Eurasia Journal of Mathematics, Science & Technology Education, 2014, **10**(5), 471-479

A Study on Identifying the Misconceptions of Pre-service and In-service Teachers about Basic Astronomy Concepts

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Received 19 January 2014; accepted 13 April 2014

Nowadays, the importance given to astronomy teaching in science and physics education has been gradually increasing. At the same time, teachers play an important role in remediating the misconceptions about astronomy concepts held by students. The present study aims to determine the misconceptions of pre-service physics teachers (n=117), pre-service science teachers (n=97) and in-service physics teachers (n=174) about astronomy concepts using a three-tier test. The Astronomy Concept and Achievement Test (ACAT), developed by Trumper (2001a, 2001b, 2006), was adapted as a three-tier instrument and used as the data collection instrument. The first tier, first and second tier and all three tier responses that were obtained from the ACAT were analyzed separately to identify misconceptions and to evaluate the respondents' achievement. The results showed that the achievement scores of pre-service and in-service teachers considerably decreased when the third tier was considered. In addition, when the misconceptions of pre-service and in-service teachers were determined using all three tiers, they held extensive misconceptions especially about the reasons for seasons, the Moon's phases, the Moon's phase in the solar eclipse and the Sun's position in the sky.

Keywords: Astronomy concepts, misconceptions, three-tier test, pre- and in-service teachers.

INTRODUCTION

Since 4000 B.C., astronomy has always been involved in the center of "nature-human" relationships, and for that reason, astronomy is accepted to be one of the oldest disciplines. Examining the historical process, it is seen that developments in astronomy are also closely related with other fields such as physics, chemistry, geology and mathematics. For instance, observing and analyzing the movement of planets have made an important contribution to expressing the law of universal gravitation in physics. Helium, which was explored during the examination of solar electromagnetic spectra, has shed light on an important development in chemistry. We encounter situations in the development of basic sciences in which astronomy generally plays a role as a driving force. Developments in astronomy have also affected studies in education in the natural sciences. For instance, when the Soviet Union launched the Sputnik into space at the end of the 1950s, it caused significant acceleration in the reform movement of science and mathematics education in the US (McDermott, 1991). The ensuing science programs that were developed to forge ahead in this space competition started to be intensively applied across all states. On the other hand, the study of astronomy (such as black holes, supernova bursts, movement of the Halley's Comet, meteor showers, solar and lunar eclipses) aroused interest in individuals from every segment of society, most especially students.

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doi: 10.12973/eurasia.2014.1120a

ISSN: 1305-8223

State of the literature

- The importance of astronomy teaching has been gradually increasing in science education in recent years.
- Examining the literature, it is emphasized that students from different levels and pre-service teachers have a number of misconceptions about even the basic concepts of astronomy. However, there are limited studies that evaluate the beliefs, experiences, understanding and misconceptions of teachers about basic astronomy.
- There are disadvantages of using multiple-choice tests to identify the misconceptions. Thus, two-tier and three-tier tests have been used in determining misconceptions about various concepts in recent years.

Contribution of this paper to the literature

- This study will make an important contribution to the literature in terms of identifying the misconceptions of not only pre-service teachers, but also in-service teachers about astronomy concepts.
- The results presented here show that physics teachers as well as pre-service science and physics teachers have misconceptions about basic astronomy concepts.
- This study will add to the research literature about the use of three-tier tests to overcome the disadvantages of multiple-choice tests that are used in determining the misconceptions in astronomy.

In the light of these facts, teaching of astronomy has been gradually increasing in science and physics education in recent years, due to the close relationship of astronomy with other disciplines, primarily physics, chemistry, geosciences, and mathematics. Additionally, one of the most important factors affecting the achievements of students in science education are their misconceptions (Champagne, Klopfer, & Anderson, 1980; Halloun & Hestenes, 1985; Eryilmaz, 2002). One source of misconceptions among students is their teachers. Misconceptions are not only to be observed in students; even teachers hold same misconceptions of their students(Arslan, Çiğdemoğlu & Moseley, 2012). Examining the literature, although there are many studies on determining students' and pre-service teachers' misconceptions in astronomy, there are few studies on teachers' misconceptions about astronomy concepts (Bailey & Slater, 2004; Summers & Mant, 1995). The purpose of this study is to determine the misconceptions and achievement levels of pre-service science and physics teachers and high school physics teachers on basic astronomy concepts using a three-tier test.

REVIEW OF THE LITERATURE

Misconceptions about astronomy concepts

Astronomy is a science discipline about which individuals gather information through their personal experiences with nature since their childhoods (Hannust and Kikas, 2007). 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.). There are a number of studies emphasizing the importance of astronomy education and investigating the conceptual understanding of children (Barnett & Morran, 2002; Baxter, 1989; Hannust & Kikas, 2007; Vosniadou & Brewer, 1992), elementary/middle school students (Stover & Saunders, 2000; Trundle, Atwood & Christopher, 2007; Vosniadou, Skopeliti & Ikospentaki, 2004), high school students (Sadler, 1992; Trumper, 2001a; 2001b; 2001c), university students (Trumper, 2000; Wallece, 2011; Zeilik, et al., 1997; Zeilik, Schau & Mattern, 1998), pre-service teachers (Abell, Martini & George, 2001; Atwood & Atwood, 1995, 1996, 1997; Frede, 2006; Küçüközer, 2007; Trumper, 2003; Trundle, Atwood & Christopher, 2002, 2006) and teachers (Brunsell and Marcks, 2005). Some of these studies that were implemented using the experimental or survey method are shown in Appendix with their samples, the educational levels of participants, assessment instruments used and some of the misconceptions. The most important result of these studies is that not only students but also pre-service and in-service teachers have misconceptions even about basic astronomy concepts.

Why multi-tier tests should be used in determining misconceptions?

It is very important to accurately determine the misconceptions in astronomy education just like in other disciplines. Various methods such as interviews, word associations, open-ended questions, and multiple-choice tests are used in measuring the misconceptions (Tsai & Chou, 2002). Each of these tools has some advantages as well as disadvantages over one another. For instance, although interviews provide in-depth information about cognitive structures of students and reasoning by its probing and flexibility, they have some disadvantages since they reach at a limited number of students and are hard to apply. On the other hand, multiple-choice tests are generally preferred in determining the misconceptions of students since they

have various advantages. It is possible to immediately and objectively score them and to apply them to a large number of students and besides, teachers can administer them easily. As is seen in Appendix, while multiple-choice tests are preferred with large samples, interviews are preferred with smaller samples in general. Even though multiple-choice tests have many advantages since they can be administered to a large number of students and their results can be evaluated very quickly and objectively, there are problems about the effectiveness of multiple-choice tests since they fail to deeply analyze the answers of students (Kaltakçı & Eryilmaz, 2010; Rollnick & Mahooana, 1999 as cited in Kutluay, 2005). Not every wrong choice is due to the misconceptions held by students (Kaltakçı & Eryilmaz, 2010). This condition might be caused either by lack of knowledge, negligence, luck factor or just an error (Hasan, Bagayokoz & Kelleyz, 1999; Peşman & Eryilmaz, 2010).

In order to overcome such problems, it is especially emphasized that students are required to confirm their answers (Eryilmaz, 2010; Tamir, 1971, 1989 as cited in Chandrasegaran, Treagust & Mocerino, 2007; Tsai & Chou, 2002; Treagust, 2006). For this particular reason, two-tier tests have been especially used in determining these misconceptions over the past several decades. While the first tier of two-tier test involves a multiple-choice question about the concept, the second tier involves a question about the reason for the answer to the first tier (Chandrasegaran et. al. 2007; Griffard & Wandersee, 2001; Haslam & Treagust, 1987; Treagust, 1986). In the three-tier test, on the other hand, in addition to questions in the two-tier test, in the third tier the students are asked about whether or not they are sure about the answers. Thus, the most accurate means to reflect the misconception of the student is provided by a three-tier test. If the student marks the wrong answer with misconception in the first tier, explains this wrong answer with reasons as if it is right and states that he or she is sure about the answers in the last tier, that student might have a misconception (Arslan et al., 2012; Eryilmaz, 2010).

METHOD

Sample

The population consisted of pre-service science/physics teachers receiving education at university, and high school physics teachers. The sample, which was chosen using the convenience sampling method, consisted of pre-service physics teachers (n=119) and pre-service science teachers (n=97) attending a teacher education program at a Turkish university. On the other hand, the high school physics teachers (n=174) in the sample consisted of in-service teachers from different regions and provinces who participated in in-service teacher training courses that were organized by the Ministry of National Education (General Directorate of In-service Education) between 2010-2012. All teachers and pre-service teachers voluntarily participated in the study.

Research Instruments

The Astronomy Concept and Achievement Test (ACAT) involving 28 questions was developed as the assessment instrument in the study, through examining multiple-choice conceptual and achievement tests that were developed by Trumper (2001a, 2001b, 2006). The test was adapted into Turkish by linguists and field experts, and it was prepared in three tiers. A concept, or problem, was asked as a multiple choice question in the first tier. In the second tier, the reason or justification for the answer given to the first tier was asked in an open-ended way. In order to discriminate any misconceptions resulting from lack of knowledge, in the third tier, they were asked to state to what extent they are sure about their answers in the first and second tiers based on the choices "I am sure" and "I am not sure". The final form of the ACAT was administered to 88 pre-service science teachers as a pilot test.

Reliability and Validity of ACAT

Reliability and validity of ACAT were performed using the scores of participants in the first tier. Being an exam internal consistency measure, KR-20 was calculated for the reliability of ACAT. In order to determine the construct validity of the test, the correlation between correct answers in the first two tiers and the state of being sure in the third tier was examined. If the correlation between the correct answers of students in the first two tiers and their states of being sure in the third tier is positive, it could be asserted that the test has construct validity (Çataloğlu, 2002; Kutluay, 2005). Reliability and validity coefficients of ACAT, during both the pilot test and the study are given in Table 1.

The fact that the Pearson correlation coefficient (r) is close to 1 shows that the test has a high construct validity, which means that students giving right answers in the first two tiers of the test have high confidence levels, whereas students giving wrong answers have lower confidence levels. When the KR-20 value is .70 and above, the test is considered reliable (Fraenkel & Wallen, 2008). Since the KR-20 value of this conceptual test was close to .70, the test could be accepted as reliable.

Table 1. Reliability and validity of ACAT

Group	N	Reliability KR-20	Validity Pearson Correlation
Pilot test	88	.68	.85
Pre-Service Physics Teachers	119	.60	.92
Pre-service Science Teachers	97	.59	.82
In-service Physics Teachers	174	.80	.98

Table 2. Achievement scores of pre-service and in-service teachers

		One-Tier		Two-Tier		Three-Tier	
Group	**N**	**Mean**	**%**	**Mean**	**%**	**Mean**	**%**
Pre-service Physics Teachers	119	9.5	34	2.0	7	1.48	5
Pre-service Science Teachers	97	9.0	32	2.2	8	1.32	5
In-service Physics Teachers	174	11.4	41	4.1	14	3.2	11

DATA ANALYSIS AND FINDINGS

A descriptive statistical analysis was conducted in an attempt to analyze misconceptions and achievement with three-tier test.

Achievement Scores of Pre-service and In-service Teachers

The ACAT data were analyzed as follows for determining achievement: Participants were considered to be successful in answering a question when they marked the correct choice in the first tier (1), made the correct explanation in the second tier (1) and finally, when they marked the choice "I am sure" in the third tier (1); in other words, the responses were coded as (1-1-1). When this coding was performed for all 28 questions, the maximum score was 28 and the lowest score was 0. Table 2 shows the achievement scores and corresponding percentages of participants in the three tiers.

Examining Table 2, it is seen that the achievement scores of physics teachers and pre-service teachers had decreased (29% on average) when evaluated according to the three tiers. This result shows that even though physics teachers and pre-service teachers selected the correct answers in the first tier, they were unable to explain the reason for that answer; even if they selected the correct answer and explained the scientific reason, they were unsure about their answers. Examining the open-ended answers of teachers and pre-service teachers in the second tier, apart from "scientific explanation", "scientific error", "misconception", the following answers were frequently given:

"I have no idea about this question/subject"
"The reason for me to mark this choice is only estimation"
"I had read it somewhere before. But I don't know why it is this way"
"This is the first time I have ever encountered such a question"
"I just think it is that way"

Misconceptions of Pre-Service Teachers and Physics Teachers

While analyzing the data obtained from the ACAT to determine the misconceptions, the wrong answer that was the misconception was marked in the first tier was coded (0); if this wrong answer was explained with its reason as if it was right in the second tier the response was coded (0); if participants stated that they were sure about their answers and coded (1), then the question was coded as 0-0-1, and was accepted as a misconception. Table 3 shows the percentage of misconceptions of pre-service teachers and teachers based on the three tiers.

One of the conclusions to be drawn from Table 3 is that the percentages of misconceptions that are measured with the first two tiers in all misconceptions are lower than the percentages (max 28% and min 1%) of misconceptions that are measured only according to the first tier. The reason for this result is that even if teachers or pre-service teachers marked the choice with misconception in the first tier, their explanations are not misconceptions. It is seen that these explanations are scientifically wrong. Similarly, the percentages of misconceptions that were measured with the three-tier

Table 3. Percentages of the misconceptions according to the first, first two and all three tiers

		Pre-service						In-service Physics Teachers		
		Physics Teachers			Science Teachers					
Concept	**Misconception(s)**	One-Tier	Two-Tier	Three-Tier	One-Tier	Two-Tier	Three-Tier	One-Tier	Two-Tier	Three-Tier
		%	%	%	%	%	%	%	%	%
Reason for seasons	Reason for seasons is the elliptical orbit of the Earth's around the Sun.	55	34	25	55	37	21	35	21	16
Sun overhead at noon	The Sun is always overhead at noon.	47	22	14	32	27	20	38	22	19
	The Sun is only overhead on the first day of summer.	4	3	1	2	1	0	11	4	3
	The Sun is only overhead on the first day of winter.	3	0	0	2	0	0	3	1	1
	The Sun is overhead on the first day of summer and winter.	7	2	1	2	0	0	4	2	1
	Total	*61*	*26*	*16*	*38*	*28*	*20*	*56*	*29*	*24*
Moon's phases	Moon moves into Earth's shadow.	42	18	13	54	27	18	33	16	15
	Moon moves into Sun's shadow.	13	3	2	13	5	1	7	3	3
	Total	*55*	*21*	*14*	*67*	*32*	*19*	*40*	*19*	*18*
Moon's phase in solar eclipse	Moon is at full phase in solar eclipse.	40	24	16	59	43	14	28	15	10
Reason for it being	Earth closer to Sun in summer.	38	18	14	28	18	14	14	5	4
	Earth closer to Sun in winter.	4	3	3	2	1	1	4	1	0
	Earth's rotational axis flips back and forth.	3	1	1	7	5	2	2	1	1
	Total	*45*	*21*	*18*	*37*	*24*	*18*	*20*	*6*	*5*
Moon's rotation-same side visible	Moon does not rotate on its axis.	34	13	8	57	31	15	16	3	3
Distance from Earth	Stars closer than Pluto	29	8	4	30	6	3	18	2	1
	Pluto closer than Sun	22	7	4	25	7	4	33	5	3
	Total	*50*	*14*	*8*	*55*	*13*	*7*	*51*	*7*	*4*
Moon's revolution around Earth	Moon's revolution around Earth in one day.	24	3	3	27	12	6	25	10	8
Moon's revolution around Sun	Moon's revolution around Sun in one day.	4	0	0	5	2	1	2	0	0
	Moon's revolution around Sun in one month.	8	1	1	9	1	0	7	1	1
	Total	*12*	*1*	*1*	*14*	*3*	*1*	*9*	*1*	*1*
Center of universe	The Sun is at the center of universe.	17	5	3	22	9	3	6	1	1
	The solar system is at the center of universe.	18	2	1	9	3	1	8	2	1
	The Milky Way Galaxy is at the center of universe.	11	2	2	11	3	1	4	1	1
	Total	*45*	*8*	*6*	*42*	*15*	*5*	*18*	*4*	*3*

test are lower than the percentages (max 45% and min 1%) of misconceptions that were measured with two-tier test. This condition is caused by lack of knowledge in teachers or pre-service teachers.

Table 4. Misconceptions of pre- and in-service teachers more than 10% based on three tiers.

Pre-service Physics Teachers	Pre-service Science Teachers	In-service Physics teachers
• Reason for seasons is the elliptical orbit of the Earth around the Sun (25%).	• Reason for seasons is the elliptical orbit of the Earth around the Sun (21%).	• Reason for seasons is the elliptical orbit of the Earth around the Sun (16%).
• The Sun is always overhead at noon (14%).	• The Sun is always overhead at noon (20%).	• The Sun is always overhead at noon (19%)
• Moon moves into Earth's shadow (13%).	• Moon moves into Earth's shadow (18%).	• Moon moves into Earth's shadow (15%).
• Moon is at full phase in solar eclipse (16%).	• Moon is at full phase in solar eclipse (14%).	• Moon is at full phase in solar eclipse (10%).
• Earth closer to Sun in summer (14%).	• Earth closer to Sun in summer (14%).	
	• Moon does not rotate on its axis (15%).	

In accordance with the data in Table 3, Table 4 summarizes that more than 10% of pre- and in-service teachers have misconceptions based on three tiers.

CONCLUSIONS AND DISCUSSION

The interest in astronomy and the close link of astronomy with other disciplines, gradually increases the importance of astronomy in science education. Examining the literature, it is seen that there are a limited number of studies aimed at determining the misconceptions of teachers concerning astronomy (Bailey & Slater, 2004; Summers & Mant, 1995). Brunsell and Marcks (2005) studied elementary and high school teachers and found that the majority of teachers could not combine rotation and orbit concepts with the sky objects and sky observations. Teachers held several misconceptions about the movement of the Moon and the Earth. In another study, Summers and Mant (1995) stated that teachers found the scientific explanation for the occurrence of night and day, the Moon's phases and the seasons confusing.

Results of this study have revealed that the percentages of pre-service and in-service teachers' achievement scores are very low on basic astronomy concepts. Besides, as well as pre-service teachers, 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. Physics teachers and pre-service teachers believed that:

Seasons change when the elliptical orbit of the Earth becomes a whole circle;

There is no shadow of a flag pole when the Sun is overhead at noon;

Dark areas on the Moon originate from the shadow of Earth;

The Moon is in the phase of full moon during a solar eclipse and it has an elliptical orbit around the Sun.

In addition pre-service teachers believed that:

Summer months are warmer than winter months due to the fact that the Earth is closer to Sun in summer;

We always see the same side of the Moon due to the fact that the Moon doesn't rotate around itself.

As seen in Appendix, these results are in agreement with previous studies (Frede, 2006; Küçüközer, 2007; Zeilik et al., 1998; Trumper, 2000, 2003; Trundle et al., 2006).

Examining the results in Table 2 and Table 3, a decrease is observed in both achievement and misconception percentages of pre-service teachers and teachers towards the third tier. When this result is analyzed in terms of success, it shows us that, the participants are not sure about their answers or cannot provide a true explanation even though they choose the correct answer. The same case is seen in misconceptions analysis. The participants tried to explain this choice through the expressions that do not involve the misconception or they are not sure about their answers. This situation could stem from lack of knowledge or scientific mistakes, but not from participants' having concept misconceptions.

SUGGESTIONS

In light of the results of this study, it is suggested that:

Teachers play an important role in reducing the misconceptions of students in teaching of astronomy as in other disciplines. For that reason, it is required to pay special attention to teachers' and pre-service teachers' training on astronomy concepts. In addition, Brunsell and Marcks (2005) state that despite many professional development efforts for teachers in astronomy education based on teaching activities that can be used in the classroom, these activities may not

provide explicit connections to overarching themes in the discipline. Thus, these efforts should be based on providing a coherent structure for astronomy, and activities for communicating that structure to their students.

The multiple-choice tests have limitations in measuring the achievement and misconceptions, compared to three-tier tests. Namely, it is required to discern misconceptions from scientific errors and lack of knowledge (Hasan, et al., 1999; Griffard & Wandersee, 2001; Chandrasegaran et. al., 2007; Eryilmaz, 2010; Arslan et al., 2012). Besides, misconception tests should not be scored based on correct scores (Eryilmaz, 2010). In the relevant literature, we have not encountered three-tier testing aimed at determining the misconceptions of pre-service and in-service teachers on astronomy-based concepts. This study will add to the literature in terms of using the three-tier test in eliminating the disadvantages of multiple-choice tests that are generally used in determining the misconceptions in astronomy.

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Appendix. Some of the most common misconceptions about astronomy in previous studies

Previous Researchers	Sample Size	Education Level	Method	Misconceptions
Atwood & Atwood, (1997)	51	Pre-service elementary teachers	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)
Zeilik et al. (1998)	Pretest n=228 Posttest n=221	University students	Multiple choice test	• Sun directly overhead at noon (pretest=77%, posttest=36%).
Stover & Saunders, (2000)	14	Elementary school students (grades 4-5)	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, (2000)	76	University students	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%). • 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%).
Trumper, (2001a)	448	Junior high school students	Multiple choice test	• The cause of the day–night cycle is that the Earth moves around the Sun (36%). • Moon moves into Earth's shadow (19%). • Sun and Earth or between the Earth, Moon and Sun, as a reason for the seasons changes (45%). • 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 center of the Universe (24%). • The Milky Way Galaxy is at the center of the Universe (11%). • The Moon does not rotate on its axis (54%).
Trumper, (2001b)	378	Senior High School Students	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 center of the Universe (21%) and the Milky Way Galaxy is at the center of the Universe (9%). • The Moon does not rotate on its axis (57%).
Trumper, (2003)	645	Pre-service elementary school teachers	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%).
Frede (2006)	60	Pre-service elementary teachers	Open written 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)	327	Prospective science teachers	Open-ended questionnaire	• The reason for seasons is the Earth revolves the Sun. (non-instructed=33%, instructed=24%) • The reason for seasons is closely related to the distance of Earth from the Sun (non-instructed=20%, instructed=16%). • Stars reflect Sunlight as planets (non-instructed=19%, instructed=11%).
Brunsell and Marcks (2005)	142	Science Teachers	Multiple-choice items	• Big Dipper can be seen from Pluto (50%). • Pluto 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 • Sun's energy comes from breaking large, heavy elements into lighter ones (about 50%) • Sun is at the center of the Universe (just over 13%).