experienced while in it. In many cases, students' naive notions are often alternative conceptions, which may impede learning of appropriate concepts in the field despite the best efforts of instructors (Redish & Steinberg, 1999).

Science educators have recommended the use of conceptual change approaches in science education (e.g., Hewson & Hewson, 1984; Stofflet, 1991). Conceptual change pedagogy is based on constructivist learning, recognizing that powerful theories are brought to the classroom and affect the learning of new material (Stofflet, 1994). This instructional approach holds that learners must first become dissatisfied with their existing conceptions, in addition to finding new concepts intelligible, plausible and fruitful, before conceptual restructuring occurs (Posner *et al.*, 1982). The effectiveness of the conceptual change approach to science has been demonstrated in several studies (e.g., Champagne *et al.*, 1985; Roth & Rosaen, 1991). This entire personal constructivist theory is grounded in Kelly's theory of Personal Constructs (Kelly, 1963) and, as noted above, many science education researchers have adopted it since his whole approach is based on the idea of the development of 'a man as a scientist'.

Constructivist-oriented science educators (Driver, 1988; Solomon, 1991; Cobern, 1993) realized that personal constructivism does not recognize the importance of the social facets of learning, and added an emphasis on teachers' and students' social construction of scientific knowledge. From a social constructivist viewpoint, learning is considered a social activity in which learners are engaged in constructing meaning

through negotiations and talks among peers, students and teachers (Edwards & Mercer, 1987). At the same time, students' individual constructions of meaning take place when their ideas are evaluated, explored and supported in a social setting, with each student having the opportunity to restructure his or her ideas through talking and listening (Driver, 1988; Solomon, 1991). Through social interactions students become aware of others' ideas, look for reconfirmation of their own thoughts, and reinforce or reject their personal constructions.

In the social constructivist perspective, referred to in Vygotsky's work (1978), thinking processes and knowledge development are seen as the consequence of personal interactions in social contexts and of appropriation of socially constructed knowledge. In any case, knowledge acquisition and conceptual change take place through a process of formulation, reformulation and reinterpretation of knowledge, in which the learner is continuously evaluating his or her significance, comparing different points of view and testing their validity. The learner is an active constructor of his/her own knowledge, and the process of knowledge acquisition is greatly assisted by interactions with peers and in particular with a teacher acting at the zone of proximal development (Vygotsky, 1978).

In this constructivist spirit, several environments for learning astronomy have been developed in the last few years. Bisard and Zeilik (1998) found that allowing student groups to work on an activity for ten to 15 minutes each class period could be very productive if the activity was well-structured and not too easy. In such a way they restructured their classes into what they call 'conceptually centered astronomy [classes] with actively engaged students'; they reported significant conceptual changes in their students' thinking (Zeilik & Bisard, 2000, p. 229).

Morrow (2000) proposed and performed 'kinesthetic' astronomy lessons in which, through a series of simple body movements, students young and old gained insight into the relationship between time and the astronomical motions of the Earth (rotation about its axis, and orbit around the Sun), and also about how these motions influence what we see in the sky at various times of the day and year. The only 'equipment' needed was a central object to represent the Sun. (A complete description of the activities performed by Morrow's classes can be found at http://www.space-science.org/Education/ResourcesForEducators/CurriculumMaterials/Kin_Astro/ST_112700.pdf.) Unfortunately, we did not find any reports about the effectiveness of these activities in changing students' conceptions.

Diakidoy and Kendeou (2001) reported a study they carried out with fifth-grade students learning astronomy concepts such as the Earth's shape and rotational movement, and the day-night cycle. Their findings showed that students who received experimental constructivist instruction in the targeted astronomy concepts demonstrated significant improvement in their understanding and learning of these concepts, in contrast to students who received standard, textbook-based instruction.

Bakas and Mikropoulos (2003) developed an educational tool based on the technologies of Virtual Reality. The objective was to create an interactive three-dimensional artificial learning environment within which students were able to come into immediate contact with the movements of the planets and the Sun and the

phenomena occurring in our solar system, in particular the Earth-Sun system. The purpose was also to provide students with environments that gave them the opportunity to experience cognitive conflict and to reject possible misunderstandings engendered by them. Findings showed that after the interaction with the virtual environment, students aged 12–13 created fewer, more concrete and scientifically accepted mental models.

Taylor *et al.* (2003) reported significant positive outcomes from a teaching package in astronomy education based on what they called Mental Model-building Strategy. In their research, junior high school students were given the opportunity to generate, critique and successively refine their mental astronomy models of the Sun-Earth-Moon system.

Suzuki (2003) described a very interesting and effective conversation-based strategy for teaching about the Moon. He documented students' ideas, and reconstructed them in two research seminars in science education for university students training to be elementary and junior high school teachers.

Methodology

The present study

Bearing in mind the alternative conceptions described in the foregoing research studies, we first studied future teachers' alternative conceptions and second created a series of constructivist activities to change future elementary and junior high school teachers' conceptions about the reason for the seasonal changes, and several characteristics of the Sun-Earth-Moon relative movements like Moon phases, Sun and Moon eclipses, and more. The activities and results concerning the Sun-Earth-Moon relative movements are now reported.

Sample characteristics and research methods

Our research project encompassed 138 university and college students, divided into four different classes, all of them studying introductory courses on astronomy for the first time. The experimental class comprised 19 technology teachers at junior high school taking a semester course in their retraining for science teaching in primary and junior high schools in the framework of their B.Ed. studies at an academic college of education. There were three different control classes; each followed a traditional lecture format. One comprised 83 university students taking a semester course in the Interdisciplinary department of the Faculty of Humanities. Another was 14 future high school physics teachers taking a semester course in the framework of their B.Sc. studies in the Physics-Mathematics Teaching department of the Faculty of Science and Science Education in the same university. The third control class was made up of 22 future primary school teachers taking a year-long course in their training for science teaching in Bedouin primary schools as part of their Teaching Certificate studies at the same academic college of education as the experimental class.

Students' astronomy conceptions were analysed by means of a written questionnaire containing 21 items, presented at the beginning of the course. Five experts in physics education research and three experienced lecturers in 'Introduction to astronomy' courses judged the content validity of the questionnaire. After some minor changes as suggested by the judges, the test was deemed valid (see Appendix). Cronbach's alpha coefficient for reliability was 0.62, a relatively high score considering that different questions were related to different concepts and understandings of astronomy. Furthermore, we performed an item analysis that provided discrimination indices measuring the extent to which the test questions differentiated between students with the highest and lowest scores on the total test. All questions discriminated positively; for most, discrimination indices were in the range 0.18–0.62 with respect to the upper and lower quarters of the sample, and 0.31–0.76 with respect to the upper and lower 10% of the sample. To acquire a more in-depth understanding of students' conceptions, several volunteer students from the experimental class were interviewed at different stages of the research according to the principles of the 'clinical interview' (Osborne & Gilbert, 1980). In these interviews the researcher played an unbiased role, trying only to clarify and get a better comprehension of students' answers to the questions asked during the research; the students were able to raise any idea they wanted while the researcher followed them trying to understand their meaning. During the interviews some of the students demonstrated learning, a fact that reinforces the contribution made by the social, group discussion.

Results of pre-test and first interview

Figure 1 shows the scores obtained by the different groups in answering the whole questionnaire, and the questions about phenomena related to Sun-Earth-Moon relative motions (questions 2, 4, 5, 11, 18 and 19), at the beginning of their introductory astronomy course.

In the whole questionnaire, there was a statistically significant difference between the success of the university students and of all the other groups with the largest effect size for the future Bedouin primary school teachers (Cohen, 1988), as can be seen in Table 2, and for questions related to Sun-Earth-Moon relative motions we found a statistically significant difference only between the university students and the future Bedouin primary school teachers ($t = 2.04$, $p\text{-value} = .05$, Cohen's effect size – $d = .77$).

In the interviews, students' conceptions proved somewhat uncertain, as indicated in the excerpts shown in Figure 2.

Experimental instructional activities and findings

The key aspects of constructivism that influenced the design of the materials and activities for developing students' understanding can be expressed as the need

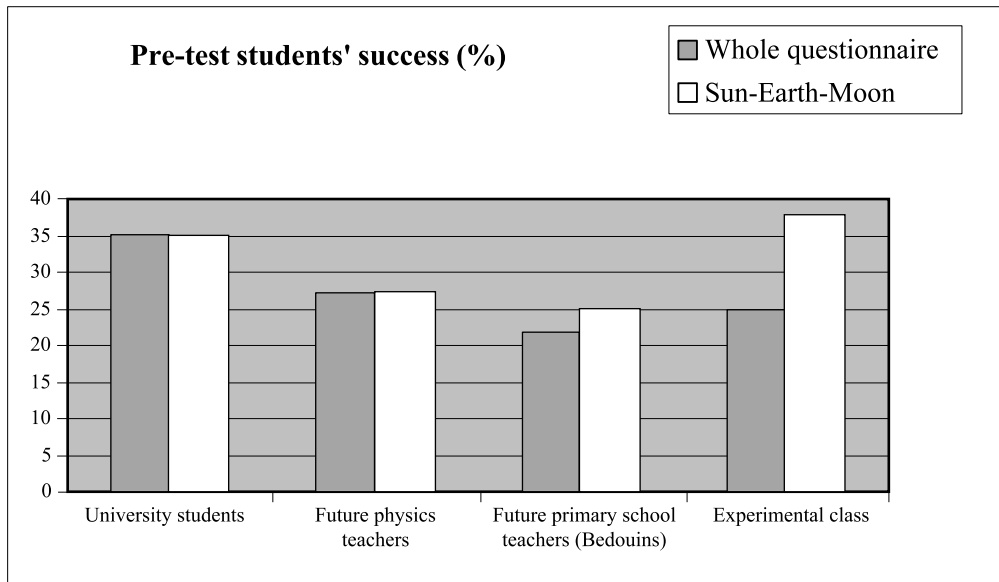


Figure 1. Correct answers percentage of the different groups in the pre-test

- (a) to have knowledge of students' existing understanding in the targeted conceptual areas, and to use this as a starting point for the design of appropriate teaching materials; and
- (b) to provide experiences that will help students to change their views and conceptions, and to accept the scientific view.

We kept to the general trend proposed by Vosniadou (1991) in science teaching in general, and particularly in astronomy. Aiming to replace well-established beliefs with a different explanatory framework, our experimental instructional activities tried to

1. create some conditions for students to question their entrenched beliefs by having them evaluate empirical evidence that is contrary to their beliefs;
2. provide a clear explanation of scientific concepts, preferably in the form of conceptual models or analogies; and

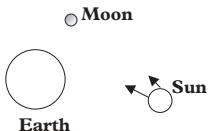
Table 2. Statistically significant difference between the university students and all the other groups in the whole questionnaire (pre-test)

	Students' success	t - test	p-value	Cohen's effect size - d
University students	35.1	–	–	–
Future physics teachers	27.2	1.862	.004	.488
Future primary school teachers (Bedouins)	21.8	4.048	< .001	.872
Experimental class	24.8	3.048	.002	.684

S1 – Question 4 (Student’s answer in questionnaire: the change between night and day is caused by the Sun going around the Earth.)

- S1: The Earth moves into the Sun’s shadow ... I think that the angle, what I thought ... I know that the Earth rotates around its own axis and around the Earth, and every time it rotates around its axis and around the Sun there is a change between day and night.
- R: How is this related to the Earth going into the Sun’s shadow?
- S1: I don’t know, I didn’t mean into the shadow. There is no Sun shadow. Is there a Sun shadow?
- R: The shadow we see outside, during daylight, is caused by the Sun.
- S1: But the cause of this phenomenon is the rotation of the Earth around its axis and around the Sun, so the Sun shines over the Earth from a different angle and the day turns into night. I think answer A is more accurate! I don’t know.

S2 – Question 5 (Student’s answer in questionnaire: the cause of the Moon phases is that the Moon moves into the Earth’s shadow.)

- S2: I’ll draw a picture ... Here’s the Earth.  This is the Sun and this is the Moon. We have the Moon, the Sun shines on this side, a relative amount of light is absorbed by Earth. We see another amount, something like this. When the Sun moves to a more parallel position, we shall see a greater part of the Moon. It will slowly increase.
- R: How is this related to the Moon moving into the Earth’s shadow?
- S2: If we see the Moon one night this way, and a larger Moon several days later, so at the beginning ... I think the correct answer is that the Moon moves around the Earth, so we see every day a larger part of the Moon exposed to us.
- R: Is it caused by the Sun’s movement or by the Moon’s movement?
- S2: Actually it’s because of the Sun’s movement.

S3 – Question 19 (Student’s answer in the questionnaire: A.)

- S3: I was wrong, the Moon remains Full!

Figure 2. Excerpts from students’ interviews after completing the pre-test (R, researcher; Sn, student number n)

3. demonstrate how the new conceptual models provide a better account of the available empirical observations than the entrenched beliefs.

The study began at the start of the semester, after the students completed the pre-test, and ran for three months. Most activities were performed in class, followed by a group discussion guided by the teacher; some activities were assigned as homework. At the beginning of March, students performed an activity concerning *the day and night change in the spinning Earth*, from sunrise to midnight. The light from an overhead projector represented sunlight and the student’s head the spinning Earth. Students were asked to look to the right side at the beginning (sunrise) and then to turn counterclockwise and to mark the position of their eyes in each of the situations. Fifteen students marked all the positions correctly, three students forgot to

Table 3. Names of the moon phases during the Hebrew (or Muslim) month

Age of the Moon (days)	Phase name
1	New Moon
2–7	Waxing Crescent
8	First Quarter
9–14	Waxing Gibbous
15	Full Moon
16–22	Waning gibbous
23	Third Quarter
24–29	Waning Crescent

mark the position of their eyes at midnight, and one student marked midnight as if it was noon.

On the same day, the students were assigned a homework activity for two weeks:

- 1 They were asked to *predict the Moon phases* during the Hebrew (or Muslim) month, beginning with the New Moon. They had to arrange the pictures seen in Figure 3 on the appropriate squares of Figure 4, writing down the names of the Moon phases as shown in Table 3.
- 2 Students were asked to watch the Moon phases every night during the next two weeks, to compare their observation with their initial prediction, and to correct it if necessary.

Ten students correctly predicted the order of the Moon phases after watching them for two weeks, and nine students made a wrong prediction.

After two weeks, the students performed an activity intended *to simulate the Moon phases as seen from Earth*. Students stood in front of the same overhead projector, as in the first activity, that represents the light coming up from the Sun. Their heads represented the Earth, and they held a Styrofoam ball with a large wooden stick slightly above their heads, representing the Moon.

Students had to stand in front of the light and stretch their right arm holding the ‘Moon’ towards the ‘Sun’. Then they had to move counterclockwise and watch how the illuminated part of the ‘Moon’ changed shape. After completing a whole turn they had to draw the successive phases of the Moon, to compare them with their predictions, and to answer several questions related to the activity, including their causal explanations of the Moon phases.

After performing the simulation of the Moon phases as seen from the Earth, the students were asked a series of questions:

- (a) *Was your initial prediction of the Moon phases correct?* The ten students who made a correct prediction found that it matched the results of the simulation. Of the students who made a wrong prediction, eight thought it matched the results of the simulation and only one saw the differences between his prediction and the result of the simulation.

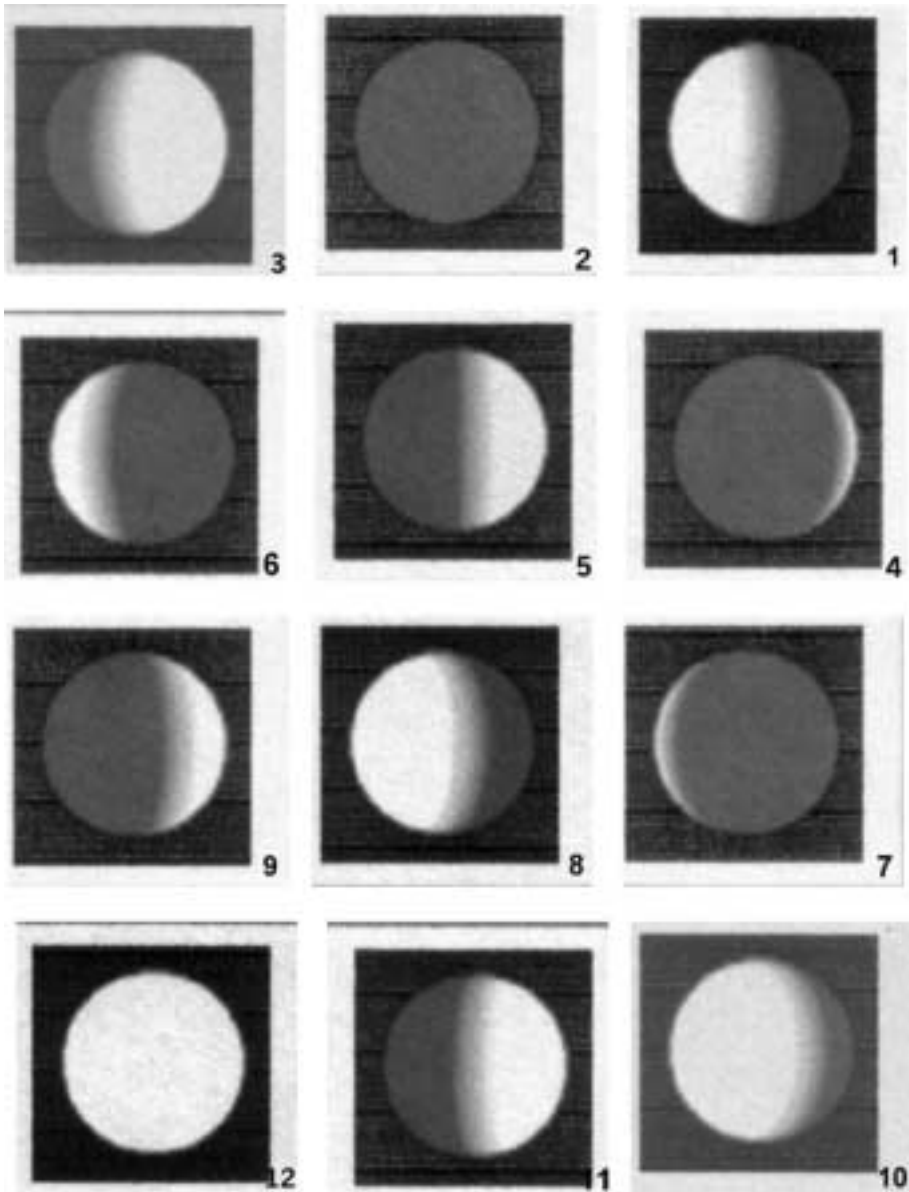


Figure 3. Moon phases arranged randomly

- (b) *How will we see the Moon two days after the First Quarter?* All the students drew a correct picture.
- (c) *How will we see the Moon ten days after the First Quarter?* Sixteen students drew a correct picture, two drew the illuminated side as the right face of the Moon instead the left one, and one drew an almost completely darkened Moon.
- (d) *What is the angle between the Sun and the Moon, with the Earth at the vertex, in the First Quarter?* All the students answered correctly.













		
Day 1: New Moon	Day 2: _____	Day 5: _____
		
Day 8: _____	Day 10: _____	Day 12: _____
		
Day 15: _____	Day 17: _____	Day 20: _____
		
Day 23: _____	Day 26: _____	Day 29: _____

Figure 4. Paper sheet for the arrangement of students' Moon phases prediction

- (e) *Let us say that we are in a Full Moon night. After how many days will the Moon be in its Last Quarter phase?* All the students answered correctly.
- (f) *In your opinion, what is the cause of the Moon phases?* Twelve students gave a correct, or almost correct, answer, such as: ‘The changing angle between the Moon and the Earth’, ‘The Moon’s revolution around the Earth and the changing angle between the Sun and the Moon relative to the Earth’, ‘The position of the Moon in its revolution around the Earth during a period of 30 days, according to the light coming up from the Sun’, ‘The angle between the Earth and the Moon changes in relation to the Sun’s light’, ‘The Moon revolves around the Earth, so every night it is positioned at a different angle’, ‘The changing angle between the Earth and the Moon, and then the amount of light reflected to us changes’, ‘Moon’s revolution around the Earth and the angle at which we see the Moon relative to the Sun’, ‘The Moon’s revolution around the Earth, so that every night the Moon will be exposed to the Sun’s rays at a different angle’. Five students wrote only ‘The Moon’s revolution around the Earth’, and two wrote ‘The periodicity of 30 days of the Moon phases’.

In the interviews carried out after finishing this activity, students still evinced some uncertainty, as indicated in Figure 5.

A week later, the students performed a group activity intended to demonstrate that *the Moon rotates on its axis once a month*, always showing us the same side. One student held the ‘Moon’ in his hand (a Styrofoam ball with a wooden stick on the top and a Bristol paper flag on it). The other students sat down in the middle of the classroom, representing observers on the ‘Earth’, and the student with the ‘Moon’ had to revolve around them showing the same face of the ‘Moon’ during the whole turn. After several tries he succeeded, and the students had to reach a conclusion about the Moon’s rotation. Next the student with the ‘Moon’ was asked to turn around the ‘Earth’ without rotating the ‘Moon’, and to complete the rotation of the ‘Moon’ around its axis in less (and in more) than a month in order to confirm the students’ conclusion.

All the students reached the right conclusion – that the Moon rotates around its axis once a month, the same time it takes the Moon to complete a revolution around the Earth.

At the beginning of April, students performed their last activity in pairs, in order to simulate *Moon and Sun eclipses*, using the same ‘Sun’, the same ‘Moon’ and the same ‘Earth’ as in activity of the Moon phases. They were given a simple explanation about eclipses and were asked to find what the relative Sun-Earth-Moon position has to be for a Moon and Sun eclipse, and what the corresponding Moon phases were when it happened.

After performing the simulation of the Moon and Sun eclipses, the 18 students participating were asked five questions:

- (a) *What is the Moon phase during a Moon eclipse?* Fourteen students answered that the Moon is in its Full phase, and four students answered that it happens in the middle of the month.

R: Regarding the Moon phases, your prediction was correct. You also verified it in the simulating activity and you answered all the questions correctly. I want you to explain in a more detailed way your answer to the questions: “In your opinion, what is the cause of the Moon phases?” Why do we see different Moon phases on different nights? What you wrote was, “The Moon revolves around the Earth every thirty days”. This explains that after thirty days we see the same Moon phases.

S2: The same shape.

R: But your answer doesn’t explain why the shape changes every night.

...

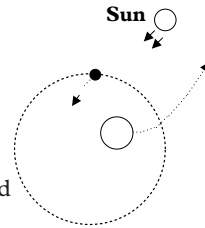
S2: Because of the relative movement of the Moon, the Sun and the Earth.

R: Do you want to explain yourself by drawing?

S2: Yes, the Moon turns around, this is the Sun.

R: Let’s assume that the Sun doesn’t move.

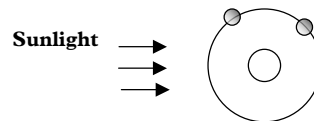
S2: Yes, and we are here on Earth. We turn around the Sun and the Moon turns around us; the Sun lights up the Moon all the time, and since we are not in front of the Moon all the time, there is some period of hiding; the Earth hides the Moon.



R: The Earth hides the Moon? Are you talking about an eclipse? We aren’t talking about a Moon eclipse now.

S2: I’ll explain it to you in another way. If the Sun moves, every time the Sun lights up the Moon, if you stand on a particular spot all the time the fact is that there is a change in the illumination; we see a different part every time... There is something hidden, because the Moon also turns around us; you don’t see the whole Moon all the time.

R: Who hides? I don’t understand. I’ll do a different drawing. The Sun is very far, this is Sunlight, O.K.?



S2: Yes.

R: We’re on Earth, here’s the Moon, though we aren’t in the same plane.

S2: Now I get it! At this stage you see this shape, but because the Moon turns around the Earth, afterwards we see only half the Moon, because the light doesn’t get up to the whole Moon.

R: The light doesn’t get up to the whole Moon? The Moon isn’t in the same plane; so are you sure that the Sunlight doesn’t always illuminate the Moon?

S2: I’m not sure.

R: So what changes? We see a different Moon phase every night. Why?

S2: Because something is hidden. The light reflection is different.

Figure 5. Excerpts from students’ interviews after completing the Moon phases’ activity
(R, researcher; S_n, student number n)

- (b) *What is the relative position of the Sun-Earth-Moon during a Moon eclipse?* Eight students answered that they have to be in the same plane, and ten students answered that the angle between the Sun, the Earth, and the Moon has to be 180° .
- (c) *What is the Moon phase during a Sun eclipse?* Ten students answered that the Moon is in its New phase, and eight students answered that it happens at the beginning or at the end of the month.
- (d) *What is the relative position of the Sun-Moon-Earth during a solar eclipse?* Seven students answered that they have to be in the same plane, six answered that the

angle between the Sun, the Moon and the Earth has to be 180° , and three students answered that they have to be positioned in the same straight line.

- (e) *Why, in your opinion, isn't there an eclipse every month?* Ten students answered that the Sun-Moon-Earth are not in the same plane every month, four answered that they are not in a the same plane or in a 180° angle every month, one answered that the angle between the Sun, the Moon and the Earth is not 180° every month, and the last student answered that the Moon turns around the Earth in a different plane from that of the Earth's revolution around the Sun, and they meet in a straight line only rarely.

Again, the interviews revealed students' ambiguity as indicated in the following excerpts (*R*, researcher; *Sn*, student number n):

R: Well, you were also asked also about the solar eclipse. The Sun is here, the Moon is between us and the Sun. You were asked again, 'What is the Moon phase during a solar eclipse?' and you wrote 'at the beginning of the month'. But what's the Moon phase at that time? If there was no eclipse, how would we see the Moon?

S4: We would see only a part of the Moon. No! ... At the beginning of the month we don't see the Moon, because the Sun lights up the Moon but we're on the other side.

Post-test results

The post-test (the same as the pre-test) was presented to the experimental class and to the control groups on their examination day, which was several weeks after finishing the course and more than two months after the experimental class performed the last activity.

Figure 6 shows the extent of success of the different groups in answering the whole questionnaire, and the questions about phenomena related to the Sun-Earth-Moon relative motions.

In the whole questionnaire, we found a statistically significant improvement in all the groups with the largest effect size for the experimental class, as can be seen in Table 4. The significant improvement of the control groups in the whole questionnaire can be explained as follows: (a) their instructors were very experienced lecturers covering most topics based on well-structured lectures with a descriptive (phenomenological) rather than conceptual approach to astronomy, and (b) the questionnaire comprised several non conceptual questions that required only factual recall.

For the Sun-Earth-Moon relative motions' questions we found a statistically significant difference only for the future Bedouin primary school teachers ($t = 5.64$, $p\text{-value} < .01$, Cohen's $d = 1.81$) and for the experimental class ($t = 9.89$, $p\text{-value} < .01$, Cohen's $d = 3.34$). The significant improvement in the future Bedouin teachers' conceptions may be explained by their very low scores in the pre-test and by the fact that they were the only group having an annual course. Nevertheless, the experimental class showed the most impressive improvement with a very large normalized gain of $g = 0.8$ (Hake, 2002) and the greatest effect size.

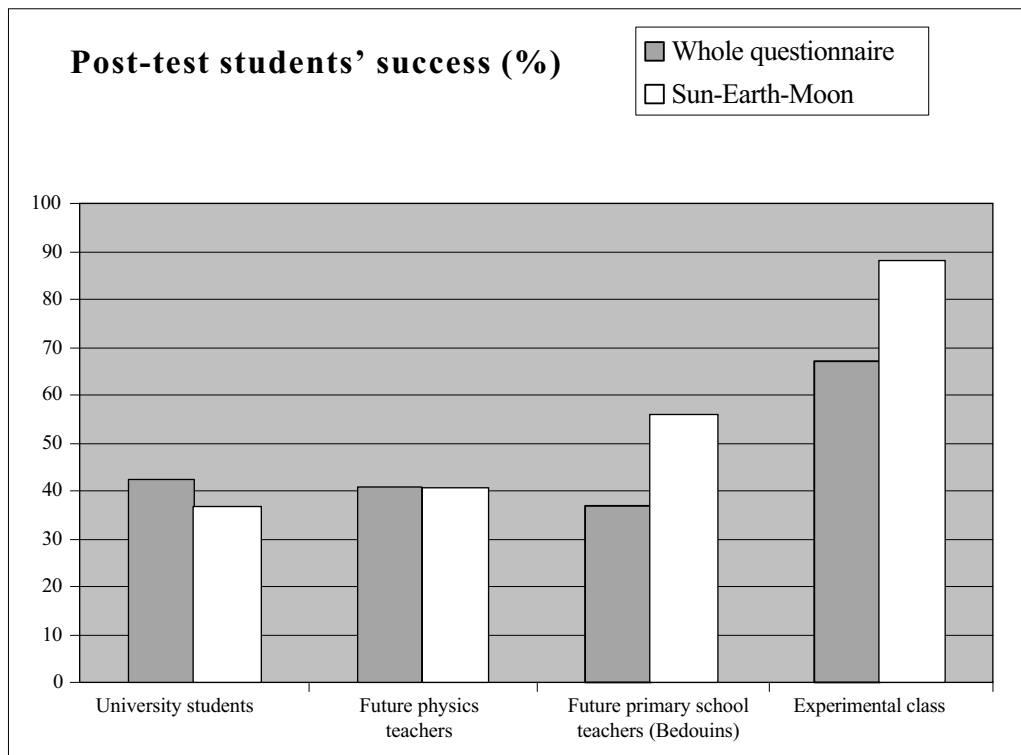


Figure 6. Correct answers (%) of the different groups in the post-test

Discussion and educational implications

Understanding the solar system involves a number of related conceptual areas that are clearly of importance in relation to students' existing conceptions and are difficult to explain since they do not match their daily observations. They include a perception of spatial aspects of the Earth, a conception of day and night, of seasonal change, etc., which include compound movements of the Moon, the Sun and the stars. In this study, we can see clearly that many students are not post-Copernican in their notions of planet Earth in space, and hold alternative notions to the accepted scientific concept in various basic astronomy subjects.

Table 4. Comparison of the total success in the pre- and post-test for all the groups

	Pre-test total success	Post-test total success	t	p-value	Cohen's effect size – d
University students	35.1	42.5	2.003	.025	.37
Future physics teachers	27.2	40.9	2.222	.023	.95
Future Bedouin primary school teachers	21.8	36.8	4.607	< .001	1.63
Experimental class	24.8	67.0	10.19	< .001	4.20

Students in the experimental class conducted both individual activities at home and in the classroom; the paired and group activities were conducted in the classroom. They also participated in guided discussions, arguing about their different notions and continuously assessing their significance, and checking their validity. The students were active constructors of their own knowledge, while the process of knowledge acquisition was greatly assisted by interactions with peers and in particular, with the teacher.

The findings of this study show that both the experimental class and the control groups improved their basic astronomy concepts in a statistically significant way. Moreover, regarding the subjects relevant to this study (Sun-Earth-Moon relative motions), only the future Bedouin primary school teachers and the experimental class showed a statistically significant improvement. In both cases, the experimental class made the most impressive improvement of all.

These findings support the constructivist approach in teaching, in which students are confronted with their alternative conceptions in a conceptually centred learning environment that actively engages them. But there is still a question that requires further research: to what extent are students' conceptions consistent and stable?

We found several cases in the experimental class, both in the interviews (as described previously) and in students' answers on the post-test, showing that we need a more in-depth study of the consistency and stability of students' conceptions even after they have been taught by a constructivist approach. For example, in the post-test:

1. eight students answered that the Moon is in its Full phase, and one answered that it is at no particular phase when there is a solar eclipse, despite the fact that they answered all the other questions related to Moon phases correctly;
2. one student answered that the reason for the change in the Moon's appearance is that it is black on one side and white on the other, and it rotates; this despite the fact that this student answered all the other questions related to Moon phases correctly; and
3. for question 18, three students chose A (instead of the correct answer D) for the position of the Moon in the case of a Waxing Crescent phase, even though they answered all the other questions related to Moon phases correctly.

Several researchers found that students' answers were inconsistent, and especially context-dependent (Halloun & Hestenes, 1985; Finegold & Gorsky, 1991; Savinainen & Viiri, 2003, Lautrey & Mazens, 2004). In a study dealing with the process of students' conceptual change while learning about force and movement, Tao and Gunstone (1999) found that most students were unsure about their answers to the post-test, using their alternative conceptions and the accepted scientific concept in different contexts. This showed that their conceptual change was context-dependent and unstable. Steinberg and Sabella (1997) claim that different contexts and presentations could trigger different responses from a given student, even if the underlying physics is identical. Bao and Redish (2001) argue that strong context dependence in student responses is very common, especially when students are just beginning to learn new material. Students are not sure of the conditions under which the rules they have learned apply, and they tend to use the rules either too broadly or too narrowly.

This context dependence raises the question of the stability of students' conceptual change. Several researchers have stated that the conceptual change process might be difficult and progressive (Driver & Bell, 1986; Vosniadou, 1991; Smith *et al.*, 1997). Lautrey and Mazens raise some questions concerning the nature of this process:

Is there a process that reassigns a concept to a new ontological category? If so, is the change a relatively abrupt process in which a concept can have the attributes of one or the other of its successive ontological categories but not of both at the same time, or is it a process of revision with experience of the naïve theory underlying that concept? In the latter case, one can assume that the change will be a slow, gradual process in the course of which the attributes of the old and new ontological categories coexist for quite some time. (Lautrey & Mazens, 2004, p. 403)

In the case of the astronomy concepts studied here, conceptual change seems to be a very gradual process in which the different presuppositions linked to ontology have different degrees of resistance. This picture of conceptual change fits best with the idea that a change occurs through the revision of the fundamental presuppositions of a framework theory.

We can conclude that although learning a new subject such as astronomy in a constructivist way may encourage students to rethink the accuracy of their alternative conceptions, they need further personal and group experiences in order to apply correctly the new concepts learned and to reinforce their understanding through a spiral learning curriculum.

For the students participating in this study, the introductory astronomy course was the first occasion where they learned some basic astronomy concepts. The instructional activities applied in the experimental class were designed to deal with students' alternative conceptions and to help them understand the accepted scientific concept. In parallel, they showed the future teachers alternative (constructivist) ways of teaching that they will be able to apply in their own classes, beginning the spiral process for their own students. Good teachers need to possess not only a detailed and subtle understanding of the subject matter, but also in-depth knowledge of how best to present it in the classroom setting, what is currently called 'pedagogic content knowledge' (Shulman, 1987; Parker & Heywood, 1998). This means that teachers need to be in control of their own learning and develop an understanding of how they might learn effectively (metacognition). When implementing reform in science curriculum as recommended by the Tomorrow 98 Report (1992), the change has to include not only the subjects being taught but also the way they are taught.

Note

1. This study was supported by the MOFET Institute, Israel.

References

- American Association for the Advancement of Science (1993) *Benchmarks for science literacy* (Project 2061) (New York, Oxford University Press).

- Bakas, C. & Mikropoulos, T. (2003) Design of virtual environments for the comprehension of planetary phenomena, *International Journal of Science Education*, 25, 949–968.
- Bao, L. & Redish, E. (2001) Concentration analysis: a quantitative assessment of student states, *American Journal of Physics*, 69, S45–S53.
- Baxter, J. (1989) Children's understanding of familiar astronomical events, *International Journal of Science Education*, 11, 302–313.
- Bisard, W. & Zeilik, M. (1998) Conceptually centered astronomy with actively engaged students, *Mercury*, 27(4), 16–19.
- Borghi, L., De Ambrosis, A. & Massara, C. (1991) Physics education in science training of primary school teachers, *European Journal of Teacher Education*, 14, 57–63.
- Champagne, A., Gunstone, R. & Klopfer, L. (1985) Effecting changes in cognitive structure among physics students, in: L. West & A. Pines (Eds) *Cognitive structure and conceptual change* (New York, Academic Press).
- Cobern, W. (1993) Contextual constructivism: the impact of culture on the learning and teaching of science, in: K. Tobin (Ed.) *The practice of constructivism in science education* (Washington, DC, AAAS).
- Cohen, J. (1988) *Statistical power analysis for the behavioral sciences* (New York, Academic Press).
- Dana, T., Campbell, L. & Lunetta, V. (1997) Theoretical bases for reform of science teacher education, *The Elementary School Journal*, 97, 419–432.
- Department of Employment, Education and Training (1989) *Discipline review of teacher education in mathematics and science* (vol. 1) (Canberra, Australian Government Publishing Service).
- Diakidoy, I.-A. & Kendeou, P. (2001) Facilitating conceptual change in astronomy: a comparison of the effectiveness of two instructional approaches, *Learning and Instruction*, 11, 1–20.
- Driver, R. (1988) Theory into practice II: a constructivist approach to curriculum development, in: P. Fensham (Ed.) *Development and dilemmas in science education* (London, The Falmer Press).
- Driver, R. & Bell, B. (1986) Students' thinking and the learning of science, *School Science Review*, 67, 443–456.
- Edwards, S. & Mercer, N. (1987) *Common knowledge* (London, Methuen).
- Finegold, M. & Gorsky, P. (1991) Students' concepts of force as applied to related systems: a search for consistency, *International Journal of Science Education*, 13, 97–113.
- Goldsworthy, A. (1997) Dream on, *Education in Science*, 172, 8–9.
- Hake, R. (2002) Assessment of physics teaching methods, proceedings of the *UNESCO-ASPEN Workshop on Active Learning in Physics*, University of Peradeniya, Sri Lanka, 2–4 December.
- Halloun, I. & Hestenes, D. (1985) The initial knowledge state of college physics students, *American Journal of Physics*, 53, 1043–1055.
- Hewson, P. & Hewson, M. (1984) The role of conceptual conflict in conceptual change and the design of science instruction, *Instructional Science*, 13, 1–13.
- Jones, B., Lynch, P. & Reesink, C. (1987) Children's conceptions of the earth, sun and moon, *International Journal of Science Education*, 9, 43–53.
- Kelly, G. (1963) *A theory of personality: the psychology of personal constructs* (New York, W. W. Norton).
- Klein, C. (1982) Children's concepts of the earth and the sun: a cross-cultural study, *Science Education*, 65, 95–107.
- Lautrey, J. & Mazens, K. (2004) Is children's naïve knowledge consistent? A comparison of the concepts of sound and heat, *Learning and Instruction*, 14, 399–423.
- Lightman, A. & Sadler, P. (1993) Teacher predictions versus actual student gains, *The Physics Teacher*, 31, 162–167.
- Morrow, C. (2000) Kinesthetic astronomy: the sky time lesson, *The Physics Teacher*, 38, 252–253.
- National Research Council (1996) *National science education standards* (Washington, DC, National Academy Press).
- Nussbaum, J. (1979) Children's conceptions of the earth as a cosmic body: a cross-age study, *Science Education*, 63, 83–93.

- Nussbaum, J. & Novak, J. (1976) An assessment of children's concepts of the earth utilizing structure interviews, *Science Education*, 60, 535–550.
- Orpwood, G. & Souque, J. (1985) Towards the renewal of Canadian science education. II. Findings and recommendations, *Science Education*, 69, 625–636.
- Osborne, R. & Gilbert, J. (1980) A method for investigating concept understanding in science, *European Journal of Science Education*, 2, 311–321.
- Parker, J. & Heywood, D. (1998) The Earth and beyond: Developing primary teachers' understanding of basic astronomical concepts, *International Journal of Science Education*, 20, 503–520.
- Posner, G., Strike, K., Hewson, P. & Gertzog, W. (1982) Accommodation of a scientific conception: toward a theory of conceptual change, *Science Education*, 66, 211–227.
- Radford, D. (1998). Transferring theory into practice: a model for professional development for science education reform, *Journal of Research in Science Teaching*, 35, 73–88.
- Redish, E. & Steinberg, R. (1999) Teaching physics: figuring out what works, *Physics Today*, 52(1), 24–30.
- Roth, K. & Rosaen, C. (1991) Investigating science concepts through writing activities, paper presented at the *Annual Meeting of the National Association for Research in Science Teaching*, Fontana, WI, April.
- Savinainen, A. & Viiri, J. (2003) Using the force concept inventory to characterize students' conceptual coherence, in: I. Haapasalo & K. Sormunen (Eds) *Towards meaningful mathematics and science education. Proceedings of the IXX Symposium of Finnish Mathematics and Science Education Research Association. Bulletin of Faculty of Education N^o 86, University of Joensuu, Finland*
- Sharp, J. (1996) Children's astronomical beliefs: a preliminary study of year 6 children in south-west England, *International Journal of Science Education*, 18, 685–712.
- Shulman, L. (1987) Foundations of the new reform, *Educational Researcher*, 15, 4–14.
- Smith, C., Carey, S. & Wiser, M. (1997) On differentiation: a case study of the development of the concepts of size, weight and density, *Cognition*, 21, 171–237.
- Sneider, C. & Pulos, S. (1983) Children's cosmographies: understanding the earth shape and gravity, *Science Education*, 67, 205–221.
- Solomon, J. (1991). Images of physics: How students are influenced by social aspects of science, in: R. Duit, F. Goldberg & H. Niedderer (Eds) *Research in physics learning: theoretical issues and empirical studies. Proceedings of an International Workshop, University of Bremen (March 1991): IPN, University of Kiel.*
- Steinberg, R. & Sabella, M. (1997) Performance on multiple-choice diagnostics and complementary exam problems, *The Physics Teacher*, 35, 150–155.
- Stofflet, R. (1991) *Conceptual change in elementary teacher candidates' content and pedagogical knowledge of science*. Unpublished doctoral dissertation, University of Utah.
- Stofflet, R. (1994) The accommodation of science pedagogical knowledge: the application of conceptual change constructs to teacher education, *Journal of Research in Science Teaching*, 31, 811–831.
- Suzuki, M. (2003) Conversations about the Moon with prospective teachers in Japan, *Science Education*, 87, 892–910.
- Tao, P. & Gunstone, R. (1999) The process of conceptual change in force and motion during computer-supported physics instruction, *Journal of Research in Science Teaching*, 36, 859–882.
- Taylor, I. (1996) Illuminating lunar phases, *The Science Teacher*, 64(3), 39–41.
- Taylor I., Barker, M. & Jones, A. (2003) Promoting mental model building in astronomy education, *International Journal of Science Education*, 25, 1205–1225.
- Tomorrow 98 (1992) *Report from the Commission on Science and Technological Education* (Jerusalem, Ministry of Education).
- Trumper, R. (2001) Assessing students' basic astronomy conceptions from junior high school through university, *Australian Science Teachers Journal*, 41, 21–31.
- Vosniadou, S. (1991) Designing curricula for conceptual restructuring: lessons from the study of knowledge acquisition in astronomy, *Journal of Curriculum Studies*, 23, 219–237.

- Vosniadou, S. (1992) Knowledge acquisition and conceptual change, *Applied Psychology*, 41, 347–357.
- Vosniadou, S. & Brewer, W. (1992) Mental models of the earth: a study of conceptual change in childhood, *Cognitive Psychology*, 24, 535–585.
- Vosniadou, S. & Brewer, W. (1994) Mental models of the day/night cycle, *Cognitive Science*, 18, 123–183.
- Vygotsky, L. (1978) *Mind in society* (Cambridge, MA, Harvard University Press).
- Wallace, J. & Louden, W. (1992) Science teaching and teachers' knowledge: prospects for reform of elementary classrooms, *Science Education*, 76, 507–521.
- Wubbels, T. (1992) Taking account of student teachers' preconceptions, *Teaching and Teacher Education*, 8, 137–149.
- Yager, R., Lutz, M. & Craven J. III (1996) Do national standards indicate the need for reform in science teacher education? *Journal of Science Teacher Education*, 7, 85–94.
- Zeilik, M. & Bisard, W. (2000) Conceptual change in introductory-level astronomy courses, *Journal of College Science Teaching*, 29, 229–232.
- A. Zeilik, M., Schau, C. & Mattern N. (1998) Misconceptions and their change in university-level astronomy courses, *The Physics Teacher*, 36, 104–107.

Appendix. Questionnaire: the Earth and the Universe (✓ indicates the correct answer)

1. As seen from your current location, when will an upright flagpole cast no shadow because the Sun is directly above the flagpole?
 - A. Every day at noon.
 - B. Only on the first day of summer.
 - C. Only on the first day of winter.
 - D. On both the first days of spring and fall.
 - E. Never from your current location. ✓

2. In order to have a total solar eclipse, the Moon must be at what phase?
 - A. Full.
 - B. New. ✓
 - C. First quarter.
 - D. Last quarter.
 - E. At no particular phase.

3. Imagine that you are building a scale model of the Earth and the Moon. You are going to use a basketball with a diameter of 30 cm to represent the Earth and a tennis ball with a diameter of 7.5 cm to represent the Moon. To maintain the proper distance scale, about how far from the surface of the basketball should the tennis ball be placed?
 - A. 10 cm.
 - B. 15 cm.
 - C. 90 cm.
 - D. 9 m. ✓
 - E. 90 m.

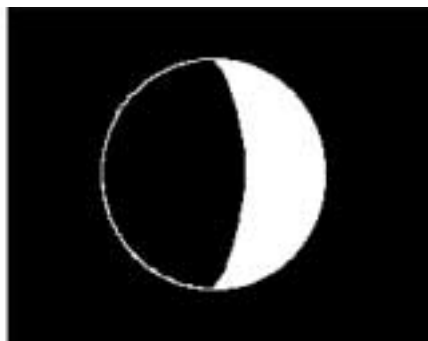
4. What causes night and day?
 - A. The Earth spins on its axis. ✓
 - B. The Earth moves around the Sun.
 - C. Clouds block out the Sun's light.
 - D. The Earth moves into and out of the Sun's shadow.
 - E. The Sun goes around the Earth.

5. The diagrams here show how the Moon appeared one night, and then how it appeared a few nights later. What do you think best describes the reason for the change in the Moon's appearance?

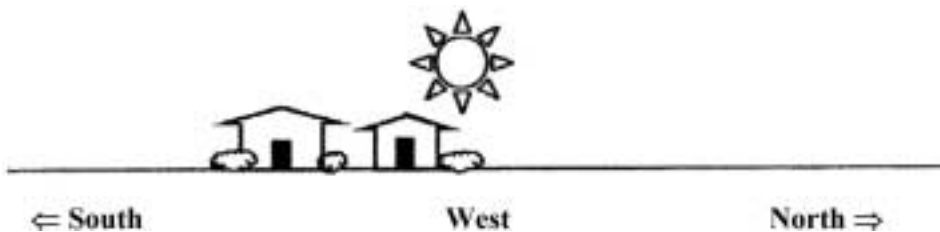
One night

A few nights later

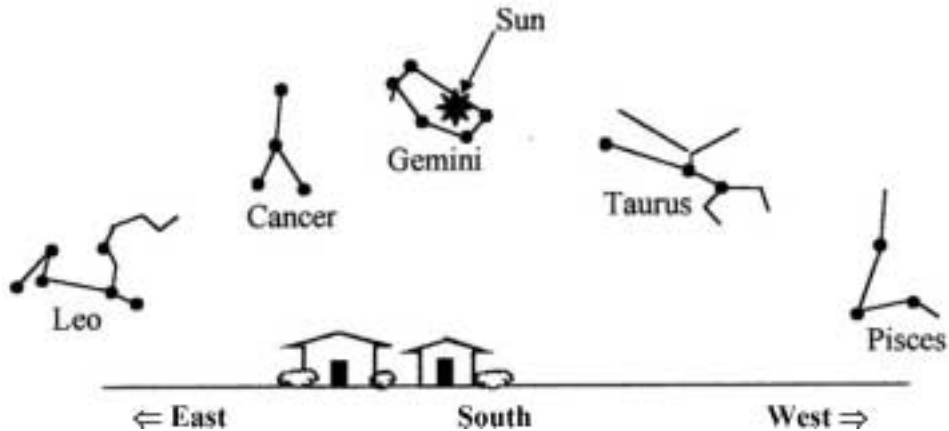
- A. The Moon moves into the Earth's shadow.



- B. The Moon moves into the Sun's shadow.
 C. The Moon is black on one side, white on the other, and rotates.
 D. The Moon moves around the Earth. ✓
6. The main reason that it is hotter in the summer than in winter is that
 A. The Earth is closer to the Sun in summer.
 B. The Earth is farther from the Sun in summer.
 C. The Earth's rotational axis flips back and forth as the Earth moves around the Sun.
 D. The Earth's axis points in the same direction relative to the stars, which is tilted relative to the plane of its orbit. ✓
 E. The Sun gives off more energy in the summer than in the winter.
7. Where does the Sun's energy come from?
 A. The combining of light elements into heavier elements. ✓
 B. The breaking apart of heavy elements into lighter ones.
 C. The glow from molten rocks.
 D. Heat left over from the Big Bang.
8. Imagine that the Earth's orbit were changed into a perfect circle around the Sun so that the distance to the Sun never changed. How would this affect the seasons?
 A. We would no longer experience a difference between the seasons.
 B. We would still experience seasons, but the difference would be much less noticeable.
 C. We would still experience seasons, but the difference would be much more noticeable.
 D. We would continue to experience seasons just as we do now. ✓
9. On about September 22, the Sun sets due west, as shown in the diagram below. Where will the Sun appear to set two weeks later?



- A. In the same place. B. Northward of the equinox position. C. Southward of the equinox position. ✓
10. If you could see the stars during the day, this is what the sky would look like at noon on a given day. The Sun is near the stars of the constellation Gemini. Near which constellation would you expect the Sun to be located at sunset?
 A. Leo B. Cancer C. Gemini ✓
 D. Taurus E. Pisces



11. When you observe the Moon from the Earth, you always see the same side. This observation implies that the Moon
 - A. does not rotate on its axis.
 - B. rotates on its axis once a day.
 - C. rotates on its axis once a month. ✓

12. As viewed from our location, the stars of the Big Dipper can be connected with imaginary lines to form the shape of a pot with a curved handle. Where would you have to travel to first observe a considerable change in the shape formed by these stars?
 - A. Across the country.
 - B. A distant star. ✓
 - C. Moon.
 - D. Pluto.
 - E. America.

13. Which of the following lists is correctly arranged in order of closest to most distant from the Earth?
 - A. Stars, Moon, Sun, Pluto.
 - B. Sun, Moon, Pluto, stars.
 - C. Moon, Sun, Pluto, stars. ✓
 - D. Moon, Sun, stars, Pluto.
 - E. Moon, Pluto, Sun, stars.

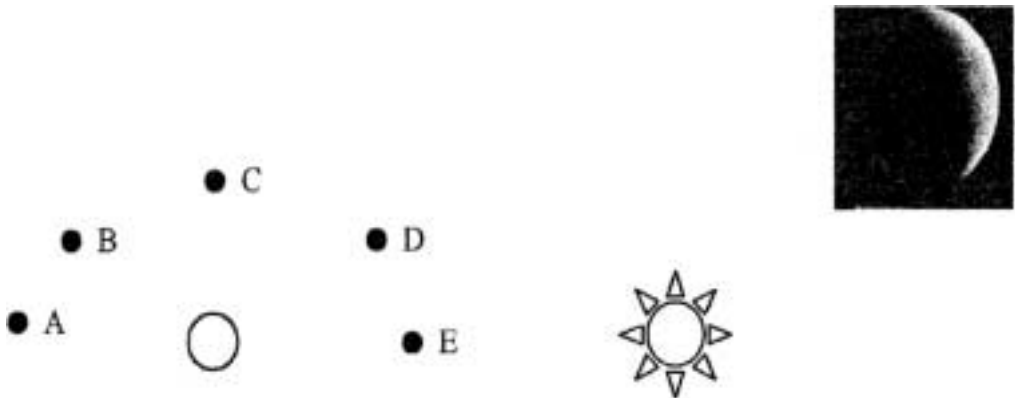
14. When is the longest daylight period in Australia?
 - A. March.
 - B. June.
 - C. September.
 - D. December. ✓

15. As you face directly east, where is the rising Sun on June 21 as seen from the Haifa area?
 - A. To the left of due east. ✓
 - B. To the right of due east.
 - C. Due east.
 - D. It varies with the phase of the Moon.

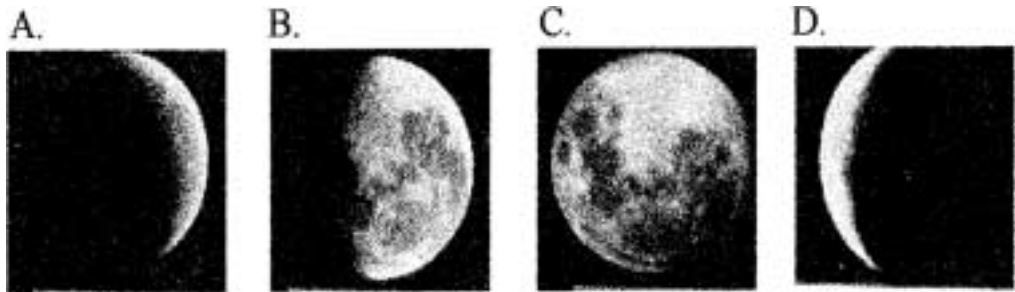
16. According to modern ideas and observations, which of the following statements is correct?
 - A. The Earth is at the center of the Universe.
 - B. The Sun is at the center of the Universe.
 - C. The Milky Way Galaxy is at the center of the Universe.
 - D. The Universe does not have a center in space. ✓

17. The hottest stars are what color?
 A. Blue. ✓ B. Orange. C. Red.
 D. White. E. Yellow.

18. The diagram below shows the Earth and Sun as well as five different possible positions for the Moon. Which position of the Moon would cause it to appear like the picture at the right when viewed from Earth?



19. You observe a full Moon rising in the east. How will it appear in six hours?



20. With your arm held straight, your thumb is just wide enough to cover up the Sun. If you were on Saturn, which is 10 times farther from the Sun than the Earth, what object could you use to just cover up the Sun?
 A. Your wrist. B. Your thumb. C. A pencil.
 D. A toothpick. ✓ E. A hair.
21. Global warming is thought to be caused by the
 A. destruction of the ozone layer.
 B. trapping of heat by nitrogen.
 C. addition of carbon dioxide. ✓

