Science and Nonscience Students' Ideas about Basic Astronomy Concepts in Preservice Training for Elemantary School Teachers

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Abstract

A 14-item questionnaire was given to 100 students in preservice training to become primary and secondary education faculty. Results showed that science and non-science majors held a series of misconceptions about several basic topics central to astronomy. The changes in astronomy misconceptions were analyzed by means of a written questionnaire completed by the students at the beginning of the semester and again at the end. Results were interpreted through comparison with the literature. In this study, some misconceptions were easy to change, even with limited instructional effort, and some were very difficult to change despite rigorous, focused instruction on basic astronomy and the universe. Results and the reasons are discussed according to the *gain index*, the actual percentage gain over the possible percentage gain.

1. INTRODUCTION

Astronomy is the oldest of the sciences, and its mysteries have been an area of great curiosity for mankind since ancient times. Since time immemorial, people have asked many questions of nature, trying to understand its answers. Questions about astronomy have played an important role in the development of science. The societies that are aware of this have begun to assess their knowledge and whether it is scientific. In this area, much work has been done all over the world during the last 20 years (Baxter 1989; Jones, Lynch, & Reesink 1987; Bailey & Slater 2004; Kikas 1998; Klein 1982; Lightman & Sadler 1988, 1993; Nussbaum 1979; Nussbaum & Novak 1976; Sadler 1992, 1998, 2001, 2002; Sharp 1996; Slater et al. 2001; Slater, Carpenter, & Safko 1996; Sneider & Pulos 1983; Trumper 2000, 2001a, 2001b, 2001c;

Vosniadou & Brewer 1994; Zeilik, Schau, & Mattern 1998).

Such research has appeared in reports from the United States (American Association for the Advancement of Science 1993; National Research Council 1996), Australia (Department of Employment, Education, and Training 1989), Canada (Orpwood & Souque 1985), Israel (Tomorrow 98, 1992), Italy (Borghi, De Ambrosis, & Massara 1991), and the United Kingdom (Secretary of State for Education and Science 1983). Finally, Bailey and Slater (2004) categorized and summarized astronomy education research literature, and their article has over 100 references to articles, books, and Web-based materials. As a result of these studies, the education systems of many countries have been restructured, and subjects related to astronomy have been added to the curricula at the primary school, high school, and university levels.

Zeilik et al. (1998) investigated the conceptions of science and non-science majors according to *gain index* on several physical and astronomical concepts. The basic results were 40% for the pretest mean, and 60% for the posttest mean; the gain index mean was 0.48. In 1994, Bisard et al.

> 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. 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. (38)

In Sadler's (1992) study with 1,414 high school students, the mean pretest score was 34%. Fifty-one student misconceptions were revealed by the test, 19 of which were preferred by students to the correct answer. In this study, the change in astronomy misconceptions was analyzed by means of administering to students a written questionnaire about basic astronomy concepts at the beginning of the semester (a pretest) and again at the end (posttest).

2. RESEARCH METHOD AND FINDINGS

2.1 Overall Characteristics of the Sample

Participants for this study were drawn from one of the largest education departments in Turkey, which conducts preservice training programs for future primary and secondary education teachers. Of the 120 students originally enrolled in the astronomy course, 100 took the pretest and the posttest; all were included in our analysis. A student background survey indicated that 50% of students were science majors and 50% were non-science majors. The class included 49 females and 51 males. Regarding their education background in astronomy, only 12% of the students had taken an introductory astronomy course in their second training year in the faculty. In the Education Faculty, the astronomy course was an elective for all students. Classes met only once a week for three hours. Before it was restructured, the class had a very effective audiovisual orientation. Course attendance averaged about 70% during the semester. Course topics were history of astronomy, cosmic distances, the space coordinate system, fundamental physics law for astronomy, Big Bang theory, galaxy, stars, Solar System, Earth, Moon, and current events related to astronomy. The methods of the lesson were expository teaching and discussion. The students watched the BBC documentary film *Space* for 30 minutes a week for six weeks and discussed it as it related to the

current subjects. The students also watched and discussed the DVD *The Universe* (by the Istanbul University astronomy department) for 14 weeks. In addition, students observed the Sun, the Moon, planets (Jupiter, Saturn, and their satellites), and stars over a two-week period. They used a Meade 14 LX200GPS Schmidt-Cassegrain telescope at the Department of Education at Ondokuz Mayis University.

2.2 Astronomy Diagnostic Test and Findings

In this study, we investigated students' misconceptions about astronomy concepts. These misconceptions were analyzed by means of a written questionnaire presented to students at the beginning of the semester (pretest), and again at the end (posttest). The questionnaire consisted of 14 questions taken from three different sources: Bisard et al. (1994), Trumper (2001c), and Zeilik et al. (1998). The questions are given in the appendix. Some are Astronomy Diagnostic Test (ADT) questions, with little or no modification, that were deemed appropriate for the course and geographical conditions in Samsun, Turkey (Deming 2002; Hufnagel 2002). These questions were not specifically discussed in class during the semester, and solutions were not posted.

As shown in Table 1, the mean for the overall correct response rate on the pretest was 38%, and the posttest mean was 56%. These results are very similar to those obtained by Zeilik et al. (1998) among university students for the pretest (40% correct) but poorer for the posttest (69% correct). Males scored significantly better than females on the pretest (61% vs. 47.4%) and the posttest (52% vs. 41.2%). Pretest and posttest results can be compared using a normalized gain index, $<g>$, the ratio of the actual average student gain to the maximum possible average gain: $<g> = (post\% - pre\%) / (100 - pre\%)$, reported by Zeilik, Schau, and Mattern (1999). Gain index values can range from 0 (no gain achieved) to 1 (all possible gain achieved). Our mean gain was a respectable 0.30 (Table 1). In a similar study conducted with the university students, Zeilik et al. (1998) reported a gain of 0.48.

Table 1. Correct answer ratio and gain index values ($<g>$) according to pretest and posttest results for science and nonscience students.

Item	SCIENCE			NONSCIENCE			SCIENCE & NONSCIENCE		
	Pretest	Posttest	Gain	Pretest	Posttest	Gain	Pretest	Posttest	Gain
	% correct	% correct	$<g>$	% correct	% correct	$<g>$	% correct	% correct	$<g>$
	N = 50	N = 50		N = 50	N = 50		N = 100	N = 100	
1. Day-night cycle	90	92	0.20	92	94	0.25	91	93	0.22

2. Moon phases	20	30	0.13	26	30	0.05	23	30	0.09
3. Dimensions and distance	8	10	0.02	28	34	0.08	18	22	0.05
4. Sun overhead at noon	16	32	0.19	42	46	0.07	29	39	0.14
5. Earth dimensions	8	16	0.09	2	12	0.10	5	14	0.09
6. Seasons	50	88	0.76	58	76	0.43	54	82	0.61
7. Relative distances	38	70	0,52	54	72	0,39	46	71	0.46
8. Moon's revolution	40	54	0.23	58	66	0.19	49	60	0.22
9. Moon's revolution	50	80	0.60	72	74	0.07	61	77	0.41
10. Time zones	40	50	0.17	52	70	0.38	46	60	0.26
11. Solar eclipse	26	46	0.27	26	38	0.16	26	42	0.22
12. Moon's rotation	14	30	0.19	12	26	0.16	13	28	0.17
13. Center of the universe	66	89	0.68	64	87	0.64	65	88	0.66
14. Seasons	58	88	0.71	76	88	0.50	67	88	0.64
Mean	**34**	**55**	**0.34**	**44**	**57**	**0.25**	**38**	**56**	**0.30**

2.3 Question-by-Question Analysis

Question 1 (day-night cycle): Most students (91% pretest and 93% posttest) answered this question correctly, indicating that the cause of the day-night cycle is the Earth spinning on its axis. These are much higher scores than those obtained in two studies, one involving university students in preservice training to become high school teachers (52% correct on the pretest; Trumper 2001a), and the other involving university students more generally (62% correct on the pretest; Trumper 2000). When compared with the literature, the higher scores may be due to this subject being covered repeatedly in primary school and high school in Turkey. However, gain index value is $<g> = 0.22$.

Question 2 (Moon phases): Only 23% of students answered this question correctly on the pretest, and 30% answered correctly on the posttest, choosing as their best answer that the Moon moving around the Earth accounts for the change in the Moon's phases. This was one of the weakest areas of students' prior knowledge. This is a poor result when compared with the university students in Zeilik et al.'s (1998) report, who had scores of 31% correct on the pretest and 66% correct on the posttest. The Moon phases concept was very resistant to change during the course, and a large number of students misunderstood the role of the Earth and the Sun in the Moon's phases. Thirty-four percent of the students believed that the Earth is involved in producing lunar phases through its shadow, obscuring portions of the Moon; 16% believed that the Moon moves into the Sun's shadow; and 21% believed that the Moon moves into the Earth's shadow. This means that the largest proportion of students have some confusion between a lunar eclipse and the Moon's phases. Gain index value is $<g> = 0.09$ for this study. For the second question, Zeilik et al. (1998) reported $<g> = 0.32$.

Questions 3 and 5 (Dimensions and distances): This too was one of the weakest areas of student knowledge. Only 18% of students taking the pretest and 22% of students taking the posttest gave the correct answer to Question 3, about the distance between the Sun and the Earth. And only 5% of students taking the pretest and 14% of students taking the posttest gave the correct answer for Question 5, about the Earth's diameter. These results are poorer than the results of Trumper's (2000) study about the distance between the Sun and the Earth (35.5% correct on the pretest) and the Earth diameter (31.6% correct on the pretest). The students are very resistant to change because they have some misconceptions about the size concept in astronomy. Our gain index value is $<g> = 0.05$ for Question 3 and $<g> = 0.09$ for Question 5.

Question 4 (Sun overhead at noon): Only 29% of students taking the pretest and 39% of students taking the posttest answered correctly that in Turkey's latitude, north of the Tropic of Cancer, the Sun is never directly overhead at noon. The largest percentage of students—37% on the pretest—believed that it is directly overhead every day. Maybe this arises from the everyday meaning of "noon" ("the middle of the day"; Trumper 2000). This is a poorer result than that obtained by Trumper with university students (32.9% on the pretest) and quite different from that reported by Zeilik et al. (1998) with university students (23% correct on the pretest and 64% correct on the posttest). Our gain index value is $<g> = 0.14$.

Questions 6 and 14 (Seasons): Most of the students—67% on the pretest and 88% on the posttest—answered Question 14 correctly, indicating that the cause of the different seasons we experience each year is the tilt of the Earth's axis relative to the plane of its orbit as it revolves around the Sun. However, 19% of students on the pretest and 9% of students on the posttest chose the varying distance between the Sun and the Earth as a reason for seasonal changes. The largest proportion of students—54% on the pretest and 82% on the posttest—chose the correct answer for Question 6; students gave the same argument as for Question 14, which asked for the main reason why it is hotter in the summer than in the

winter. Gain index values are $<g> = 0.61$ for Question 6 and $<g> = 0.64$ for Question 14.

Question 7 (Relative distances of spatial objects from Earth): Almost half of the students (46%) answered Question 7 correctly on the pretest, positioning the Moon as the closest object to the Earth and the stars as the objects farthest from Earth, with Pluto between them. This result is very similar to that obtained by Trumper (2001a). However, the largest proportion of the students (71%) answered this question correctly on the posttest. On the pretest, 40% of the students put Pluto behind the stars; this percentage became 17% for the posttest. This result shows that many students were guided in their answers by seeing the stars every night, not realizing that they may be larger or brighter, but thinking that they are farther away (Trumper 2001c). This is a poorer performance than that reported by Trumper (2000) in his study with university students. Our gain index value is $<g> = 0.46$ for this question.

Questions 8 and 9 (Moon's revolution): Most students—49% on the pretest and 60% on the posttest—chose the correct answer of a month for how long it takes the Moon to revolve around the Earth, and a year for the Moon to go around the Sun (61% pretest and 77% posttest). This is a poorer performance than that reported by Trumper (2000, 2001a) in their studies with university students. Gain index values are $<g> = 0.22$ for Question 8 and $<g> = 0.41$ for Question 9.

Questions 10 and 11 (Time zones): Almost 46% of students on the pretest and 60% of students on the posttest answered Question 10 correctly, choosing their best answer that when it is noon in Samsun, it is about sunset in Beijing. This is a somewhat better result than that obtained by Trumper (2001a) (39%) and very similar to that obtained by Trumper (2000) (49%) with university students. Gain index value is $<g> = 0.26$. Question 11 (Solar eclipse): Only 26% of students on the pretest and 42% of students on the posttest answered correctly that to have a total solar eclipse, the Moon must be in its new phase. A slightly better result was reported for this question in the Trumper 2000 (22.4% correct) and Trumper 2001a (19% correct) studies for the pretest. However, our results represent a poorer performance than that reported by Zeilik et al. (1998) with university students (28% pretest and 83% posttest). The answer chosen by the majority of students (54%) was that the Moon must be in its full phase to have a total solar eclipse. The answer (Moon must be in its full phase) chosen by the great proportion of students indicated that most students confused the Moon's phases with a solar eclipse. Gain index value is $<g> = 0.22$. For Question 11, Zeilik et al. (1998) reported $<g> = 0.76$.

Question 12 (Moon's rotation): This was another weak area of student knowledge. Only 13% of students on the pretest and 28% of students on the posttest chose the correct answer, indicating that we always see the same side of the Moon from the Earth, implying that the Moon rotates on its axis once a month. Much poorer results were reported in the Trumper studies (22.4% in Trumper 2000 and 23% in Trumper 2001a) for the pretest. Gain index value is $<g> = 0.17$; Zeilik et al. (1998) reported $<g> = 0.32$.

Question 13 (Center of the universe): Almost 65% of students taking the pretest and 88% of students taking the posttest correctly answered that according to current theories, the universe does not have a center in space. Ten percent chose the Sun, 3% chose the Earth, and 12% chose the Milky Way galaxy as being at the center of the universe. Trumper (2000) reported a better result (73.7%) with university students on the pretest. Gain index value is $<g> = 0.66$.

3. CONCLUSIONS

The findings presented in this study show that there is a serious discrepancy between education students' conceptions of some basic astronomy concepts and the corresponding accepted scientific views. Our study is very similar to the study by Percy et al. (1999). In general, students enter courses with prior knowledge of the subject area. Unfortunately, these naïve notions often are misconceptions or "folk concepts" that hinder learning of appropriate concepts in the field (Zeilik et al. 1998). Our expectations were that pretest and posttest scores would be close to the results of other studies in this area, but the outcomes surprised us for some questions. There was a significant difference between the proportion of students responding correctly and incorrectly to some questions. In particular, Questions 2, 3, 4, 5, 11, and 12 have lower pretest scores compared with those reported by Zeilik et al. (1998) and Trumper (2000, 2001a, 2001b, 2001c). These results show that science and non-science students in preservice training to become primary and secondary education teachers hold a series of misconceptions on several topics central to basic astronomy. In addition, we found it very disheartening that Questions 1, 2, 3, 4, 5, 8, 10, 11, and 12 showed such small gains, which indicates that some misconceptions are so deeply rooted that even rigorous instruction does not produce significant gains over a semester. However, Questions 6, 13, and 14 showed significant gains. We can say that some misconceptions are easy to change, even with limited instructional effort, and some are very hard to change, even with highly focused instruction. In this area, educational strategies play a crucial role in the learning process. In particular, astronomy teaching can efficiently use the constructivist approach: direct experiences and observations, representative-symbolic language, organized knowledge, and formal strategies are directly applicable (Trumper 2001a).

What can we infer from these results? The first step in reducing students' misconceptions is to ascertain their ideas about astronomy and science concepts (Trumper 2001a). Second, classroom discussions can be further used to support students in creating a state of cognitive dissonance in which they evaluate their own conceptions relative to accepted scientific concepts (Strike & Posner 1985). Third, standards for both teaching and learning science must take into account recent research into constructivist theory and its implementation in the classroom (Radford 1998). Through this process, students may begin to construct a logical and coherent understanding of science (Trumper 2000).

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APPENDIX

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