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Teaching and Teacher Education 19 (2003) 309–323

TEACHING AND TEACHER EDUCATION

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The need for change in elementary school teacher training—a cross-college age study of future teachers' conceptions of basic astronomy concepts ☆

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Received 8 February 2002; received in revised form 14 November 2002; accepted 28 November 2002

Abstract

Do students in pre-service training programs for elementary school teachers hold the correct scientific views, which will eventually allow them to plan and implement instructional strategies, which, in turn, will lead their future pupils to achieve scientific conceptions of basic astronomy concepts? The results of a cross-college age study of this issue are presented and discussed in this paper. The students' astronomy conceptions were analyzed by means of a written questionnaire presented to them during the first part of the year. The most important findings of this study will be of interest to many elementary-school teacher educators.

Keywords: Elementary school; Teacher training; Teachers' conceptions; Astronomy concepts

1. Introduction

Education reformers' attention to the state of elementary science teaching has been influenced by the public's increasing preoccupation with the apparently falling standards of students' knowledge and understanding of science (Wallace & Louden, 1992). Such developments have appeared in reports from the United States (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 United Kingdom (Goldsworthy, 1997, 1999) Italy (Borghi, De Ambrosis, & Massara, 1991), and Israel (Tomorrow 98, 1992).

The Israeli education system is undergoing a long period of changes as a result of the recommendations of the "Tomorrow 98" Report (1992). Among the reforms proposed by the report are the revision of curricula and the "implementation of a comprehensive program for the pre-service and in-service training" (p. 29) of elementary school teachers. The reform also plans, for example, the following:

> … a program named "Science in a Technological Society" in grades 1 to 3 will be taught by

☆This study was funded by the Institute for Research and Advanced Studies Ma'alot-Tarshiha, Israel.

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doi:10.1016/S0742-051X(03)00017-9

teachers who, prior to this, will undergo comprehensive training in the teaching of science and technology. There is a need to plan and implement training programs that will be suitable to the importance of the subject, in order to train the elementary teachers in College (p. 29).

According to these premises, a program including seven different topics was lately proposed for the 6 years of elementary school. One of the new topics included in the program is "The Earth and the Universe", mainly consisting of astronomy.

The limited impact of the curricular reforms made in science teaching over the past two decades in different parts of the world has been the subject of considerable interest. Wallace and Louden (1992), concluded that the "reform of elementary classrooms must be understood" through the "view of the central place of teacher's knowledge in teacher's work" (p. 519). Several recent studies analyzing the results of the reforms in science education in American elementary schools have come to the following conclusions (Dana, Campbell, & Lunetta, 1997; Radford, 1998; Yager, Lutz, & Craven, 1996):

1. Instituting reform in science education requires teachers who are knowledgeable in science content, process, and inquiry pedagogy.
2. Most elementary 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 classroom.

2. Pupils' conceptions of basic astronomy concepts

Understanding the solar system involves a number of related conceptual areas that are clearly of importance in relation to children's existing frameworks. They include understanding spatial aspects of the Earth, conception of day and night, seasonal change, etc. More than 20 years ago various workers began to examine these very intensively, and they have produced a growing body of evidence that throws doubt on the assumption that adults and children are post-Copernican in their notions of planet Earth in space. The research shows that pupils frequently come to their lessons having constructed their own explanations for many of the easily observed astronomical events, and that these children's notions are at variance with the accepted view. We have to take into account, also the social situations which pupils operate within and particularly how astronomical events are talked about and represented in day-to-day living (with the Sun rising and setting; the Moon coming out at night amongst the stars, and so on). There are commonalities in informal ways of reasoning partly because members of a culture have shared ways of referring to and talking about particular phenomena. As far as people's everyday experiences are concerned, the informal ideas are often perfectly adequate to interpret and guide action (Driver, Asoko, Leach, Mortimer, & Scott, 1994).

Early researchers concentrated on elementary school pupils' understanding of the Earth only as a cosmic body (Nussbaum & Novak, 1976; Nussbaum, 1979; Nussbaum & Sharoni-Dagan, 1983; Sneider & Pulos, 1983). Nussbaum and Novak (1976) showed that second-grade (7 and 8 years old) American children's concept of planet Earth in space develops from a naive flat-Earth notion through a series of phases towards the accepted view. In a subsequent study with an Israeli sample (Nussbaum, 1979), the characterization of those five notions was revised and refined and their prevalence at different age levels (from 9 to 13 years students) was studied.

Children's concepts of the relationship of the Earth and Sun, particularly their understanding of the notion of night and day and the relative sizes of these bodies, were examined by Klein (1982). Second-grade (7 and 8 years old) American children had many different ideas about the Earth and the Sun concepts assessed in that study. Their answers and explanations ranged from possible examples of precausal thinking, whereby some children believed that the Sun "hid" at night, to an understanding of the concept of night and day caused by the Earth's rotation. The majority of children did not demonstrate an understanding of the Earth in space, perspective, rotation of the

Earth as causes of night and day, or the reason for the difference in sunrise time at different geographical locations.

Jones, Lynch, and Reesink (1987) turned their attention to the solar system itself; in Tasmania, they investigated the elementary school children's understanding of the Earth–Sun–Moon system in terms of shape, size and motion of these components. The pupils' spatial models fell into five distinct systems. The first three of these were egocentric Earth-centered models and the last two were Sun-centered models. Furthermore when the pupils did explain that the Earth was spinning, many had no idea of how many times it would spin a year.

Baxter (1989) surveyed the understanding of basic astronomy concepts among English children in grades four to ten (9–16 years old students). He broadened his research by investigating pupils' conceptions of the phases of the Moon and the seasons. Most pupils held four alternative notions of the Moon's phases involving an object either obscuring part of the Moon or casting a shadow on its surface (e.g., clouds cover part of the Moon; shadow of planets or the Sun falls on the Moon). There appeared to be some confusion between a lunar eclipse and the Moon's phases, as the most common notion in all age groups entailed the Earth's shadow being cast on the Moon. Very few pupils held a notion that explained the phases of the Moon in terms of a portion of the illuminated side of the Moon being visible from the Earth.

Young pupils' notions on the cause of the seasons involved near and familiar objects (e.g., cold planets take heat from the Sun; heavy winter clouds stop heat from the Sun; changes in plants cause the seasons). Older children appeared to replace these ideas with notions that involved the astral bodies moving their position. Once again, younger ones saw this motion as "up", "down" or "across", and older ones replaced it by orbital motion (e.g., Sun moves to the other side of the Earth to give them the summer). The most common notion placed the Sun farther away during the winter, a notion that may have its origins in children's experience of altering their distance from a heat source. Only a few pupils explained seasons in terms of the Earth's axis being set at an angle to the Sun's axis.

In a more recent and comprehensive study, Sharp (1996) investigated a wide range of conceptions held by sixth-grade (11 years old) English pupils who had learned basic astronomical concepts. Virtually all of the children seemed aware that the Earth, Sun, and Moon are separate 'spherical' bodies. Most of them were able to place them in the correct order of relative size. Details concerning stars were less clear. Complete knowledge of Earth's gravity, its presence, effects, and implications, was only partially evident. The presence, effects, and implications of gravity elsewhere, e.g., on the Moon or associated with the solar system, were known in some instances, but were generally confused. Most pupils displayed adequate "scientific" accounts of day and night, but only a few of them for the seasons.

Vosniadou and her colleagues conducted a series of experiments investigating children and adults' knowledge of observational astronomy. They involved pre-school, elementary school, and high-school children, college undergraduates, and illiterate adults (Brewer, Hendrich, & Vosniadou, 1988; Vosniadou, 1987, 1989, 1991). In addition to studies conducted in the USA, they collected data from children and adults in India (Samarapungavan, Vosniadou, & Brewer, 1996), Samoa (Brewer et al., 1988) and Greece (Vosniadou & Brewer, 1990). These studies have provided us with specific information on children's and adults' knowledge of the size, shape, movement, temperature, composition, and location of the Earth, Sun, Moon, and stars, and their explanations of phenomena such as the day–night cycle, the seasons, the phases of the Moon, and the eclipses of the Sun and the Moon. They showed that the majority of children have well defined mental models (Vosniadou, 1992; Vosniadou & Brewer, 1992, 1994). They differentiated three types of models:

1. Initial models that are derived from and are consistent with the observations of everyday life.

2. Synthetic models that are the attempts to integrate scientific and everyday information.
3. The scientific models that agree with the accepted scientific view.

These studies showed that there are a limited number of mental models of the Earth, the Sun, the Moon, and the stars that individuals construct. For example, in the case of the Earth, they showed that many elementary-school children hold one of six mental models. Some children think that the Earth is shaped like a rectangle. Others think that the Earth is circular but flat like a disc. A few children think that there are two earths: a flat one in which people live, and a round one that is up in the sky. Others believe that the Earth is a hollow sphere and that people live on flat ground inside it. Finally, some children think that the Earth is flattened at the top and bottom where people live.

A number of different mental models of the day/night cycle have also been identified. Some elementary-school children believe that the Sun's moving down to the ground and hiding behind the mountains cause the change from day to night. Others think that clouds move in front of the Sun and block its light. Some children who have a hollow sphere mental model believe that the day/night cycle is caused by the Sun's moving from the sky, which is located inside the hollow sphere, to outer space, which is located outside the hollow sphere. Children who think that the Earth rotates in an up/down direction and that the Moon and Sun are fixed at opposite sides of the Earth hold one interesting model. They believe that the Moon is fixed in some place of the sky where it is always night; as the Earth rotates in an up/down direction our part of the Earth eventually comes to face the Moon in the night sky.

The preconceptions that children bring to science lessons are known to cause difficulties for the secondary school teacher, and the teaching of conceptual science to primary-school children can compound this problem if the science conceptions of teachers themselves are at variance with those accepted by scientists.

3. Teachers' conceptions of basic astronomy concepts

Knowing more about teachers' preconceptions in science has become increasingly recognized as essential and some important research has been carried out in this field (Hollingsworth, 1989; Weinstein, 1989). 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. Some constructivist science educators have recommended the use of conceptual change approaches in science education (e.g., Hewson & Hewson, 1988; Stofflet, 1991). Conceptual change pedagogy is based on constructivist learning theory, recognizing that powerful theories are brought to the classroom and affect the learning of new material (Stofflet, 1994). This instructional theory holds that learners must first become dissatisfied with their existing conceptions, in addition to finding new concepts intelligible, plausible, and fruitful, before conceptual restructuring will occur (Posner, Strike, Hewson, & Gertzog, 1982). The effectiveness of the conceptual change approach to science was demonstrated in several studies (e.g., Champagne, Gunstone, & Klopfer, 1985; Roth & Rosaen, 1991). This whole constructivistic theory is grounded in Piaget's (1929, 1930) early works and supported by Kelly's theory of Personal Constructs (Kelly, 1955) and, as noted above, it has been adopted by many science education researchers since Kelly's whole approach is based on the metaphor which views the development of "a man as a scientist".

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, such as that provided by the classroom, with each student having the opportunity to restructure his or her ideas through talking and listening (Driver, 1988; Solomon, 1987, 1991). Through social interactions students become aware of others' ideas, look for reconfirmation of their own thoughts, and reinforce or reject their personal constructions.

As Maor and Taylor (1995) claimed:

> Discussions between teacher and students in the science classroom are regarded as valuable if they prompt the learner to ask him- or herself questions such as: Are the solutions of others viable? Are they equally as viable as my solutions? What are the reasons for differences in my explanations and those of others? Seeking answers to these questions can result in cognitive conflict which can be resolved by the group and lead to consensual understanding. This process constitutes negotiation of meaning and recognizes the role of language in situating cognition in a social context (p. 844).

Peer discussions can be collaborative learning environments in which students are motivated to reflect on new or contradictory information they have hitherto ignored as they begin to value their peers' points of view (Dole & Sinatra, 1998).

In the social constructivist perspective thinking processes and knowledge development are seen as the consequence of personal interactions in social contexts and of appropriation of socially constructed knowledge. The basic assumption is that reasoning in children is generally exhibited in the externalised mode of reasoning and arguing with someone else. In this regard, the collaborative work that can take place in classroom group discussions on specific knowledge objects, aimed at motivating inquiry and transforming the results into knowledge, has been emphasized (e.g., Mason, 1996; Meyer & Woodruff, 1995; Pontecorvo, 1987, 1990, 1993).

A social perspective on learning in classrooms recognizes that an important way in which novices are introduced to a community of knowledge is through discourse in the context of relevant tasks, what Cobb, Boufi, McClain, & Whitenack (1997) called reflective discourse.

Driver et al. (1994) claimed:

> From this perspective knowledge and understandings, including scientific understandings, are constructed when individuals engage socially in talk and activity about shared problems or tasks. Making meaning is thus a dialogic process involving persons-in-conversation, and learning is seen as the process by which individuals are introduced to a culture by more skilled members. As this happens they "appropriate" the cultural tools through their involvement in the activities of this culture. A more experienced member of the culture can support a less experienced member by structuring tasks, making it possible for the less experienced person to perform them and to internalize the process, that is, to convert them into tools for conscious control. … If teaching is to lead students toward conventional science ideas, then the teacher's intervention is essential, both to provide appropriate experiential evidence and to make the cultural tools and conventions of the science community available to students. The challenge is one of how to achieve such a process of enculturation successfully in the round of normal classroom life. Furthermore, there are special challenges when the science view that the teacher is presenting is in conflict with learners' prior knowledge schemes (p. 7).

Do teachers, however, hold correct scientific views of basic astronomy concepts themselves? Very few studies investigating teachers' astronomy conceptions have been carried out. Barba and Rubba (1992) investigated various aspects of the subject matter knowledge of in-service (expert) and pre-service (novice) Earth and space science teachers. They found that pre-service Earth and space science teachers lacked sufficient knowledge to master the content of the typical middle school or high school Earth science curriculum.

Bisard, Aron, Franeck, & Nelson (1994) carried out an interdisciplinary study to investigate and assess suspected science misconceptions, including some astronomy conceptions, held by groups of students ranging from middle school through university. The results of this study showed a correct response rate that steadily increases from middle school (35%) to introductory college students (46%). As expected, students in advanced college classes achieved the highest correct response rate (55%). The correct response rate was slightly lower for science majors in teacher-education classes, and was much lower for general education majors, who were a small part of the whole sample. Regarding the astronomical topics separately, the main findings of these researchers were as follows:

1. Students generally performed quite poorly when asked about the Sun's position in the sky at specific times of the day and year.
2. A little less than 40% of all students correctly replied that the different phases of the Moon are caused by reflected sunlight.

Since there is very little information in literature about future elementary school teachers' astronomy conceptions, I decided to investigate them in order to: (a) compare their performance with that of students of different ages, (b) widen the range of conceptions investigated, and (c) analyze the most widespread misconceptions. In the following sections the result of a cross college-age study analyzing future elementary school teachers' conceptions of basic astronomy concepts is presented.

4. Sample characteristics and research method

Participants in the present study were drawn from the largest college in Israel that conducts pre-service training programs for primary school teachers. All the students studying in this college participated in the study, and we analyzed the responses of those who answered at least 75% of the questions presented to them, 645 students in total (212 in first year, 222 in second year, and 211 in third year). The great majority of the students were female (95%) and their average age was 23.

In first year, all the students study physics for the whole year and learn some basic concepts like force, weight and mass, buoyancy and sinking, heat and temperature, and pressure. In second year only 14% of the students in this study were defined as science-oriented, and they mainly studied the structure of matter and optics. In third year only 17% of the students were defined as science-oriented and they studied mechanics and electricity.

The astronomy conceptions of the students were analyzed by means of a written questionnaire presented to them at the beginning of the first semester. The questionnaire contained 19 questions taken from three different sources: Zeilik, Schau, and Mattern (1998), Lightman and Sadler (1993), and Bisard, Aron, Francek, and Nelson (1994). Five experts in physics education research and three experienced lecturers in Introduction to Astronomy courses judged the content validity of the questionnaire. After making some minor changes as suggested by the judges, the test (see Appendix) was deemed valid. Cronbach alpha coefficient for reliability was found to be 0.73. Furthermore, we performed an item analysis that provided discrimination indices measuring the extent to which the test questions differentiate between students with the highest and lowest scores on the total test. All the questions were positively discriminating and for most of them the discrimination indices were in the range between 0.15 and 0.59 when we took the upper and lower quarters of the sample, and between 0.28 and 0.73 when we took the upper and lower 10% of the sample.

5. Results

The overall correct response rate was 36.1%, without significant differences through the 3 years, almost the same result as that obtained by junior high-school students (Trumper, 2001a) and a poorer result than that obtained among senior high-school students (Trumper, 2001b) responding to the same questionnaire. No difference was found in the performance of the science-oriented students as against their non-science-oriented counterparts in second and third year.

5.1. Question-by-question analysis

Question 1 (Day–night cycle): Most students (51%) answered incorrectly, indicating that the cause of the day–night cycle is that the Earth moves around the Sun. Only 39% of the students indicated that the cause of the day–night cycle is the Earth spinning on its axis. This is a poor performance compared to the results reported for junior high-school students (62% success—Trumper, 2001a) and for senior high-school students (64% success—Trumper, 2001b).

Question 2 (Moon phases): Most students (51%) answered correctly, choosing their best account for change in the Moon's phases as the Moon moving around the Earth. This is a better result than that obtained by Bisard et al. (1994) with freshmen and sophomore non-science college students (40%) and by Zeilik et al. (1998) with university non-science students (31%), and the almost the same as that obtained by Trumper (2001a, b) among junior and senior high-school students. In this question we found a considerable number of students who misunderstood the role of the Earth and the Sun in the cause of change in Moon's phases. Sixteen percent of the students believed that the Earth is involved in producing lunar phases through the Earth's shadow obscuring portions of the Moon and 29% believed that the Moon moves into the Sun's shadow.

Questions 3, 5, 16 and 18 (Dimensions and distances): This was one of the weakest areas of students' knowledge. Only 33% of the students answered correctly when asked to give an estimate of the distance between the Sun and the Earth, and 25% appraised correctly the distance between the Sun and a close star. In both cases they underestimated the distances in the Universe. By contrast, a great majority of the students overestimated the Earth's diameter (91%), while only 7% guessed it correctly. These results may indicate some consistent geocentric bias in students' awareness of Earth's dimension compared with the distances in the Universe. In general, this is a poorer performance than that obtained by Trumper (2001a, b) among junior and senior high-school students.

Finally, only 35% of the students correctly answered the question about the angular size of the Sun as seen from Saturn which was presented mainly as a mathematical question. This is a poor performance compared with Zeilik's (1998) report of 63% success of non-science university students on the same question.

Questions 6, 14 and 15 (Seasons): Most students (56%) answered question 14 correctly, indicating that the reason for the different seasons we experience every year is the tilt of the Earth's axis relative to the plane of its orbit as it revolves around the Sun. Thirty-seven percent of the students chose the varying distance between the Sun and the Earth or between the Earth, Moon and Sun, as a reason for the season changes.

Only 42% of the students chose the same argument in question 6 as the main reason for it being hotter in summer than in winter, and only 28% answered both questions correctly.

Question 15 served to verify the consistency of responses to questions 6 and 14. If one incorrectly believes that Earth–Sun distance causes seasons, it follows that both hemispheres would experience the same season at the same time. Australia's longest day would therefore correspond to that of the Northern Hemisphere. Only 32% of students correctly selected December as the time of year a Southern Hemisphere location receives the longest period of daylight and only 11.5% of the students answered the three questions correctly.

This is the only question in which we found a relative significant difference through years ($\chi^2 = 13.42$, $\mathrm{df} = 6$, $p = 0.037$), showing an increase in students' rate of success from 26% in first year to 45% in third year.

Questions 17 and 19 (consequences of the Earth's axis tilt): Previously, we saw that most students recognized the tilt of the Earth's axis relative to the plane of its orbit as the reason for the change of seasons. Still, they did not understand that this tilt also causes changes in the Sun's position in the sky at specific times of the day and year. Most of them did not realize that for northern observers, the sunrise/sunset points move steadily northward between the spring equinox and the summer solstice, and then southward from the summer solstice to the fall equinox. Only 24% correctly answered question 17 (sunset position after the fall equinox) and 19% correctly selected a location to the north of directly east for the sunrise position on June 21 (question 19). The greatest proportion of students (33%) believed the Sun to rise directly east. A probable explanation for this last finding is the generalization we teach that the Sun "rises in the east", disregarding seasonal fluctuations resulting from the Earth's axial tilt.

Question 4 (Sun overhead at noon): Only 24% of the students answered correctly that at Israel's latitude, north of the Tropic of Cancer, the Sun is never directly overhead at noon. The largest proportion of students (48%) believed that it is directly overhead every day. Maybe this arises also from the widespread everyday meaning of noon (the middle of the day). This result is almost the same to that reported by Zeilik et al. (1998) with university students and lower than that reported by Trumper (2001a, b) among junior and senior high-school students.

Question 7 (relative distances of spatial objects from Earth): The largest proportion of students (42%) answered this question correctly, positioning the Moon as the closest object to and the stars as the farthest objects from Earth, with planet Pluto between them. Twenty-five percent of the students put Pluto behind the stars, and another 25% put the stars as the closest objects to Earth. This result shows that many students were guided in their answers by their seeing the stars every night, not realizing they may be larger or brighter, but farther away. This result is poorer than that reported by Zeilik et al. (1998) among university students and by Trumper (2001b) among senior high-school students, and better than that obtained by junior high-school students (Trumper, 2001a).

Questions 8 and 9 (Moon's revolution): Most students chose the correct estimate of a month for the Moon revolving around the Earth (60%) and a year for the Moon going around the Sun (47%). Thirty-eight percent of the students answered the two questions correctly. Some of the students claimed that the Moon only revolves around the Earth and not around the Sun, not understanding the meaning of a relative movement. These are similar results to those reported by Trumper (2001a) for junior high-school students, and poorer than those reported for senior high-school students (Trumper, 2001b).

Question 10 (time zones): The greatest proportion of students (36%) chose the correct answer, namely that when it is noon in Haifa, it would be about sunset in Beijing (90° east of Haifa). Another 40% of the students thought that this longitude difference would result in a greater difference in time between the two cities, but in the right direction. Some of the students claimed that if the two cities are situated in the same latitude, they are in the same time zone. As a whole, these are similar results to those reported among junior high-school students (Trumper, 2001a) and poorer than those reported among senior high-school students (Trumper, 2001b).

Question 11 (Solar eclipse): Only 18% of the students answered correctly that in order to have a total solar eclipse, the Moon must be in its New phase (unseen from the Earth). Trumper (2001a, b) reported the same result for junior and senior high-school students, and Zeilik et al. (1998) reported a better result for university students (28% correct). The answer chosen by the great majority of the students (71%) was that the Moon must be in its Full phase in order to get a total solar eclipse. This is a discouraging result, considering that about half the students correctly answered question 2, concerning the reasons for the change in Moon's phases.

Question 12 (Moon's rotation): Once again, only 23% of the students got the right answer, indicating that the fact that we always see the same side of the Moon from the Earth implies that the Moon rotates on its axis once a month. Almost the same result was reported by Trumper (2001a, b) for junior and senior high-school students, and a much poorer result was reported by Zeilik et al. (1998) among university students (10% success). The answer chosen by the greatest proportion of students (51%) was that the Moon does not rotate on its axis.

Question 13 (center of Universe): The greatest proportion of students (48%) correctly answered that according to current theories the Universe does not have a center in space. Twenty-two percent chose the Sun and 14% chose the Earth to be at the center of the Universe. This result is poorer than that obtained by Trumper (2001a, b), who reported a 56% rate of success for junior high-school students and a 65% rate of success for senior high-school students.

6. Discussion and educational implications

The research outlined above has shown that there is a serious discrepancy between student teachers' conceptions of some basic astronomy concepts and the corresponding accepted scientific view. If these concepts are to be used properly in the classroom, every effort must be made to help teachers develop their understanding.

From the constructivist perspective, humans in general are seen as subjects who actively construct understanding from experiences using their already existing frameworks (Wubbels, 1992). People continuously build their personal theories; accordingly, students enter science education with knowledge and attitudes that are deeply rooted in experience. They act as strong frameworks to interpret things that happen in classrooms and they help people to interact with their environment.

That is, students do have some ideas about most physics concepts in the syllabuses, though some of these ideas may well differ from the accepted ones. If courses are to succeed, they need to take account of these prior ideas. As Millar (1988) argues:

> For each topic, a starting point is to elicit (students') current ideas and understandings about the topic. On the basis of this, they can be directed to carefully chosen readings and practical activities, designed specifically to challenge or deepen existing ideas (p. 51).

The key aspects of constructivism that should influence the materials for developing student teachers' understanding, can be expressed as the need:

(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;
(b) for students to become aware of their own views and uncertainties;
(c) for students' to be confronted, afterwards, with the currently accepted concepts;
(d) to provide experiences that will help students to change their views and conceptions, and accept the scientific view.

However, it has already been observed that conceptual change is

> … only rarely a sharp exchange of one set of meanings for another, and is more often an accretion of information and instances that the learner uses to sort out contexts in which it is profitable to use one form of explanation or another (Fensham, Gunstone, & White, 1994, p. 6).

Moreover, conceptual change involves the learner recognizing his/her existing ideas and then deciding whether or not to reconstruct them (Gunstone & Northfield, 1992). This description clearly places the direct responsibility for conceptual change with the learner. Obviously, major demands are made of the teacher to provide contexts wherein the learner is more likely to undertake these weighty tasks. This links with metacognition, the importance of which may be illustrated by negative cases where the context provided by the teacher cannot have any impact on conceptual change because of existing ideas and beliefs about learning held by the learners (Gunstone, 1994).

For example, a conceptually centered astronomy course with actively engaged students might be planned (Bisard & Zeilik, 1998). Key astronomical concepts may be organized into goal clusters: motions, distances, light and scientific models. Teaching strategies and assessment instruments may be developed to engage the students more actively with connected concepts and to assess the effects of such instruction upon the students' conceptual learning. For instance, after verbal instruction regarding the connection among different concepts, concept maps may be used as organizers for each major set of concepts. Students may be organized into teams either randomly or in dedicated groups, following a format of accepted cooperative learning strategies. Some of the possible activities, including a process of prediction, observation, discussion and conclusions, are:

(a) Follow the position of the sun in the sky from sunrise to sunset, by means of a transparent half-sphere shaped dome.

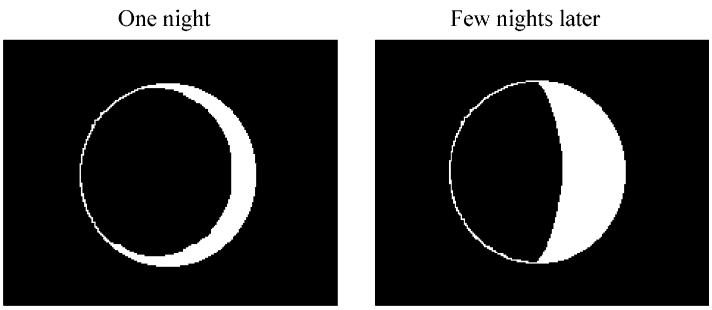
(b) Follow the exact position and time of sunset for a period of several months.
(c) Measure the Sun's diameter by means of a pierced aluminum sheet and a common white sheet at a fixed known distance (using triangle similarity).
(d) Construct a model including a bright lamp (Sun), a tennis ball (Earth) and a ping-pong ball (Moon) in order to simulate the day–night cycle, the lunar phases and the relative motions between Sun, Earth and Moon.

Furthermore, night-sky observations, video-taped films, computerized simulations and the many existing Internet resources may be used following the same instruction principles stated above.

Appendix. Questionnaire—The Earth and the Universe

1. 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.

2. 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?



   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. √

3. If you used a basketball to represent the Sun, about how far away would you put a scale model of the Earth?
   A. 30 cm or less.
   B. 1.5 m.
   C. 3 m.
   D. 7.5 m.
   E. 30 m.

4. As seen from your home, when is the Sun directly overhead at noon (so that no shadows are cast)?
   A. Every day.

B. On the day of the summer solstice.
C. On the day of the winter solstice.
D. At both of the equinoxes (spring and fall).
E. Never from the latitude of your home. √

5. Give the best estimate of the Earth's diameter from among the following numbers:
A. 1500 km.
B. 15,000 km.
C. 150,000 km.
D. 1,500,000 km.
E. 15,000,000 km.

6. The main reason for it being hotter in 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 to 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. Which of the following lists shows a sequence of objects that are closest to the Earth to those that are farthest away?

A. Moon → Stars → Pluto.
B. Pluto → Moon → Stars.
C. Stars → Moon → Pluto.
D. Stars → Pluto → Moon.
E. Moon → Pluto → Stars. √

Choose your best estimates of the times for the events listed. Choices may be used more than once.

8. The Moon to go around the Earth:
A. Hour.
B. Day.
C. Week.
D. Month. √
E. Year.

9. The Moon to go around the Sun:
A. Hour.
B. Day.
C. Week.
D. Month.
E. Year. √

10. Beijing is 90° east of Haifa. If it is noon in Haifa, in Beijing it would be about:
A. Sunrise.
B. Sunset. √

C. Noon.
D. Midnight.
E. Noon the next day.

11. 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.

12. 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. √

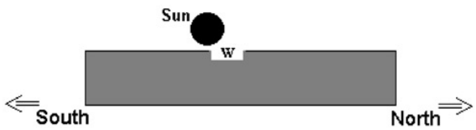
13. According to modern ideas and observations, which of the following statements is correct?
A. The Earth is at the center of the Universe.
B. The Sun is at the center of the Universe.
C. The Milky Way Galaxy is at the center of the Universe.
D. The Universe does not have a center in space. √

14. The different seasons that we experience every year are due to:
A. The varying distance between the Sun and the Earth.
B. The varying distances between the Earth, Moon and Sun.
C. The tilt of the Earth's axis as it revolves around the Sun. √
D. Varying degrees of atmospheric pollution that dilute the Sun's rays.

15. When is the longest daylight period in Australia?
A. March.
B. June.
C. September.
D. December. √

16. Two grapes would make a good scale model of the Sun and a close star, if separated by
A. 0.5 m
B. 1 m.
C. 100 m.
D. 1.5 km.
E. 150 km. √

17. The diagram here shows the position along the horizon of the Sun just about to set on the fall equinox. Where would the sunset position appear a week later as seen from your home? North is to the right and south is to the left. The "W" indicates due west on the horizon where the Sun sets on the equinox.



A. In the same place.
B. Northward of the equinox position.
C. Southward of the equinox position. √

18. As seen from the Earth, the Sun covers an angle on the sky of about $\frac{1}{2}^{\circ}$. The angular diameter is proportional to the ratio of the actual diameter to distance. Imagine you observed the Sun from Saturn, which is about 10 times farther away from the Sun than the Earth. You would predict that the Sun's angle on the sky would be
A. The same.
B. $1/20^{\circ}$ √
C. $1/40^{\circ}$
D. $1/200^{\circ}$

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

References

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

Barba, R., & Rubba, P. (1992). A comparison of pre-service and in-service Earth and space science teachers' general mental abilities, content knowledge, and problem-solving skills. *Journal of Research in Science Teaching*, *29*, 1021–1035.

Baxter, J. (1989). Children's understanding of familiar astronomical events. *International Journal of Science Education*, *11*, 302–313.

Bisard, W., Aron, R., Francek, M., & Nelson, B. (1994). Assessing selected physical science and Earth science misconceptions of middle school through university pre-service teachers. *Journal of College Science Teaching*, *24*, 38–42.

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.

Brewer, W., Hendrich, D., Vosniadou, S. (1988). A cross-cultural study of children's development of cosmological bodies: Samoan and American data. Unpublished manuscript.

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* (pp. 163–186). New York: Academic Press.

Cobb, P., Boufi, A., McClain, K., & Whitenack, J. (1997). Reflective discourse and collective reflection. *Journal of Research in Mathematics Education*, *28*, 258–277.

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.

Dole, J., & Sinatra, G. (1998). Reconceptualizing change in the cognitive construction of knowledge. *Educational Psychologist*, *32*, 109–128.

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., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher*, *23*(7), 5–12.

Edwards, S., & Mercer, N. (1987). *Common knowledge*. London: Methuen.

Fensham, P., Gunstone, R., & White, R. (1994). Science content and constructivist views of learning and teaching. In P. Fensham, R. Gunstone, & R. White (Eds.), *The content of science—a constructivist approach to its teaching and learning* (pp. 1–8). London: The Falmer Press.

Goldsworthy, A. (1997). Dream on. *Education in Science*, *172*, 8–9.

Goldsworthy, A. (1999). Primary changes. *Education in Science*, *184*, 9.

Gunstone, R. (1994). The importance of specific science content in the enhancement of metacognition. In P.

Fensham, R. Gunstone, & R. White (Eds.), *The content of science—a constructivist approach to its teaching and learning* (pp. 131–9146). London: The Falmer Press.

Gunstone, R., Northfield, J. (1992). Conceptual Change in Teacher Education: The Centrality of Metacognition. Paper presented at *the meeting of the American Educational Research Association,* April.

Hewson, P., & Hewson, M. (1988). An appropriate conception of teaching science: A view from studies on science learning. *Science Education*, *72*, 597–614.

Hollingsworth, S. (1989). Prior beliefs and cognitive change in learning to teach. *American Educational Research Journal*, *26*, 160–189.

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. (1955). *The psychology of personal constructs, Vols. 1 and 2.* 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.

Lightman, A., & Sadler, P. (1993). Teacher predictions versus actual student gains. *The Physics Teacher*, *31*, 162–167.

Maor, D., & Taylor, P. (1995). Teacher epistemology and scientific inquiry in computerized classroom environments. *Journal of Research in Science Teaching*, *32*, 839–854.

Mason, L. (1996). An analysis of children's construction of new knowledge through their use of reasoning and arguing in classroom discussions. *International Journal of Qualitative Studies in Education*, *9*, 411–433.

Meyer, K., Woodruff, E. (1995). A framework for inquiry discourse and consensus-building in science teaching. Paper presented at *the annual meeting of AERA,* San Francisco, CA, March.

Millar, R. (1988). Teaching physics as a non-specialist: The in-service training of science teachers. *Journal of Education for Teaching*, *14*, 39–53.

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.

Nussbaum, J., & Sharoni-Dagan, N. (1983). Changes in second grade children's preconceptions about the Earth as a cosmic body resulting from a short series of audio-tutorial lessons. *Science Education*, *67*, 99–114.

Orpwood, G., & Souque, J. (1985). Towards the renewal of Canadian science education. II. Findings & recommendations. *Science Education*, *69*, 625–636.

Piaget, J. (1929). *The child's conception of the world.* New York: Harcourt, Brace.

Piaget, J. (1930). *The child's conception of physical causality.* London: Kegan Paul.

Pontecorvo, C. (1987). Discussing for reasoning: The role of argument in knowledge construction. In E. De Corte, H. Lodewijks, R. Parmentier, & P. Span (Eds.), *Learning and instruction. European research in an international context*, Vol. 1. Oxford: Pergamon Press and Leuven University Press.

Pontecorvo, C. (1990). Social context, semiotic mediation, and forms of discourse in constructing knowledge at school. In H. Mandl, E. De Corte, S. Bennet, & H. Friedrich (Eds.), *Learning and instruction. European research in an international context. Analysis of complex skills and complex knowledge domains*, Vol. 21. Oxford: Pergamon Press.

Pontecorvo, C. (1993). Forms of discourse and shared thinking. *Cognition and Instruction*, *11*, 189–196.

Posner, G., Strike, K., Hewson, P., & Gertzog, W. (1982). Accommodation of a scientific conception. *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.

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.

Samarapungavan, A., Vosniadou, S., & Brewer, W. (1996). Mental models of the Earth, Sun and Moon: Indian children's cosmologies. *Cognitive Development*, *11*, 491–521.

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.

Sneider, C., & Pulos, S. (1983). Children's cosmographies: Understanding the earth shape and gravity. *Science Education*, *67*, 205–221.

Solomon, J. (1987). Social influences on the construction of pupil's understanding of science. *Studies in Science Education*, *14*, 63–82.

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. University of Kiel: IPN.

Stofflet, R. (1991). *Conceptual change in elementary teacher candidates' content and pedagogical knowledge of science. Unpublished doctoral dissertation.* Salt Lake City: 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.

Tomorrow 98 (1992). Report from the commission on science and technological education. Jerusalem: Ministry of Education.

Trumper, R. (2001a). A cross-age study of junior high school students' conceptions of basic astronomy concepts. *International Journal of Science Education*, *23*, 1111–1124.

Trumper, R. (2001b). A cross-age study of senior high school students' conceptions of basic astronomy concepts. *Research in Science & Technological Education*, *19*, 97–109.

Vosniadou, S. (1987). Children's acquisition and restructuring of science knowledge. Paper presented in *a symposium on "Children's procedural knowledge in science" at the annual meeting of AERA,* Washington, DC.

Vosniadou, S. (1989). On the nature of children's naive knowledge. *Proceedings of the 11th annual conference of the cognitive science society.* Ann Arbor, MI.

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. (1990). A cross-cultural investigation of children's conceptions about the Earth, the Sun, and the Moon: Greek and American data. In H. Mandl, E. Decorte, N. Bennett, & H. Friedrich (Eds.), *Learning and instruction: European research in an international context* (pp. 605–629). Oxford: Pergamon.

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.

Wallace, J., & Louden, W. (1992). Science teaching and teachers' knowledge: Prospects for reform of elementary classrooms. *Science Education*, *76*, 507–521.

Weinstein, C. (1989). Teacher education students' preconceptions of teaching. *Journal of Teacher Education*, *39*, 53–60.

Wubbels, T. (1992). Taking account of student teachers' preconceptions. *Teaching and Teacher Education*, *8*, 137–149.

Yager, R., Lutz, M., & Craven III, J. (1996). Do national standards indicate the need for reform in science teacher education? *Journal of Science Teacher Education*, *7*, 85–94.

Zeilik, M., Schau, C., & Mattern, N. (1998). Misconceptions and their change in university-level astronomy courses. *The Physics Teacher*, *36*, 104–107.