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A questionnaire of 19 questions given to 76 students entering an 'Introduction to astronomy' course at university showed that the students held a series of misconceptions on several central topics in basic astronomy.

Students generally enter courses with some prior knowledge of the subject area. In many cases, their naive notions are often misconceptions, or alternative frameworks, which may impede learning of the appropriate concepts in the field. Much research on this issue has concentrated on physics courses, but few insights have come from university-level astronomy courses.

In September 1998, S Raj Chaudhury shared with his colleagues in the Physics Learning Research List a very unusual response that he received 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 anti-clockwise 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/anticlockwise' theory was the *change in clocks in the spring and autumn*—clocks moving forawrd in spring and backwards in autumn.
>
> 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 on astronomy concepts have been investigated far less than those of elementary school students, which have been researched extensively during the last 20 years (see e.g., Baxter 1989, Jones *et al* 1987, Kikas 1998, Klein 1982, Nussbaum 1979, Nussbaum and Novak 1976, Sharp 1996, Sneider and Pulos 1983, Vosniadou 1992, Vosniadou and Brewer 1992, 1994).

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 to university. The results 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. This suggests that future general elementary teachers will have about as many misconceptions concerning the topics covered in this survey as typical middle-school students.

When dealing with astronomical topics separately the researchers' findings 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.
3. About three-quarters of all students did not realize that the highest Earth tides occur on opposite sides of the globe when the Earth, Moon and Sun are all aligned.

More recently, Zeilik *et al* (1998) investigated science and non-science university majors' conceptions on several physical and astronomical concepts. 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 phases of the Moon and the solar eclipse.

Overall characteristics of the sample

Here we report the results of a survey of 76 students' prior knowledge when entering an 'Introduction to astronomy' course at the University of Haifa. On a student background survey, 32% said that they were science majors (13% geography, 8% computer sciences, 8% mathematics and 3% biology), 43% social studies, 7% humanities, 5% fine arts and 13% undecided. The class included 49 females and 27 males. Only two students were over 30 years old; most of the class were under 25 (70%), making an average age of 23.4. In their educational background, only three students had taken a physics course in high school, including astronomy concepts.

Research method and overall findings

Our Misconceptions Measure test contained 19 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 48.5%, very similar to the result obtained by introductory college students in the study of Bisard *et al* (1994). Males scored significantly better (57%) than females (43.2%) ($t = 3.47$, p-value $= 0.001$). This result differs substantially from that of a study by Francek *et al* (1993) investigating the persistence of geographic misconceptions. They found significant gender differences, with males consistently scoring better than females at the middle-school level. These differences decreased into high school and college and were essentially nonexistent in upper-level classes. The present result may be explained by the fact that 37% of the male students and only 28% of the female students were science majors. Science majors indeed performed better (54.4%) than non-science majors (45.7%), but this difference was statistically significant only on a 0.04 level.

Question by question analysis

Question 1 (Day–night cycle):
Most students (62%) answered correctly, indicating that the cause of the day–night cycle is that the Earth spins on its axis. This result is very similar to that obtained by Lightman and Sadler (1993) among high-school students.

Question 2 (Moon phases):
More than half of the students (51.3%) answered correctly, choosing their best account for the changes in the Moon's phases as being due to the Moon moving around the Earth. This is a better result than that obtained by Bisard *et al* (1994) among introductory and advanced college students (40%), and by Zeilik *et al* (1998) among university students (31%).

However, in these two questions we found a considerable number of students who misunderstood the role of the Earth in the day–night cycle or in the reason for the change in the Moon's phases. Almost 36% of the students indicated that the cause of the day–night cycle is that the Earth moves around the Sun, and 31.6% of the students believed that the Earth is involved in producing lunar phases through the Earth's shadow obscuring portions of the Moon.

Questions 3, 5, 16 and 18 (Dimensions and distances):
This was one of the weakest areas of students' prior knowledge. Only 35.5% of the students answered correctly when asked to give an estimate of the distance between the Sun and the Earth, and only 19.7% correctly appraised the distance between the Sun and a close star. In both cases they underestimated the distances in the universe. By contrast, most students overestimated the Earth's diameter (59.2%), while only 31.6% guessed it correctly. These results may indicate some consistent geocentric bias in the students' awareness of Earth's dimensions compared with distances in the universe.

Finally, only 39.5% of the students answered correctly the question about the angular size of the Sun as seen from Saturn that was presented mainly as a mathematical question. This is a poor performance compared with Zeilik *et al*'s (1998) report, which gave a 63% success rate for university students on the same question.

Questions 6, 14 and 15 (Seasons):
Most students (67.1%) 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. Most students (50%) chose the same argument in question 6 as the main reason why it is hotter in the summer than in the winter. However, only half of the students who indicated that the tilted Earth's axis is the reason for the different seasons answered question 6 correctly. Among the other half, seven students chose the Earth being closer to the Sun in summer and ten 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 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. Almost 65% of students correctly selected December as the time of year when a southern hemisphere location receives the longest period of daylight. This seems a very encouraging result, but we noted that only 30.2% of the students answered the three questions correctly.

Questions 17 and 19 (Consequences of the Earth's axis tilt):
Previously, we saw that students recognized the tilt of the Earth's axis relative to the plane of its orbit to be the reason for the change of seasons. Despite that, 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 autumn equinox. Only 27.6% correctly answered question 17 (sunset position after the autumn equinox) and 17.1% correctly selected a location to the north (left) of directly east for the sunrise position on 21 June (question 19). The greatest proportion of students (55.3%) 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 32.9% of the students answered correctly that in our latitude, north of the Tropic of Cancer, the Sun is never directly overhead at noon. The greatest proportion of students (47.4%) believed that it happens every day. Maybe this arises also from the widespread everyday meaning of noon ('the middle of the day'). This result is slightly better than that reported by Zeilik *et al* (1998) among university students for the same question (23% success).

Question 7 (Relative distances of spatial objects from Earth):
Exactly half of the students answered this question correctly, positioning the Moon as the closest object to and the stars as the furthest objects from Earth, with planet Pluto between them. Three students did not answer this question, and all the others (46.1%) put Pluto behind the stars. This result shows that many students are guided by seeing the stars every night, without realizing that they may be larger or brighter, but farther away than the planets. This result is very similar to that obtained by Lightman and Sadler (1993) among high-school students.

Questions 8 and 9 (Moon's revolution):
Most students chose the correct estimate of a month for the Moon revolving around the Earth (60.5%) and a year for the Moon going around the Sun (68.4%). Exactly half of the students answered the two questions correctly. These are better results than those reported by Lightman and Sadler (1993).

Question 10 (Time zones):
Almost 49% of the students chose the correct answer that when it is noon in Haifa, it would be about sunset in Beijing (90° east of Haifa). Another 29% of the students thought that this latitude difference would result in a greater difference in time between the two cities, but in the correct (time) direction. This is a similar result to that reported by Lightman and Sadler (1993).

Question 11 (Solar eclipse):
Only 22.4% of the students answered correctly that in order to have a total solar eclipse, the Moon must be in its 'new' phase (unseen from Earth). A slightly better result was reported by Zeilik *et al* (1998) among university students for this question (28% success). The answer chosen by the great majority of students (71.1%) was that the Moon must be in its 'full' phase in order to get a total solar eclipse. This is a discouraging result after having more than half of the students correctly answering question 2, which dealt with the reasons for the change in the Moon's phases.

Question 12 (Moon's rotation):
Once again, only 22.4% 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. 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 (46%) was that the Moon does not rotate on its axis.

Question 13 (Centre of universe):
Most students (73.7%) correctly answered that according to current theories the universe does not have a centre in space.

Conclusions

The findings reported above show that university students hold a series of misconceptions on several central topics in basic astronomy. Reducing misconceptions begins by revealing them. A discussion of widespread science misconceptions serves as a fruitful source of class discussion and provides an ideal opportunity for breaking up the standard lecture format (Laws 1997).

Classroom discussions can further be used to support students in creating a state of cognitive dissonance in which students evaluate their own conception relative to accepted scientific concepts (Strike and Posner 1985). Through this process, students may begin to construct a logical and coherent knowledge of science.

To further strengthen and extend this research, other assessment instruments such as clinical interviews may be of value. Additionally, further testing of larger samples may be needed.

Appendix. Questionnaire—The Earth and the universe

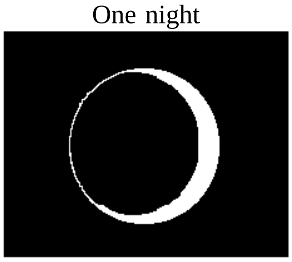
In the following a ✓ indicates a correct response.

1. What causes night and day?

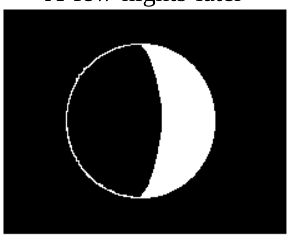
a. The Earth spins on its axis. ✓
b. The Earth moves around the Sun.
c. Clouds block out the Sun's light.
d. The Earth moves into and out of the Sun's shadow.
e. The Sun goes around the Earth.

2. The diagrams below 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. ✓

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 metres.
c. 3 metres.
d. 7.5 metres.
e. 30 metres. ✓

4. As seen from your home [Haifa], 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 autumn).
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 further 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. Which of the following lists shows a sequence of objects that are closest to the Earth to those that are furthest away?

a. Moon $\longrightarrow$ Pluto $\longrightarrow$ stars. ✓
b. Moon $\longrightarrow$ stars $\longrightarrow$ Pluto.
c. Pluto $\longrightarrow$ stars $\longrightarrow$ Moon.
d. Stars $\longrightarrow$ Pluto $\longrightarrow$ Moon.

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 in 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.

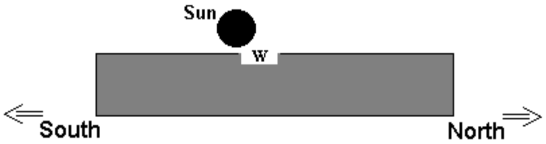
15. When is the longest daylight period in Australia?

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 metre.
b. 1 metre.
c. 100 metres.
d. 1.5 kilometre.
e. 150 kilometres. ✓

17. The diagram below shows the position along the horizon of the Sun just about to set during the autumn 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 $\frac{1}{2}$ degree. The angular diameter is proportional to the ratio of the actual diameter to distance. Imagine that you observed the Sun from Saturn, which is about 10 times further 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 degree. ✓
c. 1/40 degree.
d. 1/200 degree.

19. As you face directly east, where is the rising Sun on 21 June 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.

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