Science Education International
Vol. 26, Issue 2, 2015, 148-165

Using a Two-tier Test to Analyse Students' and Teachers' Alternative Concepts in Astronomy

U. KANLI*

ABSTRACT: This paper presents an analysis of physics teachers' as well as university and high school students' understanding of some astronomy concepts. In recent years, the significance of astronomy teaching in science education has gradually increased. Many research studies indicate that students have misconceptions about the reasons for seasons, the Moon's phases, the Moon's phase in the solar eclipse and the Sun's position. Nevertheless, there have not been many studies reported, which measure students' and especially teachers' beliefs, experiences and understanding and their misconceptions regarding comets, shooting stars, star orbits, astrology, sunspots, and source of solar energy. This is the first aim of the paper. The second is to emphasize the inadequacy of multiple-choice tests, which are commonly used to determine the conceptual understanding and achievement using multi-tier tests such as two-tier tests. To achieve these aims, this study analyses and compares the alternative conceptions of high school and university students, and physics teachers concerning some astronomy subjects. An Astronomy Concept Test (ACT), consisting of two-tier items, was administered to high school students (n=176), university students (n=208), and physics teachers (n=174). The results showed that students' and teachers' test scores are quite low. Besides, participants (even teachers) showed limited understanding of comets, shooting stars, astrology, movement of stars, sunspots, solar energy, moon rotate, and solar and lunar eclipses.

KEY WORDS: Astronomy concepts, alternative conceptions, misconceptions, two-tier test, physics teachers.

INTRODUCTION

Astronomy, recognized as the most ancient science discipline, is one of the most popular science branches within science and technology. Astronomy concepts (for instance, black holes, dual-star system, meteor streams, solar eclipses, moon eclipses, and supernova explosions) attract every member of society, especially the youth. Advances in astronomy have also made contributions to other natural sciences (such as physics, chemistry, and

* Corresponding Author: Gazi University, Faculty of Gazi Education, Department of Physics Teaching Programme, TURKEY, E-mail: ukanli@gazi.edu.tr, Phone: +90 (312) 202 80 23

geology). The community's interest in astronomy and astronomy's close ties with other science disciplines have contributed to the popularity and significance of astronomy in science and physics education.

Astronomy is a science discipline about which individuals have gathered information through their personal experiences with nature since their childhood (Hannust & Kikas, 2006). However, this information acquired through personal experience often contradicts with scientific explanations (for example, the Sun appears as if it rotates around the Earth; the Earth seems to have a plane surface instead of being a sphere, etc.). Students come to university science classes with these naïve and unscientific concepts, though they seem meaningful to the students (Trundle, Atwood & Christopher, 2002). Some of these alternative and unscientific conceptions do not change with age and it is not possible to dismiss them in science classes (Atwood & Atwood, 1997).

Astronomy is an important subject for the science curriculum because it provides a useful alternative to the experimental mode in the scientific method and literacy (Timberlake, 2011). Also, it can be used to show many concepts of physics: gravitation and relativity, and light and spectra. In a geography course, it provides obvious examples of comparative planetology, the observational mode, and the use of simulation and modeling in science (Percy, 2006). In recent years, the teaching of astronomy has become quite important for teaching science. Therefore, it is important to identify the thoughts, beliefs, and understanding of students and even teachers about basic astronomy concepts.

LITERATURE REVIEW

Misconceptions about Astronomy

There are numerous studies in astronomy education that identify alternative conceptions of high school students, university students, and pre-service teachers from different age groups and cultures. All such studies conclude that there is a certain level of misconception concerning basic astronomy concepts among:

- children (Barnett, 2002; Baxter, 1989; Hannust & Kikas, 2007; Vosnidou & Brewer, 1992);
- elementary/middle school students (Stover & Saunders, 2000; Trundle, Atwood & Christopher, 2007; Vosnidou, Skopeliti & Ikospentaki, 2004);
- high school students (Sadler, 1992; Trumper, 2001a; 2001b; 2001c);
- university students (Kanli, 2014; Trumper, 2000; Wallace, 2011; Zeilik, et al. 1997; Zeilik, Schau & Mattern, 1998), and

- even among pre-service teachers (Abell, Martini & George, 2001; Atwood & Atwood, 1995; Atwood & Atwood, 1996, 1997; Frede, 2006; Kanli, 2014; Küçüközer, 2007; Trumper, 2003; 2006; Trundle, Atwood & Christopher, 2002; 2006).

The results of some previous studies are summarized in Appendix 1. When this table is examined, it can be seen that there are misconceptions among students and pre-service teachers about reasons for the occurrence of night-day, reasons for seasons, phases of the moon and its phases, position of the sun in the sky, etc. The number of studies, which measure knowledge levels of teachers about core astronomy concepts, is quite limited (Bailey & Slater, 2004; Kanli, 2014; Summers & Mant, 1995). Also, teachers as well as students and pre-service teachers have misconceptions about basic astronomy concepts. For example, Brusnell and Marck (2005) working with primary and secondary school teachers show that:

i) The majority of teachers are not aware of the distance between the Moon and the Earth (many respondents do not know about the proportional view concerning the solar system like the distances between the stars which can be observed today).
ii) Teachers hold several misconceptions concerning the movement of the Moon and the Earth.

A large number of teachers could not combine rotation and orbit concepts with the sky objects and sky observations. In another study, Summers and Mant (1995) showed the difference in the understanding of teachers regarding scientific explanations of night and day occurrence, the moon's phases and the seasons. The study revealed that teachers found most of these concepts confusing. Kanli (2014) stated that the high school physics teachers have numerous misconceptions about the reasons for seasons, the Sun's position, the Moon's phases, and the Moon's phase in a solar eclipse.

Multi-tier Test to Identify Misconceptions

As it is the same as in other disciplines such as physics, chemistry, and biology, multiple-choice tests are usually used in the measurement of alternative conceptions and misconceptions in astronomy subjects because of several advantages (Appendix 1). Although there are many advantages of using multiple-choice tests such as they can be administered to a greater number of students and results can be evaluated in a comparably shorter time than open-ended questionnaires, there are problems about the effectiveness of multiple-choice tests in accurately measuring the target concept (Kaltakçı & Eryilmaz, 2010). Since students' answers cannot be explored and analyzed deeply, responses to multiple-choice tests offer limited value to researchers (Rollnick & Mahooana, 1999, as cited in Kutluay, 2005). Furthermore, because one cannot follow up with the students' answers, students' misconceptions may be the result of lack of knowledge, carelessness, and chance factor or error (Hasan, Bagayokoz & Kelleyz, 1999; Peşman & Eryilmaz, 2010). Thus, recently two-tier and three-tier tests have been used in the determination of misconceptions. While the first tier of two-tier tests involves a multiple-choice question about the concept, the second tier involves a question about the reason for the answer to the first tier question (Chandrasegaran et. al. 2007; Griffard & Wandersee, 2001; Treagust, 1986; Haslam & Treagust, 1987). In three-tier tests, on the other hand, the student is asked about whether she/he is sure about the answers in the third tier in addition to questions in the two-tier test. Thus, the most accurate percentage to reflect the misconception of the student is provided by three-tier tests. If the student marks the wrong answer with a misconception in the first tier, and explains this wrong answer with reasons as if it is right and tells that she/he is sure about her/his answers in the last tier, then the student can be said to have a misconception about it (Eryilmaz, 2010; Arslan, Cigdemoglu & Moseley, 2012). Similarly, if in the first-tier, students select the correct answer, in the second tier, they make a correct explanation, and in the third tier, if they are sure about the answers given in the first two tiers, students are considered as successful.

Based on these reasons, the present study measures alternative conceptions of high school and university students as well as physics teachers in basic astronomy subjects. Moreover, apart from the astronomy subjects and concepts exhibited on Appendix 1, this study contributes to the literature regarding alternative conceptions of participants about *comets, shooting stars, star orbits, astrology, sunspots, and source of solar energy.* Furthermore, by means of the astronomy test applied in two tiers, it aims to measure both success and alternative conceptions of participants accurately. Thus, it becomes possible to determine whether given answers are the result of lack of knowledge or not.

METHODOLOGY

Sample

The population of this study consisted of high school students, physics and pre-service science teachers and physics teachers. The sample was selected from this population through a convenient sampling method. The sample of the study consisted of 176 senior students from two high schools (12^{th} graders), 208 university students from the department of physics education and science education of a state university, and 174 physics teachers in Turkey. Students and teachers participated in this study voluntarily.

Research Instruments

A multiple-choice Astronomy Concept Test (ACT), a 16-question instrument that had been developed by Orbay and Gökdere (2006), was administered to the participants as a two-tier test. As shown in the following sample questions, the test was only used as only a two-tier test, since the ACT was a conceptual test and the choices in each question were reasons. In the first tier, the concept was asked through multiple choice questions. In the second tier, respondents asked to what extent they were sure about their answers which they gave in the first-tier. In this second tier, respondents were given two choices; namely, "I am sure" and "I am not sure" (Figure 1).

Sample Question-1

1.1. Is comet a star?

a) This is star with a structural tail.
b) This is a light beam reflected from other stars and scattered into deep space.
c) These are bright celestial bodies, which seems bright because of melting of the substances in the core ice structure when it comes close to the sun.
d) These are the stars, which occur as a result of fragmenting of meteors, while they are passing by the earth's atmosphere.

1.2. Are you sure about your answers

A. Yes, I am sure.
B. No, I am not sure.

Sample Question-2

1.1. Is Astrology a science discipline?

a) This is a subsidiary branch of astronomy.
b) Astrology is not a science discipline.
c) This is a science, which makes scientific estimations regarding the future.
d) It has a scientific foundation; it interprets horoscopes based on position of stars.

1.2. Are you sure about your answers

A. Yes, I am sure.
B. No, I am not sure.

Figure 1 Sample Questions from the Astronomy Concept Test (ACT)

Reliability and Validity of the ACT

The reliability and validity of ACT were performed according to the rate of success. The reliability of the test was determined through calculation of the KR-20 coefficient for one-tier scores. In determination of construct validity of the test, the correlation between the correct answers given in the first tier and the respondents' confidence level about their answers in the first tier were taken into consideration. The construct of the test could be considered valid when the correlation was positive between the two tiers (Çataloğlu, 2002; Kirbulut & Geban, 2014; Kutluay, 2005). The reliability and validity coefficients of the ACT were as summarized in Table 1.

Table 1 Reliability and validity coefficients of the ACT

Group	N	KR-20	Validity (r)
High School Students	176	.62	.60
University Students	208	.65	.66
Physics Teachers	174	.78	.87

While the KR-20 values of students' tests are close to .70, the reliability coefficient of teachers' ACT is above .70. When the KR-20 value is .70 and above, this is acceptable for the reliability of the test (Fraenkel, Wallen & Hyun, 2012). However, as distinct from success or achievement tests, the reliability coefficients are lower in conceptual or misconception tests (Eryılmaz, 2010). Kaltakçı (2012) state that the reliability coefficient of .60 or higher usually can be consider as good. Since the KR-20 values calculated in this study are above .60, the ACT can be accepted as reliable for all groups. On the other hand, the Pearson correlation coefficient (r) is close to 1 shows that the test has a high construct validity (Cohen, 1988), which means that participants who gave the right answers in the first two tiers of the test had high confidence levels, whereas participants who gave wrong answers had lower confidence levels.

FINDINGS

Test Scores of Students and Physics Teachers

In our analyses of the ACT data, when (1-1) coding is obtained, as a result of selection of the correct choice in the first tier (1) and then selection of the "I am sure" choice in the second tier (1), students and teachers are considered successful in this question. Accordingly, when similar coding is applied to all of the 16 questions, the highest score is 16, whereas the lowest score is 0. Two-tier based success percentages of high school students and teachers are given Table 2.

Table 2 Test scores of participants according to first and two-tier test.

		One-Tier				Two-Tier				
Group	**N**	**Min**	**Max**	**χ**	**% of success (a)**	**Min**	**Max**	**χ**	**% of success (b)**	*b-a*
High School Students	176	0	8	4.3	26.9	0	7	2.1	12.8	14.1
University Students	208	0	15	7.3	45.4	0	13	4.1	24.9	20.5
Physics Teachers	174	0	16	8.6	54.1	0	16	6.9	49.6	4.5

b-a: The difference between the percentages of success

When Table 2 is examined, it can be seen that the high school students' test scores are very low and university students' and physics teachers' percentages of success are close to 50% in the first-tier. When the scores are evaluated based on two-tiers, it can be seen that participants' success levels fall between 4.5% and 20.5%. This result indicates that students and teachers selected the correct answers; however, they are not sure about the answers they have given. Also, it can be said that multiple-choice items are poor tools for measuring achievement.

While analyzing the data obtained from the ACT to determine the alternative conceptions, the wrong answer that was the misconception was marked in the first tier was coded (0); if participants stated that they were sure about their answers and coded (1), the question was coded as 0-1, and was accepted as an alternative misconception. Percentages of students and teachers regarding their some alternative concepts were as summarized in Table 3. Based on the data in Table 3, it could be said that students and even physics teachers had alternative conceptions about basic astronomy concepts. Also, the percentages of alternative conceptions that were measured with the two-tier items in all subjects were lower than the percentages of alternative conceptions that were measured only according to the first tier when Table 3 was examined. This condition was caused by lack of knowledge among students and physics teachers.

Table 3 Distribution of the Percentage of Alternative Conceptions of Participants

Subject	**Alternative Conceptions**	**High School Students** One-Tier %	**High School Students** Two-Tier %	**University Students** One-Tier %	**University Students** Two-Tier %	**Physics Teachers** One-Tier %	**Physics Teachers** Two-Tier %
Comet	The comet is a star.	45	19*	43	12*	29	16*
Shooting star	The shooting star is a movement of a star.	44	25*	34	8	16	7
Astrology	Astrology is a science discipline.	79	42*	78	32*	53	27*
Stars	Stars do not move.	22	9	25	8	10	6
	Unlike planets, stars do not rotate around their axis.	26	12*	34	13*	14	10*
Moon's same side	The Moon does not rotate on its axis.	54	32*	50	24*	17	7
Sun's energy come from…	The breaking apart of heavy elements into lighter ones.	33	11*	57	20*	23	15*
	Heat left over from the Big Bang.	38	17*	18	5	3	1
Sunspots	Sunspots are the places where nuclear reactions take place exactly.	25	9	26	6	31	15*
Moon and Solar eclipses	While the lunar eclipse can be observed from everywhere at night, the solar eclipse can only be observed from a certain belt on the earth.	28	8	34	8	36	12*
	For a certain geographical region, the solar eclipse always takes longer than the lunar eclipse.	35	8	38	10*	37	18*

In accordance with the data in Table 3, Table 4 summarizes that more than 10% of students and teachers have alternative conceptions based on two tiers.

Table 4 Alternative conceptions held by more than 10% of participants based on two tiers.

High School Students	University Students	Physics teachers
• The comet is a star (19%). • A shooting star is a movement of a star (25%). • Astrology is a science discipline (42%) • Stars do not rotate around their axis (12%) • The Moon does not rotate on its axis (32%). • The Sun's energy come from the breaking apart of heavy elements into lighter ones (11%) • The Sun's energy come from the heat left over from the Big Bang (17%).	• The Comet is a star (12%). • Astrology is a science discipline (32%) • Stars do not rotate around their axis (13%) • The Moon does not rotate on its axis (24%). • The Sun's energy come from the breaking apart of heavy elements into lighter ones (20%). • For a certain geographical region, the solar eclipse always takes longer than the lunar eclipse (10%).	• The Comet is a star (16%). • Astrology a science discipline (27%) • Stars do not rotate around their axis (10%) • The Sun's energy come from the breaking apart of heavy elements into lighter ones (15%). • Sunspots are the places where nuclear reactions take place exactly (15%). • While the lunar eclipse can be observed from everywhere at night, the solar eclipse can only be observed from a certain belt on the earth (12%) • For a certain geographical region, the solar eclipse always takes longer than the lunar eclipse (18%).

DISCUSSION AND CONCLUSION

Results of the present study can be summarized based on two essential points:

First, this study revealed that physics teachers as well as students have remarkable misunderstandings in basic astronomy subjects; for instance, comets, astrology, sunspots, solar power, and eclipses. Based on the data exhibited in Table 4, it can be said that students and even teachers have following alternative conceptions based on two tiers:

- The comet is a star *(students and teachers).*
- A shooting star is a movement of a star (*only high school students*).
- Astrology is a science discipline *(students and teachers).*
- Stars do not rotate around their axis *(students and teachers).*
- The Moon does not rotate on its axis *(high school and university students).*
- The Sun's energy come from the breaking apart of heavy elements into lighter ones *(students and teachers).*
- The Sun's energy come from the heat left over from the Big Bang *(only high school students).*
- For a certain geographical region, the solar eclipse always takes longer than the lunar eclipse *(university students and teachers).*
- Sunspots are the places where nuclear reactions take place exactly *(only teachers).*
- While the lunar eclipse can be observed from everywhere at night, the solar eclipse can only be observed from a certain belt on the earth *(only teachers).*

These results are similar to previously studies indicating that teachers may have misconceptions or alternative conceptions about some astronomy concepts (Bailey & Slater, 2004; Kanli, 2014; Summers & Mant, 1995). Hashweh (1987) reports that teachers sometimes have the same misconceptions that their students hold (as cited in Arslan, Cigdemoglu & Moseley, 2012). Besides, teachers play an important role in removing the misconceptions of students. Since teachers have positive effects on remedying their students' misconceptions, special attention must be paid to the astronomy education of pre-service and in-service teachers.

Second, this study sets an example for the literature in terms of using the multi-tier tests in eliminating the disadvantages of multiple-choice tests that are used in determining the alternative conceptions in astronomy. When the two tiers tests are taken into consideration, a significant decrease is observed in both percentages of correct answers and wrong answers. In terms of correct answer percentages (Table 2), while high school students exhibit a 14.1% decrease, university students exhibit 20.5%, and physics teachers exhibit a 4.5% decrease. A similar situation exists in the erroneous choices where there is referral to alternative conceptions (Table 3). That is, students and teachers are not sure about their answers. This situation can be a result of lack of knowledge, carelessness, mischance or an error (Arslan, Cigdemoglu & Moseley, 2012; Chandrasegaran et. al. 2007; Eryilmaz, 2010; Griffard & Wandersee, 2001; Hasan, et al. 1999). In addition, the results of the present study are similar to a previous study in revealing the inadequacy of multiple-choice tests about astronomy concepts (Kanli, 2014).

It is very important to accurately determine the misconceptions in astronomy education just like in other disciplines. Though multiple choice tests have many advantages, such as they can be administered to a great number of students simultaneously and test results can be analyzed in a short time, there are some issues with effectiveness of multiple choice tests in measuring students' and teachers' conceptual understanding. Hence, a multi-tier test must be administered if we want to make more accurate assessments in determination of misconceptions and in measurement of success.

REFERENCES

Abell, S., Martini, M. & George, M. (2001). That's what scientists have to do: pre-service elementary teachers' conceptions of the nature of science during a moon ınvestigation. *International Journal of Science Education*, *23*(11), 1095-1109. doi: 10.1080/09500690010025049

Arslan, H. Ö., Çigdemoğlu, C. & Moseley, C. (2012). A three tier diagnostic test to assess pre-service teachers' misconceptions about global warming, greenhouse effect, ozone layer depletion, and acid rain. *International Journal of Science Education*, *34*(11), 1667-1686. doi: 10.1080/09500693.2012.680618

Atwood, V. A. & Atwood, R. K. (1995). Pre-service elementary teachers' conceptions of what causes night and day. *School Science and Mathematics*, *95*, 290.

Atwood, R. K. & Atwood, V. A. (1996). Pre-service elementary teachers' conceptions of the causes of seasons. *Journal of Research in Science Teaching*, *33*(5), 553-563.

Atwood, R. K. & Atwood, V. A. (1997). Effects of instruction on pre-service elementary teachers' conceptions of the causes of night and day and the seasons. *Journal of Science Teacher Education*, *8*(1), 1–13.

Bailey, M. J. & Slater, T. F. (2004). A Review of Astronomy Education Research. *The Astronomy Education Review*, *2*(2), 20-45.

Barnett, M. & Morran, J. (2002). Addressing children's alternative frameworks of the moon's phases and eclipses. *International Journal of Science Education*, *24*(8), 859-879. doi: 10.1080/09500690110095276

Baxter, J. (1989). Children's understanding of familiar astronomical events. *International Journal of Science Education, 11*(5), 502-513. doi:10.1080/0950069890110503

Brunsell, E., & Marcks, J. (2005). Identifying a baseline for teachers' astronomy content knowledge. *Astronomy Education Review*, 2(3), 38-46.

Çataloğlu, E. (2002). *Development and validation of an achievement test in introductory quantum mechanics: The quantum mechanics visualization instrument*. Unpublished PhD Thesis, The Pennsylvania State University.

Chandrasegaran, A., Treagust, D. & Mocerino, M. (2007). The development of a two-tier multiple-choice diagnostic instrument for evaluating secondary school students' ability to describe and explain chemical reactions using multiple levels of representation. *Chemistry Education Research and Practice*, 2007, *8*(3), 293-307.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences (2nd edition).* Hillsdale, NJ: Lawrence Erlbaum Associates.

Eryilmaz, A. (2002). Effects of conceptual assignments and conceptual change discussions on students' misconceptions and achievement regarding force and motion. *Journal of Research in Science Teaching*, *39*(10), 1001-1015. doi: 10.1002/tea.10054

Eryilmaz, A. (2010). Development and application of three-tier heat and temperature test: Sample of bachelor and graduate students. *Eurasian Journal of Educational Research*, *40*, 53-76.

Fraenkel, J.R., Wallen, N.E. & Hyun, H.H. (2012). *How to design and evaluate research in education*. (Eighth edition). New York: Mograw-Hill Companies Inc.

Frede, V. (2006). Pre-service elementary teacher's conceptions about astronomy. *Advances in Space Research*, *38*, 2237–2246. doi:10.1016/j.asr.2006.02.017

Griffard, P. B. & Wandersee, J. H. (2001). The two-tier instrument on photosynthesis: what does it diagnose? *International Journal of Science Education*, *23*(10), 1039-1052.

Hannust, T. & Kikas, E. (2007). Children's knowledge of astronomy and its change in the course of learning. *Early Childhood Research Quarterly*, *22*, 89–104. doi:10.1016/j.ecresq.2006.11.001

Hasan, S., Bagayokoz, D. & Kelleyz, E. L. (1999). Misconceptions and the Certainty of Response Index (CRI). *Physics Education*, *34*(5), 294-299.

Haslam, F. & Treagust D. F. (1987). Diagnosing secondary students' misconceptions of photosynthesis and respiration in plants using a two-tier multiple choice instrument. *Journal of Biological Education*, *21*, 203–211.

Kaltakçı, D. (2012). *Development and Application of a Four-Tier Misconception Test to Assess Pre-Service Students' Misconceptions About Geometric Optics*. Unpublished Doctoral Thesis, Middle East Technical University, Institute of Educational Sciences, Ankara, Turkey.

Kaltakçı, D. & Eryilmaz, A. (2010). Identifying Pre-service Physics Teachers' Misconceptions with Three-Tier Tests. *GIREP-ICPE-MPTL Conference 2010 in Reims*, France.

Kanli, U. (2014). A Study on Identifying the Misconceptions of Pre-service and In-service Teachers about Basic Astronomy Concepts. *Eurasia Journal of Mathematics Science and Technology Education*, 10(5), 463-471., Doi: 10.12973/eurasia.2014.1120a

Kirbulut & Geban, (2014). Using Three-Tier Diagnostic Test to Assess Students' Misconceptions of States of Matter. *Eurasia Journal of Mathematics Science and Technology Education,* 2014, 10(5), 509-521., Doi: 10.12973/eurasia.2014.1128a

Kutluay, Y. (2005). *Diagnosis of eleventh grade students' misconceptions about geometric optic by a three-tier test*. Unpublished master thesis, Middle East Technical University, Ankara.

Küçüközer, H., (2007). Prospective science teachers' conceptions about astronomical subjects. *Science Education International*, *18*(2), 113-130.

Orbay, M., & Gökdere, M. (2006). The determination of pre-service science and elementary teachers' knowledge related to basic astronomy concepts. *7. National Science and Mathematics Congress*. 7-9 September, Gazi University, Ankara, Turkey.

Peşman, H. & Eryilmaz, A. (2010). Development of a three-tier test to assess misconceptions about simple electric circuits. *The Journal of Educational Research*, *103*, 208-222. doi: 10.1080/00220670903383002

Percy, J. R. (2006). Teaching Astronomy: Why and How? *The Journal of the American Association of Variable Star Observers (JAAVSO)*, *35*(1), 248-254.

Sadler, P. M. (1992). *The initial knowledge state of high school astronomy students.* Unpublished doctoral dissertation, Harvard University, Cambridge, MA.

Stover, S. & Saunders, G. (2000). Astronomical misconceptions and the effectiveness of science museums in promoting conceptual change. *Journal of Elementary Science Education*, *12*(1), 41-52.

Summers, M. & Mant, J. (1995) A survey of British primary school teachers' understanding og the Earth's place in the universe. *Educational Research*, *37*(1), 3-19.

Timberlake, T. (2011). Alan Hirshfeld: Astronomy Activity and Laboratory Manual. *Science & Education, 20*(3-4), 389-392. doi: 10.1007/s11191-010-9264-9

Treagust, D. F. (1986). Evaluating students' misconceptions by means of diagnostic multiple choice items. *Research in Science education*, *16*, 199-207.

Trumper, R. (2000). University students' conceptions of basic astronomy concepts. *Physics Education*, *35*(1), 9-15.

Trumper, R. (2001a). A cross-age study of junior high school students' conceptions of basic astronomy concepts. *International Journal of Science Education*, *23*(11), 1111-1123, 2001a. doi: 10.1080/0950069001002508 5

Trumper, R. (2001b). Across-age study of senior high school students' conceptions of basic astronomy concepts. *Research in Science and Technological Education*, *19*(1), 97-109. doi: 10.1080/0263514012004625 9

Trumper, R. (2001c). A cross-college age study of science and nonscience students' conceptions of basic astronomy concepts in pre-service training for high-school teachers. *Journal of Science Education and Technology*, *10*(2), 189-195.

Trumper, R. (2003). The need for change in elementary school teacher training-a cross-college age study of future teachers' conceptions of basic astronomy concepts. *Teaching and Teacher Education*, *19*, 309-323. doi:10.1016/S0742-051X(03)00017-9

Trumper, R. (2006). Teaching future teachers basic astronomy concepts–seasonal changes–at a time of reform in science education. *Journal of Research in Science Teaching*, *43* (9), 879-906. doi: 10.1002/tea.20138

Trundle, K. C., Atwood, R. K., & Christopher, J. E. (2002). Pre-service elementary teachers' conceptions of moon phases before and after instruction. *Journal of Research in Science Teaching*, *39*(7), 633. doi: 10.1002/tea.10039

Trundle, K. C., Atwood, R. K., & Christopher, J. E. (2006). Pre-service elementary teachers' knowledge of observable moon phases and pattern of change in phases. *Journal of Science Teacher Education*, *17*(2), 87-101. doi: 10.1007/s10972-006-9006-7

Trundle, K. C., Atwood, R. K., & Christopher, J. E. (2007). Fourth grade elementary students' conceptions of standards-based lunar concepts. *International Journal of Science Education*, *29*(5), 595-616. doi: 10.1080/09500690600779932

Vosniadou, S., & Brewer, W. F. (1992). Mental models of the earth: a study of conceptual change in childhood. *Cognitive Psychology*, *24*(4), 535-585.

Vosniadou, S., Skopeliti, I. & Ikospentaki K. (2004). Modes of knowing and ways of reasoning in elementary astronomy. *Cognitive Development*, *19*, 203-222. doi:10.1016/j.cogdev.2003.12.002

Wallace, C. S. (2011). *An investigation into introductory astronomy students' difficulties with cosmology, and the development, validation, and efficacy of a new suite of cosmology lecture tutorial*. Unpublished doctoral thesis. Faculty of the Graduate School of the University of Colorado, Department of Astrophysical and Planetary Sciences.

Zeilik, M., Schau, C., Mattern, N., Hall, S., Teague, K. W., and Bisard, W. J. (1997). Conceptual astronomy: A novel model for teaching post-secondary science courses. *American Journal of Physics*, *65*(10), 987-996. doi: 10.1119/1.18702

Zeilik, M., Schau, C. & Mattern, N., (1998). Misconceptions and their change in university-level astronomy courses. *The Physics Teacher*, *36*(2), 104-107. doi: 10.1119/1.880056.

APPENDICES

Appendix 1 Summary of results from previous studies

	Author(s)	Participants (N)	Data-Gathering Method	Misconception(s)
Elementary/High School Students	Stover and Saunders, (2000)	Elementary school students (4th and 5th) (n=14)	Questionnaire	• The Earth's revolution around the sun causes night and day (pretest=28.5%, posttest=14.3%). • The tilt of the Earth changes from season to season (pretest=50%, posttest=50%). • The Sun revolves around the Earth (pretest=35.7% posttest=14.3%). • The phase cycle of the Moon represents one full revolution around the Sun (pretest=35.7%, posttest=21.4%).
	Trumper, (2001a)	Junior high school students (n=448)	Multiple choice test	• The cause of the day–night cycle is that the Earth moves around the Sun (36%). • The Moon moves into the Earth's shadow (19%). Sun and Earth or between the Earth, Moon and Sun, as a reason for the seasons changes (45%). • The Moon must be in its full phase in order to get a total solar eclipse (74%). • The Sun is directly overhead at noon (35%). The Sun is at the centre of the Universe (24%). • The Milky Way Galaxy is at the centre of the Universe (11%). • The Moon does not rotate on its axis (54%).
	Trumper, (2001b)	Senior High School Students (n=378)	Multiple choice test	• The main reason why it is hotter in summer than in winter is the Earth being closer to the Sun in summer (13%) and Earth's rotational axis flipping back and forth as the Earth moves around the Sun (24%). • The Sun is directly overhead every day (36%). • The Moon must be in its full phase in order to get a total solar eclipse (77%). • The Sun is at the centre of the Universe (21%) and the Milky Way Galaxy is at the centre of the Universe (9%). • The Moon does not rotate on its axis (57%).

Appendix 1 Summary of results from previous studies (cont'd)

University students	Zeilik et al. (1998)	University students Pretest (n=228) Posttest (n=221)	Multiple choice test	• The Sun is directly overhead at noon (pretest=77% posttest=36%).
	Trumper, (2000)	University students (n=76)	Multiple choice test	• The cause of the day–night cycle is that the Earth moves around the Sun (34%). • The Earth is involved in producing lunar phases through the Earth's shadow obscuring portions of the Moon (31.6%). • The Sun is directly overhead at noon (47.4%). • The Moon must be in its 'full' phase in order to get a total solar eclipse (71%). • The Moon does not rotate on its axis (50%).
Pre-Service Teachers	Atwood and Atwood, (1997)	Pre-service elementary teachers (n=51)	Interviews	Pre-assessment: • The cause of night and day is the Earth moving around the Sun (n=8). • The cause of seasons: distance between the Earth and Sun (n=20).
	Trumper, (2003)	Pre-service elementary school teachers (n=645)	Multiple choice test	• The cause of the day–night cycle is that the Earth moves around the Sun (51%). • The Earth's shadow obscuring portions of the Moon (16%). • The Moon moves into the Sun's shadow (29%). • The varying distance between the Sun and the Earth or between the Earth, Moon and Sun, as a reason for the season changes (32%). • Earth–Sun distance causes seasons (37%). The Sun is directly overhead at noon (48%). • The Moon must be in its full phase in order to get a total solar eclipse (71%). • The Moon does not rotate on its axis (51%).

Appendix 1 Summary of results from previous studies (cont'd)

	Frede (2007)	Pre-service elementary Teachers (n=60)	Open-ended questionnaire	• The cause of the day–night cycle is that the Earth moves around the Sun (32%). • Earth–Sun distance causes seasons (50%). • Moon phases are caused by the shadow of the Earth falling on the Moon (34%).
	Küçüközer (2007)	Prospective science teachers (n=327)	Open-ended questionnaire	• The reason for seasons is the Earth revolves round the Sun (non-instructed=33% instructed=24%). • The reason for seasons is closely related to the distance of the Earth from the Sun (non-instructed=20% instructed=16%). • Stars reflect sunlight as planets (non-instructed=19% instructed=11%).
	Kanli, (2014)	Pre-Service Science Teachers (n=97)	Three-tier test	• Reason for seasons is the elliptical orbit of the Earth's movement around the Sun (21%). • The Sun is always overhead at noon (20%). • The Moon moves into the Earth's shadow (18%). • The Moon's phase is full phase in solar eclipse (14%). • The Earth is closer to Sun in summer (14%). • The Moon does not rotate on its axis (15%).
	Kanli (2014)	Physics Teachers (n=119)	Three-tier test	• Reason for seasons is the elliptical orbit of the Earth around the Sun (25%). • The Sun is always overhead at noon (26%). • The Moon moves into the Earth's shadow (13%). • The Moon's phase is full phase in a solar eclipse (16%). • The Earth is closer to the Sun in summer (14%).
In-Service Teachers	Summers and Mant (1995)	In-service primary school teachers (n=66) recent teacher graduates, (n=54)	Closed items questionnaire	• The phases of the Moon are caused by a shadow (usually the Earth's) blocking the Moon. • The Moon has a part to play as a cause for day and night.

Appendix 1 Summary of results from previous studies (cont'd)

Brunsell and Marcks (2005)	Science Teachers (n=142): Elementary teachers (n=43), middle school teachers (n=73), and high school teachers (n=26)	Multiple-choice items	• The Big Dipper can be seen from Pluto (50%). • Pluto is closer to the Sun than the Earth (47%) • Stars are closer to the Earth than Pluto (20%). • There is no gravity in space (40% of elementary science teachers, 20% of middle school science teachers, and 10% of high school science teachers) • The Sun's energy comes from breaking large, heavy elements into lighter ones (about 50%) • The Sun is at the center of the Universe (just over 13%).
Kanli (2014)	Physics Teachers (n=174)	Three-tier test	• Reason for seasons is the elliptical orbit of the Earth around the Sun (16%). • The Sun is always overhead at noon (19%) • The Moon moves into the Earth's shadow (15%). • The Moon's phase is full phase during solar eclipse (10%).