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A Cross-age Study of Senior High School Students' Conceptions of Basic Astronomy Concepts

RICARDO TRUMPER, *Faculty of Science and Science Education, Haifa University, Israel*

ABSTRACT *Senior high school students' astronomy conceptions were analysed by means of a written questionnaire presented to them during the beginning of the first semester. The main findings were: (1) Most students answered correctly the questions dealing with the following subjects: the day–night cycle, the reason for the different seasons, and the time of the Moon's revolution around the Earth and the Sun. (2) Most students chose their best account for changes in the Moon's phases as the Moon moving around the Earth. Despite that, most students thought that the Moon must be in its full phase in order to get a total solar eclipse. (3) Most students underestimated distances in the Universe and overestimated the Earth's diameter. (4) Most students answered incorrectly the questions dealing with the following subjects: Sun overhead at noon, longitude time zones, and Moon's rotation. (5) Students studying physics succeeded significantly better than their colleagues in some of the subjects that were taught as a part of their optics and mechanics courses.*

Introduction

Education reformers constantly turn their attention to the state of school science teaching. This movement has been influenced by the public's increasing pre-occupation with the quality of school science teaching and the apparently falling standards of students' knowledge and understanding of science (Wallace & Louden, 1992). Such developments have appeared in reports from 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 (Secretary of State for Education and Science, 1983), Italy (Borghi *et al.*, 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, including the introduction of a new compulsory and interdisciplinary programme called 'Science and Technology in the Modern Society' for senior high school students (aged 16–18 years) who do not study any other scientific subject.

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The *Tomorrow 98* Report claims:

> Educators and education policy makers in many countries had lately dealt with the question of a scientific course for all high school students. The main problem is not if we have to introduce such a course but how to do that. Most education policy makers all over the world are convinced that the basic instruction of every citizen has to include a scientific and technological understanding (p. 36).

According to these premises, a programme including different topics is being written for the 3 years of senior high school. One of the new topics included in the programme is 'The Earth and the Universe', whose core subject is astronomy.

The limited impact of the reforms made in science teaching over the past two decades in different parts of the world has been the subject of considerable interest. Various explanations have been proposed, such us a lack of time and money (Johns, 1984) and inadequate teaching pedagogy (Stronck, 1986). Wallace and Louden (1992), concluded that the reform of 'classrooms must be understood' through the 'view of the central place of teacher's knowledge in teacher's work' (p. 519). Several recent studies analysing the results of the reforms in science education in American schools have come to 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 do not teach reform-based science and need training to be able to do so.
(3) Standards for both teaching and learning science must take into account recent research into constructivist theory and its implementation in the classroom.

Young 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. 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 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 characterisation of those five notions was revised and refined and their prevalence at different age levels (fourth to eighth grades) was studied. Kramer (1977) branched off the original study to investigate junior high school students' conceptions of the 'structure of the Universe'. He found that elements of various notions about the Earth still appear in the ninth graders' more detailed notions about the Universe.

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 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 the cause of night and day, or the reason for the difference in sunrise time in different geographical locations.

Jones *et al.* (1987) turned their attention to the solar system itself; they investigated elementary school Tasmanian (Australia) 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-centred models and the last two were Sun-centred 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 4–10. 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. At first this motion was 'up', 'down' or 'across', later being replaced by orbital motion (e.g. Sun moves to the other side of the Earth to give them their 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.

Although the results of this survey showed a reduction in the more naive views as age increased, misconceptions persisted in many pupils up to 16 years of age, supporting the claim that children's naive concepts frequently pass on into adulthood. This has been confirmed by Durant *et al.* (1989), who quoted the results of two parallel public national surveys, carried out in Great Britain and the USA, indicating that only 34% of Britons and 46% of Americans appeared to know that the Earth goes round the Sun once a year. A poll carried out in parallel in France (Acker & Pecker, 1988) showed that about 33% of the public still believed that the Sun orbits the Earth.

Vosniadou and her colleagues conducted a series of experiments investigating children's and adults' knowledge of observational astronomy. They involved pre-school, elementary school, and high school children, college undergraduates, and illiterate adults (Brewer *et al.*, 1988; Vosniadou, 1987, 1989, 1991). In addition to studies conducted in the USA, they collected data from children and adults in India (Samarapungavan *et al.*, 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: (a) initial models that are derived from and are consistent with the observations of everyday life; (b) synthetic models that are the attempts to integrate scientific and everyday information; and (c) scientific models that agree with the accepted scientific view.

These studies showed that there is 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 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 moving down to the ground and hiding behind the mountains causes 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 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/own direction our part of the Earth eventually comes to face the Moon in the night sky.

High School Students' Conceptions of Basic Astronomy Concepts

In September 1998, S. Raj Chaudury shared with his colleagues in the Physics Learning Research List a very unusual response he got from one of his students:

> I asked my introductory physical science class the other day what caused the seasons—why was it warmer in the summer and colder in the winter. Along with the usual 'closer to the Sun in the summer' answers, I got one I have never heard before: the student indicated that the change in seasons had something to do with the fact that the Earth rotated clockwise in the summer and counterclockwise in the winter (diagrams showing this were provided). I asked the student how she came to this conclusion. She admitted never having thought about the cause of seasons before, but her reason for the 'clockwise', 'counterclockwise' theory was the *change in clocks in the spring and the fall*—spring forward and fall back. I said 'thanks' and let her go—with the promise that we would soon discuss this in class. Have the astronomy folks ever encountered this particular view of the world?

This is indeed a very rare view, but nevertheless high school and university students' conceptions of astronomy concepts have been much less investigated than those of elementary school students. Lightman and Sadler (1993) found that students in grades 8–12 shared some of the conceptions held by elementary school children. Although 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 a correct conception about the phases of the Moon, the Sun overhead and the Earth's diameter, and only 10% knew the reason for the seasons' changes.

Bisard *et al.* (1994) carried out an interdisciplinary study whose purpose was to investigate and assess suspected science misconceptions 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. The correct response rate for this latter group was approximately equivalent to middle school students. Regarding the astronomical topics separately, their findings were as follows:

(1) The authors were surprised by the large number of students answering the questions dealing with the causes of the seasons correctly, as several studies suggest that this misconception is much more widespread.
(2) The students generally performed quite poorly when asked about the Sun's position in the sky at specific times of the day and year.
(3) A little less than 40% of all students correctly responded that the different phases of the Moon are caused by reflected sunlight. Consistent with other studies, nearly 60% of students believed that the Earth was in someway involved in producing lunar phases, either through the Earth's shadow obscuring portions of the Moon or sunlight reflecting off the Earth and clouds.

In the following sections we present the result of a cross-age study analysing senior high school students' conceptions of basic astronomy concepts.

A Cross-age Study

The participants in the present study were drawn from two rural regional schools in Israel that have not yet begun to implement any of the *Tomorrow 98* (1992) reforms. In junior high school, the physics topics were compulsory for all students. In seventh grade, the topic taught was the particulate state of matter; in eighth grade there were two main topics taught: (a) heat and temperature; and (b) basic electric circuits. In ninth grade, there were also two main topics: (a) mass, force and weight; and (b) transformation and conservation of energy. In senior high school, 20% of the present sample studied physics as an elective subject. In 10th grade (about 15-year-old students), the topic taught was optics and waves, in 11th grade (about 16 years) mechanics and in 12th grade (about 17 years) electromagnetism and modern physics.

All the students studying in these schools participated in the study, and we analysed the responses of those who answered at least 75% of the questions presented to them, namely 378 students (153 in grade 10, 116 in grade 11 and 109 in grade 12), omitting only three students. The sample included 193 girls and 185 boys.

The astronomy conceptions of the students were analysed by means of a written questionnaire presented to them during the beginning of the first semester. The questionnaire contained 16 questions taken from three different sources: Zeilik *et al.* (1998), Lightman and Sadler (1993), and Bisard *et al.* (1994). The questions are given in the Appendix.

The overall correct response rate was 43·6%, somewhat increasing through the 3 years, from 40·9% in grade 10 to 47·0% in grade 12. However, a statistically significant difference was found only when comparing the results of the 10th and 12th grade students ($t = 3{\cdot}15$, df $= 260$, p value $= 0{\cdot}0018$). Boys scored significantly better (47·0%) than girls (40·4%) ($t = 4{\cdot}29$, df $= 375$, p value $< 0{\cdot}0001$). Students studying physics (20% of the whole sample), performed significantly better (52·8% success) than their colleagues ($t = 6{\cdot}07$, df $= 375$, p value $< 0{\cdot}0001$).

We performed an item analysis that provided us with discrimination indices measuring the extent to which the test questions differentiated 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. For all these cases, there was a statistically significant difference between the proportion of students responding correctly and incorrectly in the extreme groups. There were only two questions with relative low discrimination indices: in question 3 (Earth's diameter) we got a discrimination index of 0·08 for both divisions of the extreme groups, and in question 12 (Moon's rotation) we got a discrimination index of 0·11 when we took the upper and lower quarters of the sample, and 0·14 when we took the upper and lower 10% of the sample. The difficulty level of these two questions seems to be high, since the proportion of students responding correctly was low in both extreme groups. We also calculated the Kuder-Richardson 20 reliability of the test obtaining an estimate of 0·49, a relatively high score considering the fact that different questions in the test were related to different astronomy concepts and understandings, as may be seen in the following question-by-question analysis.

Question-by-question Analysis

Question 1 (Day–night Cycle)

Most students (64%) answered correctly, indicating that the cause of the day–night cycle is that the Earth is spinning on its axis. This result is very similar to that obtained by Lightman and Sadler (1993) with high school students and by Trumper (2000) with university students. Thirty per cent of the students pointed out that the cause of the day–night cycle is that the Earth moves around the Sun. There was a statistically significant difference between students who studied physics (82% success) and those who did not (59% success) ($\chi^2 = 12{\cdot}04$, df $= 1$, p value $= 0{\cdot}001$), and also between boys (72% success) and girls (56% success) ($\chi^2 = 6{\cdot}27$, df $= 1$, p value $= 0{\cdot}0012$).

Question 2 (Moon Phases)

Most students (53%) answered correctly, choosing their best account for the change in the Moon's phases as the Moon moving around the Earth. This is a better result than that obtained by Lightman and Sadler (1993) and by Bisard *et al.* (1994) with introductory and advanced college students (40%). However, we found a considerable number of students who misunderstood the role of the Earth and the Sun in the cause of the change in the Moon's phases. Twenty-seven per cent of the students believed that the Earth is involved in producing lunar phases through the Earth's shadow obscuring portions of the Moon and 17% believed that the Moon moves into the Sun's shadow. For a considerable number of students there appeared to be some confusion between a lunar eclipse and the Moon's phases. A 10th year student claimed that 'one side of the Moon is always exposed to the Sun's rays and the other side is hidden by the Earth'.

Questions 3, 5 and 16 (Dimensions and distances)

This was one of the weakest areas of students' knowledge. Only 25% of the students answered correctly when asked to give an estimate of the distance between the Sun and the Earth, and 19% 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 (84%), while only 14% answered it correctly. In this last question there was a statistically significant difference between students who studied physics (29% success) and those who did not (10% success) ($\chi^2 = 15{\cdot}69$, df $= 3$, p value $= 0{\cdot}001$), and also between boys (19% success) and girls (8% success) ($\chi^2 = 8{\cdot}25$, df $= 3$, p value $= 0{\cdot}0041$). These results may indicate some consistent geocentric bias in students' awareness of the Earth's dimensions compared with distances in the Universe.

Questions 6, 14 and 15 (Seasons)

Most students (62%) 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. The largest proportion of students (47%) chose the same argument in question 6 as the main reason why it is hotter in the summer than in the winter. However, only 62% of the students who indicated that the tilted Earth's axis is the reason for the different seasons answered question 6 correctly. Among them, 13% chose the Earth being closer to the Sun in summer and 24% indicated the Earth's rotational axis flipping back and forth as the Earth moves around the Sun as the main reason why it is hotter in summer than in winter.

Question 15 served to verify the consistency of responses to questions 6 and 14. If one incorrectly believes that the 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 34% of students correctly selected December as the time of year a Southern Hemisphere location receives the longest period of daylight and only 13% of the students answered the three questions correctly.

Question 4 (Sun overhead at noon)

Only 36% of the students answered correctly that in Israel's latitude, north of the Tropic of Cancer, the Sun is never directly overhead at noon. The same number of students believed that it is directly overhead every day. Maybe this arises from the widespread everyday meaning of noon ('the middle of the day'). This is a somewhat better result than that obtained by Lightman and Sadler (1993) with high school students (about 20% success) and by Trumper (2000) with university students (32%).

Question 7 (Relative Distances of Spatial Objects from the Earth)

Almost half of the students (49%) answered this question correctly, positioning the Moon as the closest object to and the stars as the farthest objects from the Earth, with planet

Pluto between them. Thirty-two per cent of the students put Pluto behind the stars, and another 9% put the stars as the closest objects to the Earth. This result shows that many students were guided in their answers by seeing the stars every night, not realising they may be larger or brighter, but farther away. There was a statistically significant difference between students who studied physics (66% success) and those who did not (44% success) ($\chi^2 = 10{\cdot}80$, df = 3, p value = 0·013), and also between boys (59% success) and girls (40% success) ($\chi^2 = 9{\cdot}98$, df = 4, p value = 0·041).

Questions 8 and 9 (Moon's revolution)

Most students chose the correct estimate of a month for the Moon revolving around the Earth and a year for the Moon going around the Sun (70% in both cases). Fifty-eight per cent of the students answered the two questions correctly. In question 9 there was a statistically significant difference between students who studied physics (88% success) and those who did not (65% success) ($\chi^2 = 14{\cdot}53$, df. = 2, p value = 0·001), showing a somewhat better understanding of the meaning of a relative movement.

Question 10 (Time Zones)

The largest proportion of students (44%) chose the correct answer that when it is noon in Haifa, it would be about sunset in Beijing (90° east of Haifa). Another 39% 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. This is a similar result to that reported by Lightman and Sadler (1993).

Question 11 (Solar eclipse)

Only 19% 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). The answer chosen by the great majority of the students (77%) 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 more than half of the students correctly answered question 2, concerning the reasons for the change in the Moon's phases. There was a statistically significant difference between students who studied physics (30% success) and those who did not (16% success) ($\chi^2 = 5{\cdot}23$, df = 1, p value = 0·022).

Question 12 (Moon's rotation)

Only 20% 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. Zeilik *et al.* (1998) reported a much poorer result with university students (10% success). The answer chosen by the largest proportion of students (57%) was that the Moon does not rotate on its axis.

Question 13 (Centre of the Universe)

Most students (65%) correctly answered that according to current theories the Universe does not have a centre in space. Twenty-one per cent chose the Sun, and 9% the Milky

Way Galaxy to be at the centre of the Universe. There was a statistically significant difference between students who studied physics (78% success) and those who did not (61% success) ($\chi^2 = 6{\cdot}49$, df = 2, p value = 0·039), and also between boys (77% success) and girls (53% success) ($\chi^2 = 14.84$, df = 3, p value = 0·002).

Discussion and Educational Implications

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

In 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 experiences. 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, although 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 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 *et al.*, 1994, p. 6).

Moreover, conceptual change involves the learner recognising 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, whose importance 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).

Correspondence: Ricardo Trumper, Kibbutz Hahoterim, Doar Na Hof Hacarmel 30870, Israel. E-mail: rtrumper@research.haifa.ac.il

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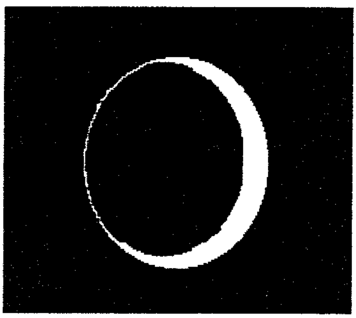
Appendix

Questionnaire—The Earth and the Universe. What causes night and day?

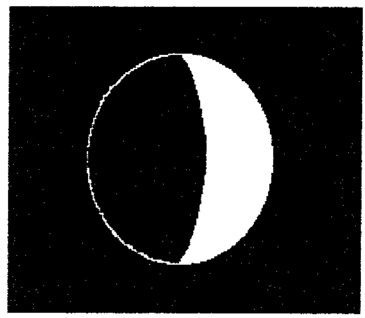
1. What causes night and day?

   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?



One night



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.√

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 that it is hotter in the summer than the 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 centre of the Universe.
    B. The Sun is at the centre of the Universe.
    C. The Milky Way Galaxy is at the centre of the Universe.
    D. The Universe does not have a centre 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 which 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. √.