Third Misconceptions Seminar Proceedings (1993)

Paper Title: **The Effect of Astronomy Teaching Experience on the Astronomy Interest and Conceptions of Elementary School Teachers**
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Keywords: Concept Formation,Educational Methods,Teacher Education,Misconceptions,Change Strategies,Teaching Experience,Inservice Teacher Education,Experimental Learning,Scientific Concepts
General School Subject: Earth Science
Specific School Subject: Astronomy
Students:

Macintosh File Name: Shore - Astronomy
Release Date: 12-16-1993 C, 11-6-1994 I

Publisher: Misconceptions Trust
Publisher Location: Ithaca, NY
Volume Name: The Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics
Publication Year: 1993
Conference Date: August 1-4, 1993
Contact Information (correct as of 12-23-2010):
Web: www.mlrg.org
Email: info@mlrg.org

A Correct Reference Format: Author, Paper Title in The Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics, Misconceptions Trust: Ithaca, NY (1993).

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The Effect of Astronomy Teaching Experience on the Astronomy Interest and Conceptions of Elementary School Teachers

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SIGNIFICANCE

During the last twenty years, descriptions of the science misconceptions held by students and adults have become an increasingly popular component of the educational research literature (Wandersee and Mintzes, 1987). While much is known about the kinds of private theories people hold, far less is known about how to successfully replace misconceptions with accepted scientific views. Thus far, few pedagogical strategies has proven to be successful in producing long term conceptual change (Lawson, Abraham, and Renner, 1989).

One of the most striking and disturbing characteristics of science misconceptions has been their resistance to change. Various theorists have attempted to explain the tenacity of misconceptions by suggesting that context determines the type of science concept that one prefers (Gunstone and Northfield, 1986; Hills, 1989). For example, scientists hold "scientific" -- often counterintuitive --conceptions because of the desire to understand how nature works and to do so using conceptions agreed upon by the scientific community. For non-scientists, there may be little motivation to accept scientific views as long as their alternative conceptions have explanatory power (Posner, Strike, Hewson and Gertzog, 1982; Hills, 1989). Thus, the acceptance of a scientific concept by non-scientists may only result when non-scientists are placed in contexts where they perceive it is their advantage to do so.

Other than scientific settings, what other contexts might promote the acceptance of scientific theories by non-scientists? Is science teaching a context that promotes the acceptance of scientific concepts? Some researchers (Gabel, Rubba, and Franz, 1977; Gunstone and Northfield, 1986; Hauslein, Good, and Cummins, 1990) have suggested that the desire to be well informed for their students may be enough to motivate science teachers to abandon their misconceptions in favor of scientific explanations.

RATIONALE

Despite the theoretical basis for examining the science conceptions of experienced high school or college science teachers, such investigations are rare; however, the science conceptions of both preservice and inservice elementary school teachers have been investigated by several researchers (Cohen, 1982; Stephans and McCormack, 1985; Lawrenz, 1986) and it has been shown that these teachers hold a variety of erroneous beliefs. It may be that elementary school teachers hold misconceptions because they function in a context where the possession of accurate science conceptions is irrelevant to them. Surveys of elementary school classrooms show that teachers typically devote relatively little time to science instruction compared to reading, language arts, mathematics, and social science (Horn and James, 1981). Science teaching does not appear to be a priority for most elementary school teachers. Thus, the rationale for investigating the effect that astronomy teaching experience has had on the astronomy concepts of elementary school teachers was as follows: *If the science concepts that people hold depends on context and elementary school science teaching is a context in which scientific conceptions need to be adopted, then elementary astronomy teaching experience should improve the astronomy conceptions of elementary school teachers who have not taught this discipline in the past.*

SUBJECTS

The astronomy concepts of two groups were examined and compared. The experimental group consisted of second grade teachers in a large, upper-middle income suburb of Bostonn for this study because their elementary science coordinator had developed a hands-on astronomy unit for grade two that had been used in the school district for over three years prior to this study. The control group consisted of first, second, and third grade teachers from the same school district. The control teachers were not required to teach astronomy and had not done so for three year prior to participating in this research.

In this school district, science is taught from kindergarten though 8th grade. At each grade level, the science curriculum is multidisciplinary. Children in the elementary grades (K through 6) are engaged in age appropriate, hands-on activities concerning biology, earth science, and physical science each year. Therefore, teachers in both the experimental and control groups had experience teaching scientific disciplines other than astronomy.

Description of the Astronomy Experience of the Experimental Group

Since 1987, astronomy has been the major focus of the second grade science curriculum. The second grade astronomy unit used by the experimental group during this time was described by a 110 page teacher's guide entitled *Beyond the Earth*. This manual contained detailed descriptions of classroom activities, a review of basic astronomy for the teachers, and various worksheets and handouts for teachers to reproduce for their students. *Beyond the Earth*, which was designed to take approximately 30 class sessions to complete, covered five major topics:

The Earth, The Moon, Gravity, The Solar System, and Stars. The following astronomy concepts were addressed by activities in the curriculum:

- Day and night are caused by the Earth's rotation.
- The seasons are caused by the tilt of the Earth's rotation axis. During the year, this tilt results in a variation in the length of the days and in the Sun's altitude.
- The Earth completes one rotation in a day and completes one revolution about the Sun in a year.
- The Moon completes one revolution about the Earth in a month.
- The Moon does not emit its own light. It reflects light from the Sun.
- The Moon spins. Its period of rotation equals its period of revolution about the Earth.
- The phases of the Moon are caused by the relative positions of the Earth, Moon, and Sun.
- The force of gravity pulls things toward the center of the Earth.
- The Moon, Sun, and stars all have gravity.
- Gravitational force causes the planets to orbit around the Sun and moons to orbit around planets.
- Weight is a measure of the gravitational force on an object.
- Planets, moons, the Sun, asteroids, and comets are objects that comprise the Solar System.
- Distance from the Earth affects the relative brightness of the stars.
- Circumpolar constellations never set.
- Galaxies are collections of stars.

Other goals described by the manual which are relevant to this research include:

- Understanding the relative size and distance between the Earth and Moon.
- Understanding the relative size and distance between objects in the solar system.

In addition to using this astronomy curriculum, teachers in the experimental group received a great deal of support from their elementary science coordinator. Prior to introducing the astronomy unit into the second grade curriculum, teachers were required to attend a workshop led by the science coordinator. The goals of this workshop were to review basic astronomy, show teachers how to do the activities and exercises in the unit, and introduce teachers to the objectives of the curriculum. In addition, the science coordinator visited each of the second grade classrooms, providing teachers with advice and encouragement. When necessary, the coordinator also met with the teachers privately. These one-on-one sessions generally focused on improving teaching style and showing teachers the correct use of various demonstration devices.

According to the science coordinator, approximately half of the second grade teachers in the school system had used *Beyond The Earth* for over three years. The remaining teachers, who were either new to the school district or had been switched into the second grade, had used the unit from one to three times.

Evidence Of The Treatment

Because the treatment was not monitored in this investigation, the science coordinator was asked to provide some proof that the second grade teachers were actually using the *Beyond The Earth* unit. The coordinator offered the following evidence:

- Over 85% of the second grade teachers regularly check out supplementary astronomy materials from the science resource center (most of the materials needed to teach the unit are in the second grade science kits stored in each teacher's classrooms).
- Over 50% of the second grade teachers request "observation nights" for their students. Teachers must have completed the "Moon journals" activity and covered the cause of the Moon's phases before they can request an observation night. This event is run throughout the year by the science coordinator, and is an opportunity for children, their parents, and their teachers to identify constellations, note the motion of the sky, and observe astronomical objects through a telescope. Attending this evening event is optional for the children, but teachers who request an observation night are required to attend.
- Over 75% of the second grade classrooms are decorated with posters and/or student work relating to astronomy.
- Approximately 1/3rd of the elementary schools in the district selected a visit to the planetarium as their annual second grade field trip.
- Parents of children in the second grade regularly comment on the astronomy unit.
- Children in the second grade regularly comment on the astronomy unit.

Description of the Astronomy Teaching Experience of the Control Group

Teachers in the control group who were responsible for grades 1 through 3, did not use *Beyond The Earth*, and were not required to teach astronomy concepts. Any astronomy instruction that the control teachers engaged in was due to their own volition and interest in the discipline.

Some second grade teachers were also eligible to be controls because they had not used *Beyond The Earth*. These teachers, who had previously taught first or third grade, were assigned to teach second grade just two months before this research began and had not started to use *Beyond The Earth* at the time that data for this study was collected. Their prior science teaching experience was the same as the first and third grade teachers in this school district.

THE INSTRUMENT

The instrument consisted of demographic questions, an assessment of astronomy interest, and 12 multiple choice questions concerning astronomy concepts (see Figures 1 through 3).

Description Of Astronomy Interest Assessment

The assessment of astronomy interest (Figure 2) was designed to measure the teacher's interest in astronomy at the time of their participation in this study and three years prior. The assessment consisted of nine questions, each containing two parts. The first part of each question asked teachers to report (1) how frequently they engaged in a particular astronomy activity at the time of the workshop, and (2) how frequently they engaged in the same activity three years prior to the workshop. The activities listed in the interest assessment, which included subscribing to astronomy magazines, reading science fiction books, observing astronomical objects through a telescope or binoculars, and naming and locating constellations, were suggested and later reviewed by sixteen "experts" as indicators of astronomy interest. These experts included two professional astronomers, three amateur astronomers, seven middle and high school astronomy teachers, and four elementary science specialists.

Participants in this study received two scores for the astronomy interest assessment: one for current interest in astronomy and another for interest three years prior to filling out the instrument. For items 1 through 7, choices A through E had a value of 0 to 4 points, respectively. Subjects additionally received one point for each activity checked off in item 8 and one point for each of the six officially commissioned U.S. Space Shuttles correctly named in item 9. Therefore, a subject could receive maximum scores of 43 points for both their past and present astronomy interest.

Description Of Astronomy Concept Survey

The astronomy concept survey consists of 12 multiple choice questions designed to uncover misconceptions. All of these questions were taken from a more extensive misconceptions test developed by Project STAR (Science Teaching through its Astronomical Roots), a high school curriculum development project at the Harvard-Smithsonian Center for Astrophysics.

All questions on the Project STAR misconceptions test had been extensively reviewed for readability and content validity by a panel consisting of high school astronomy teachers, scientists at the Center for Astrophysics, statisticians, and educational researchers. Those items on the STAR misconceptions survey that dealt with topics covered by the unit used by the teachers in the experimental group were selected (see Figure 3). These items cover the following concepts:

- The relative size and distance between the Earth and Moon (Question 1).
- The position of the stars relative to other astronomical objects (Question 2).
- The relative distance between the Earth and Sun (Question 3).
- The cause for day and night. (Question 4).
- The cause for the seasons and the resulting change in the number of hours of daylight in the northern hemisphere (Questions 5 & 6).
- The cause for the Moon's phases (Question 7).
- The periods of revolution and rotation of the Earth and Moon (Questions 8 through 12).

Scoring the astronomy concept survey was accomplished by establishing a "misconception hierarchy" for each of the astronomy concept questions. This scoring system is based on the assumption that the possession of certain misconceptions reflects a more naive view of astronomy than do others.

Some researchers have invented classification schemes for astronomy misconceptions (Nussbaum and Novak, 1976; Vosniadou and Brewer, 1988; Finegold and Pundak, 1989). Other researchers have demonstrated that certain astronomy misconceptions are more common among children than adults (Schoon, 1989). Whenever possible, scores for items on the astronomy concept survey were based on classification schemes described in the literature. Otherwise, misconceptions found primarily among young children were assigned smaller point values compared to notions more prevalent in older students or adults.

For each item on the survey, scores ranged from 1 (most naive idea) to 5 (correct response). The only exception was Question 1, where scores ranged from 1 (most naive idea) to 6 (correct response). Figure 3 lists the point value of each multiple choice response. The justification behind these scores is as follows:

Question 1 (*Relative size and distance of the Moon*): Sadler (1987) found that high school students believe the Moon is both larger and closer to the Earth than it actually is.

Therefore, the farther a subject placed the Moon from the Earth in Question 1, the more points he/she received. Subjects also had a choice of two different lunar diameters. Because the smaller model of the Moon was correct, subjects received a higher score for selecting it. (A = 1pt, B = 2 pts, C = 3 pts, D = 4 pts, E = 5 pts, and F = 6 pts (the correct response)).

Question 2 (*Position of the stars*): Piaget (1983) discovered that young children believe that stars are tiny points of light scattered uniformly throughout space. Finegold and Pundak (1989) have suggested that the understanding that the stars are far outside the boundaries of the solar system is an advanced conception held by only a minority of high school students. In scoring this question, the farther a respondent placed the stars from the Earth, the higher his or her score (A = 1 pt, B = 2 pts, C = 3 pts, D = 4 pts, E = 5 pts (the correct response)).

Question 3 (*Relative distance between the Earth and Sun*): Like Question 1, the farther a subject placed the scale model of the Earth from the basketball representing the Sun, the higher his/her score (A = 1pt, B = 2 pts, C = 3 pts, D = 4 pts, E = 5 pts (the correct response).

Question 4 (*Cause for day/night cycle*): The correct response to Question 4 is that the Earth spins on its axis and subjects who selected this answer received 5 pts. Because many researchers classify heliocentric notions of the Earth/Sun system as more advanced than geocentric conceptions (Vosniadou and Brewer, 1988; Finegold and Pundak, 1989), subjects who believed that the Earth's orbit around the Sun causes night and day received 4 pts. Subjects who selected C received 3 pts. Both Piaget (1983) and Vosniadou and Brewer (1988) have found that the belief that day and night occur because an object blocks the Sun is common among preschool children. Therefore, subjects who selected D received 2 pts. Item E, a distractor, was worth 1 pt.

Question 5 (*Longest day of the year*): Schoon (1989) has found that many adults believe that the hours of daylight continue to increase throughout the months of July and August (Schoon, 1989). Therefore, subjects received 5 pts for selecting June 15 (the correct response) and progressively fewer points for selecting July 15 (4 pts), August 15 (3 pts), and September 15 (2 pts). Because E ("all dates are the same") is the most naive response, subjects who selected it received 1 pt.

Question 6 (*Cause For The Seasons*): Subjects received 5 pts for selecting C, the correct response. A commonly held misconception is that it is warm in the northern hemisphere during the summer because the Earth is closer to the Sun (Sadler, 1987; Schoon, 1989). Sadler (1990) has more recently found that many people who acknowledge the role of the Earth's tilt in the cause for the seasons, still carry this misconception. On probing, Sadler found that high school and college students believe that the Earth's tilt causes the northern hemisphere to be closer to the Sun during the summer. Therefore, subjects received 4 pts for selecting B and 3 pts for selecting A, the more naive response. Subjects who selected D received 2 pts. Because "clouds blocking the Sun" is the most naive explanation for the changing seasons (Piaget, 1983), subjects who selected it received 1 pt.

Question 7 (*Cause for the Moon's phases*): Subjects received 5 pts for selecting D, the correct response. The misconception that the Earth's shadow causes the lunar phases is reported to be particularly popular among adults (Schoon, 1989). Subjects who selected choice B received 4 pts. Several researchers (Piaget, 1983; Vosniadou and Brewer, 1988) have found that young children believe that clouds blocking the Moon cause it to change shape. Therefore, subjects who selected choice A received 3 pts. Choice E represents the most naive explanation for the Moon's phases, and subjects who selected it received 2 pts. Item C, a distractor, was worth 1 pt.

Questions 8 (*Period of Earth's rotation*): Subjects received 5 pts for selecting B (a day), the correct response. Because of the possibility that the Earth's rotational axis may have been confused with its axis of revolution, respondents who selected E (a year) received 4 pts. The other responses, all distractors, were worth 1 pt.

Question 9 (*Period of Earth's revolution about the Sun*): Subjects who selected E (a year -- the correct response), received 5 pts. The belief that the Earth orbits the Sun in one day was found to be commonly held by children (Schoon, 1989). Therefore, teachers who selected B (day) received 3 pts. The other responses, all distractors, were worth 1 pt.

Question 10 (*Period of Moon's revolution about the Earth*): Schoon (1989) found that the belief that the Moon takes one day to orbit once around the Earth is held by both children and adults. He also found that this misconception appears to decrease in popularity with age. Therefore, subjects received 5 pts for selecting D (a month -- the correct response) and 3 pts for selecting B (a day). The other responses, all distractors, were worth 1 pt.

Question 11 (*Period of Moon's revolution about the Sun*): Subjects who selected E (a year -- the correct response), received 5 pts. The selection of other responses suggests that the heliocentric model of the solar system has not been fully accepted by the respondent. Subjects who associated the monthly phase cycle with the relative position of the Sun and Moon, but possessed a geocentric view of the solar system, were likely to choose D (a month). Subjects who held a geocentric conception of the solar system, but believed that the Moon's phase cycle is completed in a day (Schoon, 1987), were likely to choose B (a day). Since B is a more naive response than D, they were worth 3 and 2 pts, respectively. The other responses, both distractors, were worth 1pt.

Question 12 (*Period of Moon's rotation*): Subjects who held the correct conception of the Moon's geosynchronous orbit about the Earth were likely to select D (a month -- the correct response). These respondents received 5 pts. Subjects who recognized that the Moon's motion is geosynchronous but naively believed that the Moon takes only a day to complete one orbit (Schoon, 1989), were likely to choose B (a day). Response B was worth 3 pts. Other responses (distractors) were worth 1 pt.

Determination Of Validity And Reliability

Validity

Item validity for the nine questions on the astronomy interest assessment was established by the group of sixteen "experts" (described in the previous section) who originally suggested the items that comprised the instrument. Sampling validity of the astronomy interest assessment was determined by the four elementary science specialists, who were asked to judge whether the instrument was a valid measure of an elementary teacher's interest in astronomy. After incorporating their suggestions for improvement, the elementary science specialists agreed that the astronomy interest assessment would provide sound information.

Because *each question* on the astronomy concept survey had already been judged to be valid by Project STAR, the item validity of *individual questions* was assumed. Sampling validity of the astronomy concepts survey was established by asking an expert to judge whether the instrument is a valid measure of the conceptual mastery of teachers using *Beyond The Earth*. In this case, the "expert" was the previous elementary science coordinator for the school system examined in this study. This expert served as science coordinator during the first two years that *Beyond The Earth* was used and has kept in close contact with the current science coordinator since that time. Therefore, he was familiar with both the unit and the way that teachers were actually using it. After examining the astronomy concept survey, this expert agreed that it was a valid measure of the astronomy concepts held by the teachers using *Beyond The Earth*.

Retest Reliability

The instrument was pilot tested with 29 undergraduate elementary education majors at a large, private university in Boston, MA. These students were enrolled in a required science methods course and all were within one year of elementary certification. The purpose of the pilot was to (1) see whether the survey could be completed in under 20 minutes, (2) make sure that the items were not ambiguously worded, and (3) determine the instrument's retest reliability. The education majors were asked to fill out the instrument six weeks after the initial pilot test. Their responses to each item and their total scores on the astronomy interest assessment and astronomy concept survey were compared.

The test-retest reliability of the astronomy interest assessment was determined by correlating the astronomy interest pre- and posttest scores of the 29 elementary education majors and calculating the coefficient of stability (r). The past and present components of the astronomy interest assessment had a test-retest reliability of $r = 0.825$ and $r = 0.918$ respectively and were significant at the $p \leq 0.05$ level.

Individual questions on the astronomy concept survey were judged reliable if the two-tailed Sign Test failed to uncover significant differences between the pre- and posttest scores that the subjects received for each item ($p \leq 0.05$). None of the differences between the pre- and posttest scores for the 12 items were statistically significant. Therefore, each item on the astronomy concepts survey has test-retest reliability at the $p \leq 0.05$ level of significance.

The test-retest reliability of the astronomy concept survey was determined by correlating total astronomy concept pre- and posttest scores of the elementary education majors and calculating the coefficient of stability (r). The calculated value of $r = 0.716$ for the correlation between scores was significant at the $p \leq 0.05$ level.

PROCEDURES

All teachers in grades one through three were invited to attend a 90 minute workshop on "hands-on" astronomy run by the author. The session was held on an inservice day when all teachers in the district are required to attend one of several different teacher enhancement workshops.

A total of 15 second grade teachers, 15 first grade teachers, 2 third grade teachers, 2 teacher's aides, and 2 student teachers attended the workshop. All workshop participants were asked to fill out the demographic questionnaire, astronomy interest assessment, and astronomy concept survey during the first 20 minutes of the workshop. The teachers were reassured of their anonymity, told to make "educated guesses" on concept questions they felt unsure about, and reminded to work alone.

One first grade teacher did not answer any of the questions on the astronomy concepts survey and was eliminated from the study. Five more respondents were eliminated because they were either teacher's aides (2), preservice teachers (2), or working for other school districts (1). Accounting for elimination and attrition, a total of 30 teachers remained in the sample. This group consisted of 15 second grade teachers, 2 third grade teachers, and 13 first grade teachers.

CONTROL OF EXTRANEOUS VARIABLES

Two extraneous variables controlled in this investigation were (1) teaching experience with extensive astronomy units other than *Beyond The Earth*, and (2) prior interest in astronomy. A respondent's previous experience with a hands-on, elementary level, astronomy unit was documented and measured by questions 6C through 6G of the questionnaire. Teachers in either the experimental or control groups were eliminated from the study if the following conditions were met: the response to 6C and D was "yes," the unit was taught more than once in the three years prior to the study, took six or more class sessions to complete, and dealt with four or more of the topics covered by *Beyond The Earth*. One teacher in the experimental group and four teachers (one third grade and three first grade) in the control group were eliminated because of their extensive astronomy teaching experience.

This investigation was designed to determine what effect astronomy teaching experience has on the astronomy concepts of elementary school teachers. However, a subject's prior interest in astronomy was a confounding variable that needed to be controlled. Therefore, teachers in either group had to be eliminated if their *past interest* in astronomy was too high. "Past interest" was operationally defined as the number of astronomy activities a subject engaged in three years prior to the study -- the time when teachers in the experimental group began using *Beyond The Earth*.

Past astronomy interest was measured by questions on the interest assessment labeled "three years ago" (see Figure 2). The *mean past interest score* received by the 32 first through third grade teachers who participated in the study was 5.87 points. The *standard deviation of the past interest scores* was 4.41 points. Teachers were defined as having "high previous astronomy interest" if their past interest score was greater than one standard deviation above the mean, or 10.28 points. Because subjects could only receive integer scores on the assessment, teachers scoring 10 points or higher on past astronomy were eliminated from the study. One teacher in the experimental group and two first grade teachers in the control group were eliminated because their past interest score equaled or exceeded 10 points. Two control teachers (one first grade and one third grade), already eliminated for previous astronomy teaching experience, also had past interest scores exceeding one standard deviation above the mean.

To monitor other variables that might affect the internal validity of this study, the subjects in the experimental (N = 12) and control (N = 10) groups were compared on the basis of average age, sex, average years of teaching experience, highest college degree received, and prior course work in astronomy. This information was gathered by demographic questions 1 though 5.

Two-tailed t-tests for two independent samples were used to determine whether differences between the two groups' *mean age* and *mean years of teaching experience* were significant at the p = 0.05 level. The Fisher-Exact Test was used to determine whether differences between the distributions of *males and females*, *highest college degrees*, and *formal astronomy course work* was significant between groups. These tests showed that differences between experimental and control groups were not significant at the p = 0.05 level.

RESEARCH HYPOTHESES

The following hypotheses were tested in this study:

H_1: *Elementary teachers who have taught from "Beyond The Earth" will show greater gains in astronomy interest compared to control teachers who have not used this unit.*

H_2: *For each concept survey item, elementary teachers who have taught from "Beyond The Earth" will demonstrate a more sophisticated understanding of the idea being examined compared to control teachers who have not used this unit.*

H_3 = *Elementary teachers who have taught from "Beyond The Earth" will have a higher total score on the astronomy concepts survey compared to control teachers who have not used this unit.*

RESULTS

Analysis of the Astronomy Interest Assessment

Teachers in the experimental and control groups each received two scores on the astronomy interest assessment. One score (*past interest*) corresponded to a teacher's astronomy interest three years prior to participating in this study. The other score (*present interest*) corresponded to a teacher's interest at the time of the workshop. Teachers could receive integer scores ranging from 0 to 43 points for either their past or present astronomy interest. The *mean past interest scores* received by the experimental and control groups were 4.83 and 3.30, respectively. The *mean present interest scores* received by the experimental and control groups were 9.67 and 4.90, respectively.

The difference (D) between each respondent's past and present interest scores was calculated. Teachers whose present interest scores were higher than their past scores had positive values for D. Teachers with negative values for D had present interest scores that were lower than past scores. If there was no difference between past and present astronomy interest, D = 0. The difference scores received by all teachers in this study was ranked. A rank of 1 was assigned to the lowest D and tied scores received the average rank.

The one-tailed, Wilcoxon-Mann-Whitney test was used to test the null hypothesis: H_o = The difference scores (D) received by the teachers in the experimental group are not significantly higher than the difference scores received by the controls. The sum of the ranks of teachers in the experimental group was $W_E = 174$. For the control group, the sum of the ranks was $W_C = 79$. After adding a correction factor for tied ranks to the Wilcoxon formula (Siegel and Castellan, 1988), a value of $z = -2.43$ was calculated. For this value of z, the probability of $W_E = W_C$ is $p = 0.0075$. Since $p \leq 0.05$, H_o was rejected in favor of H_1: *Teachers who used "Beyond The Earth" showed greater gains in their astronomy interest scores compared to control teachers who had not used this unit.*

Astronomy Concept Survey Item Analysis

For each item on the astronomy concepts survey, scores received by the experimental and control groups were arranged in a cumulative frequency distribution. The differences between cumulative distributions was calculated and the one-tailed, Kolmogorov-Smirnov test for two independent samples was used to test the null hypothesis. For each question analyzed, H_o was the same: the distribution of scores received by the experimental group was not stochastically larger than the scores earned by the controls.

Because m and n were both less than 25, the Kolmogorov-Smirnov statistic for small samples, $mnD_{m,n}$, was calculated for each item. For the $\alpha = 0.05$ level of significance, the critical value for $mnD_{m,n}$ is 60.00 when m = 12 and n = 10. Therefore, H_o was accepted for items in which $mnD_{m,n} < 60.00$.

Because none of the values of mnDm,n exceeded the critical value, the null hypothesis was accepted for all items on the survey. *Ho: For each question, the distribution of scores received by teachers in the experimental group was not stochastically larger than the scores received by the control teachers.*

Analysis of Astronomy Concept Scores

The sum of the scores earned for the items on the concept survey was a subject's *astronomy concept score* . Teachers in the experimental and control groups were ranked according to their concept scores on a scale from 1 to 22. The rank of 1 was assigned to the lowest astronomy concept score received by the teachers and tied scores received the average rank.

The one-tailed, Wilcoxon-Mann-Whitney test was used to test the null hypothesis: H_o = The astronomy concept scores received by the teachers in the experimental group are not significantly higher than the concept scores received by the controls. The sum of the ranks of teachers in the experimental group was $W_E = 133.5$. For the control group, the sum of the ranks was $W_C = 119.5$. After adding a correction factor for tied ranks to the Wilcoxon formula (Siegel and Castellan, 1988), a value of $z = 0.33$ was calculated. For this value of z, the probability of $W_E = W_C$ is $p = 0.37$. Since $p > 0.05$, H_o was accepted. *Teachers who used "Beyond The Earth" did not have higher astronomy concept scores compared to control teachers who did not use this unit.*

Description Of The Astronomy Misconceptions Held By The Teachers

The Kolmogorov-Smirnov tests failed to uncover statistically significant differences in the way that the two groups of teachers responded to any of the questions on the astronomy concepts survey. Teachers who used *Beyond The Earth* appeared to hold the same astronomy misconceptions as control teachers who had not used this unit. Table 1 summarizes how the 22 teachers responded to questions on the astronomy concepts survey.

The following astronomy misconceptions were pervasive among the 22 elementary school teachers who participated in this study:

- *Over 75% of the elementary school teachers did not hold the correct conception concerning the Earth-Moon distance. These teachers believed that the Moon's distance is roughly between 2 and 7 Earth diameters.* This result is similar to those reported by Sadler (1987), who reported that "almost all" of the 25 ninth grade earth science students he interviewed drew sketches in which the Earth and Moon were *less than one Earth diameter apart*. However, the elementary school teachers in this study were able to more accurately estimate the Earth-Moon distance than the elementary education majors who participated in the author's pilot study (Shore, 1990). Of the 87 education majors surveyed, 90% drew diagrams in which the Earth and Moon were less than two Earth diameters apart.
- *Over half the teachers in the study (59%) believed that the stars are closer to the Earth than Pluto.* This result corroborates the author's pilot study (Shore, 1990), which found that 58% of the 87 education majors surveyed believed there are "hundreds and thousands of stars between the Earth and Pluto." A possible origin of this misconception is described by Cohen (1982), who found that several of the inservice elementary teachers he

interviewed believed that the stars are "small points of light in the sky." Teachers holding the misconception that the stars are tiny points of light scattered throughout space may have also concluded that there are stars between Pluto and the Earth.

- *The vast majority of the teachers (82%) held the misconception that it is hotter in Boston during the summer because the Sun is closer to the northern hemisphere.* This finding is somewhat supported by Schoon (1988), who found that more than 72% of the 226 college students he surveyed believed summer is warmer than winter because the Sun is closer to the Earth. However, Schoon's study was not designed to distinguish between subjects who believed that "the Sun is closer to the Earth" and those who thought "the Sun is closer to the Earth's northern hemisphere." The results of this investigation suggest that the role that the Earth's tilt plays in the seasons was not only misunderstood by these teachers, but may be misinterpreted by others as well. People who identify the Earth's tilt as the cause of the seasons may not actually hold the scientific explanation.
- *Nearly half the teachers (45%) believed that the Moon's phases are caused by the Earth's shadow.* This finding corroborates the results reported in Cohen's study of the lunar phase conceptions of 50 preservice and inservice elementary school teachers (Cohen, 1982). Cohen found that 48% of these subjects thought that the Earth's shadow causes the Moon's phases.

Although they did not represent the majority of the participants, some of the elementary school teachers in this study appeared to possess other astronomy misconceptions:

- *Over one third of the teachers (36%) had difficulties identifying the correct scale distance between the Earth and the Sun.* Because Question 3 involved mathematical estimation, it is possible that the incorrect responses were random guesses as opposed to firmly held misconceptions. Happs and Coulstock (1987) reported that many of the adults they interviewed had difficulty estimating the distance between the Earth and Sun. Twenty of their 24 subjects were unable to attach any kind of number to their conception and could only make qualitative comparisons between the Earth-Sun distance and the Earth-Moon distance. Similarly, teachers in this study may have resorted to guessing because they could not convert their conceptions to a scaled distance.
- *Over one quarter (27%) of the teachers selected either July 15, August 15, or September 15 as the longest day of the year in Boston.* The misconception that the days get progressively longer during the summer months (June, July, and August) has also been reported by Schoon (1988), who found that 26% of the college students he surveyed held this belief.

- *Nearly one third of the teachers (32%) believed that it takes one day for the Moon to spin once on its axis.* Twenty-seven percent of the college students surveyed by Schoon (1988) believed that it takes *one day for the Moon to orbit once around the Earth*. As Schoon suggested, this misconception probably arises from observation. Since the Moon rises and sets daily, it does *appear* to take only one day to go once around the Earth. The belief that it also takes one day for the Moon *to spin on its axis* may arise directly from this misconception. Elementary teachers who recognized that the Moon's motion is geosynchronous but naively believed that the Moon takes only a day to complete one orbit, may have concluded that the Moon takes a day to spin once.
- *The large number of "no responses" to Question 12 suggests that a large percentage of the teachers (27%) may hold the misconception that the Moon does not spin.* Forty percent of the education majors surveyed by the author in the pilot study (Shore, 1990) believed that the Moon does not rotate.

The elementary school teachers also demonstrated that they hold a number of scientific astronomy concepts :

- *The relative size of the Moon compared to the Earth seemed to be understood by the majority of the teachers (82%).* The elementary school teachers appeared to do significantly better at estimating the relative size of the Moon than has been reported elsewhere. In Sadler's interviews with 25 high school earth science students, he found that "almost every student drew the Earth, Moon and Sun either the same size or within a factor of 2x of each other's diameter" (Sadler, 1987). In the author's pilot study, only 59% of the education majors were able to draw the relative size of the Earth and Moon correctly (Shore, 1990).
- *The vast majority of the teachers (91%) appeared to hold the correct explanation for what causes night and day.* Surprisingly, only 72% of the college students studied by Schoon (1988) were able to correctly identify the Earth's rotation as the cause for night and day. In his study, 20% of the college students held the misconception that the Earth's orbit about the Sun causes the day/night cycle while 4% thought the cycle is caused by the Sun orbiting the Earth. In comparison, these two misconceptions were held by only 9% (2 of 22) and 0% of the elementary teachers, respectively.
- *Almost 2/3rds of the teachers (64%) correctly identified June 15 as having more hours of daylight than July 15, August 15, or September 15 (in the northern hemisphere).* Compared to Schoon's sample of adults, the elementary school teachers in this investigation appeared to hold more accurate conceptions concerning the length of summer days. In Schoon's study, only 39% of the adults surveyed maintained (correctly) that the

number of daylight hours progressively shorten during "the summer months." Thirty-six percent of his adult sample held the misconception that "during the summer months, the amount of daylight is more than the day before" (Schoon, 1988). However, because Schoon did not define "summer months" or specify that this question referred to the northern hemisphere, his results need to be interpreted with caution.

- *The vast majority of the teachers correctly identified the period of (1) the Earth's rotation (100%), (2) the Earth's revolution about the Sun (100%), (3) the Moon's orbit around the Earth (95%), and (4) the Moon's orbit around the Sun (86%).* Compare the results of (3) to those reported by Schoon (1988). In his study, only 59% of the college students were able to correctly identify one month as the time it takes the Moon to orbit the Earth.

SUMMARY

Implications Of The Study

Theoretical Implications

Astronomy teaching experience may not be a context that promotes conceptual change in elementary school teachers: Although researchers have hypothesized that teaching experience may have been responsible for improving the science conceptions of *preservice* elementary teachers (Gabel, Rubba, and Franz, 1977) and *preservice* high school physics teachers (Gunstone and Northfield, 1986) they studied, the results of this investigation failed to support the theory that science teaching is a context that encourages the acceptance of scientific conceptions by *inservice* elementary school teachers.

Elementary school teachers may not be an appropriate population to use to measure the effect of science teaching experience on conceptual change. First, elementary school teachers typically do not have strong science backgrounds (Dystra, 1987). While this deficiency contributes to anxiety and a lack of confidence in their ability to teach science (James and Hord, 1988), it may also contribute to what this study found to be their resistance to adopt new conceptions. When their science misconceptions are challenged by new information, elementary school teachers may avoid mentally working through the problem because they believe they can't "do science" and are too afraid to try.

In addition, some researcher have suggested that, generally speaking, elementary school teachers may not be formal operational thinkers (Kolb, 1976). Lawson and Weser (1989) have suggested that concrete thinkers may not possess the reflective skills necessary to consider various alternative theories, the available evidence, and the arguments in favor of accepted scientific conceptions. If the ability to think formally is a prerequisite for conceptual change, then elementary school teachers may be at a disadvantage when it comes to adopting new ideas.

Increased astronomy interest may not be a factor in improving the astronomy conceptions of elementary school teachers: The science attitudes of elementary school teachers have been extensively studied because it is widely believed that teachers with positive attitudes will be more likely to teach science than teachers with negative attitudes (Sherwood and Gabel, 1980). However, researchers have also discovered that interest in science does not predict how inservice or preservice elementary teacher's will teach science (Koballa, 1986) or how well they will perform on science content achievement tests (Stephan and McCormack, 1985). The results of this investigation additionally suggest that increasing a teacher's interest in science does not necessarily lead to improvements in their science concepts.

Other reasons may explain why increased astronomy interest did not lead to better astronomy conceptions. It is possible that the astronomy conceptions of the experimental group would have been significantly better than the controls had some kind of "threshold" level of astronomy interest been exceeded. The mean present astronomy interest score of the teachers using *Beyond The Earth* was only 9.67 out of a possible 43 points. Perhaps interest in astronomy, although apparently increased as a result of astronomy teaching, was still not high enough to arouse the teachers' curiosity or overcome their science anxiety.

Practical Implications

The misconceptions held by inservice elementary school teachers may need to be directly confronted: The results of this investigation suggest that teaching from an activity-based unit designed to address student astronomy misconceptions may not be enough to improve the astronomy conceptions of elementary school teachers who use it. Furthermore, although the experimental group in this study received extensive, on-going support from their elementary science coordinator, it appears that the teachers may have needed even more assistance than this school system provided.

What else could this school system have done to improve the astronomy conceptions of the teachers using *Beyond The Earth*? According to the elementary science coordinator, the workshops and private tutorial sessions she led focused on showing second grade teachers how to do *Beyond The Earth* activities and *not* on uncovering and addressing astronomy misconceptions held by the teachers. The astronomy conceptions of the teachers using *Beyond*

The Earth may have improved had these teachers been given direct opportunities to examine and test their beliefs.

"Beyond The Earth" may have reinforced teacher-held misconceptions: While hands-on activities are generally designed to encourage the adoption of correct science conceptions, they can inadvertently reinforce private theories, as well. Cohen (1982) described how the popular "Moon on a stick" activity can promote the Earth shadow explanation for the lunar phases. In this activity, a styrofoam ball (representing the Moon) is placed on the end of a pencil. The student holds the Moon model and stands 6 to 10 feet away from a light source (representing the Sun). As the student moves the Moon model in a circle around his/her head (representing the Earth) and the relative position of the "Moon," "Earth," and "Sun" change, the styrofoam ball will exhibit each of the lunar phases.

Although the "Moon on a stick" activity demonstrates why the Moon changes phase, it occasionally generates confusion. When the student stands directly between the light source and the styrofoam ball, the shadow of the student's head is often cast on the Moon model -- causing an "eclipse." Because of this phenomenon, Cohen has suggested that students may come away from this activity even more convinced that the Earth's shadow causes the Moon's phases.

The "Moon on a stick" activity was described at length in *Beyond The Earth.* Although the diagrams accompanying the activity show a child holding the ball above his head (which would prevent the child's shadow from darkening the "full moon"), the written description of "Moon on a stick" does not explicitly caution teachers about the confusion that might result if the child's shadow is cast on the "Moon." Because *Beyond The Earth* lacks this warning, teachers who tried or observed their students doing this lesson may have had their previous misconceptions concerning lunar phases and the role of the Earth's shadow reinforced.

In addition, there were diagrams in *Beyond The Earth* that may have reinforced astronomy misconceptions held by the elementary teachers. Sadler (1987) suggested that textbook figures not drawn to scale may promote misconceptions concerning the size and distance of astronomical objects, and there are several examples of such diagrams in the teacher's guide. For example, the Earth-Moon distance is depicted as being under two Earth diameters several times in *Beyond The Earth.* Drawings of the Earth-Sun distance are greatly underestimated as well. Although the correct distances between the Earth and Moon (240,000 miles) and the Earth and Sun (93,000,000 miles) are stated in the manual, accurate representations of these separations are never presented to the reader.

Suggestions For Further Research

Classroom monitoring: Since the science coordinator provided evidence suggesting that teachers were engaged in some kind of astronomy instruction, we can probably rule out the possibility that teachers in the experimental group avoided using *Beyond The Earth* altogether. However, the actual extent to which the unit has been used and whether it has been used correctly is unknown. Detailed information concerning how the elementary school teachers use *Beyond The Earth* may help explain why their astronomy conceptions did not appear to evolve.

The following questions could be addressed by an ethnographic study of the second grade classrooms using *Beyond The Earth:* Are the teachers doing all the hands-on activities described in the teacher's guide, or are they selecting to cover certain activities? Are teachers doing the activities correctly? If activities are being done correctly, are teachers using their misconceptions to explain the results to their students? To what extent are the teachers using *Beyond The Earth* lecturing? Are the teachers stressing the acquisition of astronomy facts over astronomy concepts? Classroom monitoring might also determine if and how *Beyond The Earth* activities and diagrams in the teacher's guide might be reinforcing teacher-held astronomy misconceptions?

The relationship between the cognitive development and astronomy conceptions of elementary school teachers: Lawson and Thompson (1987) discovered that concrete operational seventh graders held more misconceptions concerning genetics and natural selection than their formal operational cohorts. Lawson and Weser (1989), who found the same results in a population of college students, additionally determined that concrete operational college students held their biology misconceptions more tenaciously than their formal peers.

Do the results of these studies apply to elementary school teachers, as well? Because the results of this investigation suggest that neither astronomy teaching experience nor increased interest in astronomy affects the astronomy misconceptions held by elementary teachers, it may be worthwhile to determine what role cognitive development plays in the formation and apparent tenacity of an elementary teacher's astronomy beliefs, i.e. do concrete operational elementary teachers have more astronomy misconceptions than their formal operational peers? Do concrete operational teachers hold on to their astronomy misconceptions more firmly than teachers who reason formally ?

Studying the effect of astronomy teaching experience on the astronomy conceptions of high school or college science teachers: High school and college level science teachers generally have much stronger backgrounds in science than elementary school teachers. As a result, high school and college level teachers may be more secure about their ability to examine and judge the appropriateness of their science conceptions. Furthermore, researchers have suggested that there may be proportionally more formal operational thinkers among high school and college science teachers than among elementary school teachers (Kolb, 1976). *Therefore, studying the effect that astronomy teaching experience has on the astronomy conceptions of high school or college science instructors may avoid the complications that result from a teacher's (1) lack of confidence in their ability to "do science" and (2) inability to reason formally.*

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FIGURE 1: DEMOGRAPHIC QUESTIONNAIRE

1. **Sex**: (circle one) M F

2. **Age**: __________

3. **College Education**: Please check the college degrees you have completed.

   ____ Bachelors degree (BA, BS, etc.)
   ____ Masters degree (MA, MS, MAT, etc.)
   ____ Doctorate (PhD, EdD, etc.)

4. **Teaching Experience**:

   a) What grade do you teach now? _____________
   b) Total years of teaching experience ___________

5. **Astronomy Background** (check as many as apply):

   ____ Astronomy or earth science class(es) in high school.
   ____ College level astronomy course(s).
   ____ Inservice workshop(s) in astronomy.
   ____ Amateur astronomer/Astronomy is a hobby of yours.
   ____ Other (please specify)______________________________

6. **Astronomy Teaching Experience**:

a) How many times have you taught the second grade unit, *Beyond The Earth* (circle one)?

never once twice three times 4 times or more

b) Do you currently teach *Beyond The Earth?* ____ Yes ____ No

c) Have you ever taught an astronomy unit **other than** *Beyond The Earth?* (check one)

____ No (skip parts d through g) ___ Yes (please answer parts d through g)

d) Was this unit *hands-on* (i.e. activity based)? ____ Yes ____ No

e) Circle the approximate number of class sessions (science periods) you needed to complete this unit:

1 - 5 6 - 10 over 10

f) Circle the number of times you have used this unit during the last 3 years:

Once 2 times 3 times or more

g) Please check the topics that you covered in this unit:

_____ Cause for day and night
_____ Cause for the seasons
_____ The Moon
_____ Gravity
_____ Constellations
_____ The Sun
_____ The stars
_____ Galaxies
_____ Other (describe):

_____ The Solar System _____ Life on other worlds

FIGURE 2: ASTRONOMY INTEREST ASSESSMENT

The questions below concern your participation in astronomy related activities. Please answer each of these questions for both the present (**NOW**) and recent past (**THREE YEARS AGO**). Circle the letters that correspond to what you feel is the best response.

1. Approximately how many planetarium shows do you see a year?

Now A. none B. 1 C. 2 D. 3 E. more than 3
Three years ago A. none B. 1 C. 2 D. 3 E. more than 3

2. Look at the list of popular science magazines below:

Scientific American *Astronomy* *Science Digest* *Discover*
Sky and Telescope *Popular Science* *Science News* *Omni*

How many of these magazines do you subscribe to?

Now A. none B. 1 C. 2 D. 3 E. more than 3
Three years ago A. none B. 1 C. 2 D. 3 E. more than 3

3. Look at the list of science education magazines below:

Science and Children *Science Teacher* *Connect* *Universe in the Classroom*
The Physics Teacher *Science Scope* *MASThead*

How many of these magazines do you subscribe to?

Now A. none B. 1 C. 2 D. 3 E. more than 3
Three years ago A. none B. 1 C. 2 D. 3 E. more than 3

4. Approximately how many books about astronomy do you own?

Now A. none B. 1 - 2 C. 3 - 4 D. 5 - 6 E. more than 6
Three years ago A. none B. 1 - 2 C. 3 - 4 D. 5 - 6 E. more than 6

5. Approximately how many science fiction books do you read a year?

Now A. none B. 1 C. 2 D. 3 E. more than 3
Three years ago A. none B. 1 C. 2 D. 3 E. more than 3

6. Approximately how many constellations can you *name and locate* in the sky?

Now A. none B. 1 - 2 C. 3 - 4 D. 5 - 6 E. more than 6
Three years ago A. none B. 1 - 2 C. 3 - 4 D. 5 - 6 E. more than 6

7. Approximately how many times a year do you look at stars, planets, or other astronomical objects through a telescope or pair of binoculars?

Now	A. none	B. 1	C. 2	D. 3	E. more than 3
Three years ago	**A. none**	**B. 1**	**C. 2**	**D. 3**	**E. more than 3**

8. Look at the list of statements below and check as many as apply to you now. Also check those statements that were true three years ago:

NOW:

___ I own a telescope.
___ I am a member of the NSTA.
___ I have seen the IMAX movie, *The Dream Is Alive*.
___ I have seen the IMAX movie, *Hail Columbia*.
___ I have seen the PBS series, *Cosmos*.
___ I have attended at least two astronomy inservice workshops.
___ I have lead an astronomy inservice workshop.
___ I have lead astronomy observation nights ("star parties") for children.
___ I have taken a college extension class in astronomy.

THREE YEARS AGO:

___ I owned a telescope.
___ I was a member of the NSTA.
___ I had seen the IMAX movie, *The Dream Is Alive*.
___ I had seen the IMAX movie, *Hail Columbia*.
___ I had seen the PBS series, *Cosmos*.
___ I had attended at least two astronomy inservice workshops.
___ I had lead an astronomy inservice workshop.
___ I had lead astronomy observation nights ("star parties") for children.
___ I had taken a college extension class in astronomy.

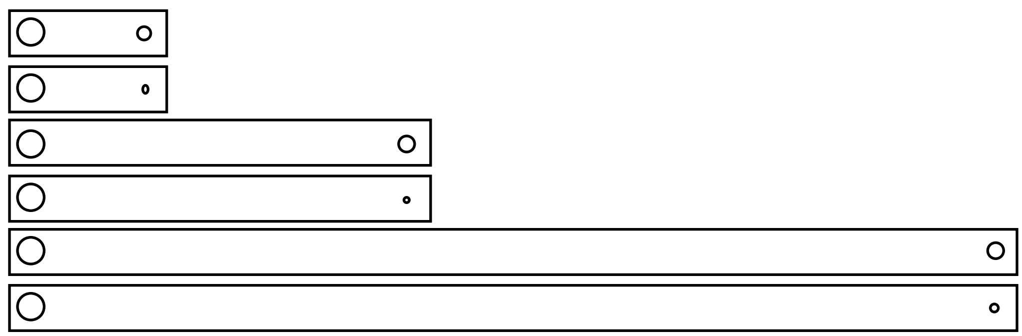
9. Write the names of as many U.S. Space Shuttles as you can in the space provided below:

(Shuttle names):
____
____
____

Approximately how many of these Space Shuttle names did you know three years ago? ______

FIGURE 3: ASTRONOMY CONCEPTS SURVEY

(1) Place a check mark in front of the most accurate model of the Moon in relative size and distance from the Earth (*The larger object in each picture is the Earth*).



(2) Look at the list of objects below:

The Moon
The Sun
Clouds
The Stars
Pluto

Place a check mark in front of the statement which you believe correctly lists these objects **starting with the closest object** to the Earth and **ending with the object that is farthest away**.

______ Stars << Clouds << Moon << Sun << Pluto

______ Clouds << Stars << Moon << Sun << Pluto

______ Clouds << Moon << Stars << Sun << Pluto

______ Clouds << Moon << Sun << Stars << Pluto

______ Clouds << Moon << Sun << Pluto << Stars

More

Multiple Choice:

_____ (3) If you used a basketball to represent the Sun, about how far away from the basketball would you put a scale model of the Earth?

A. 1 foot, or less
B. 5 feet
C. 10 feet
D. 25 feet
E. 100 feet

_____ (4) What causes night and day?

A. The Earth spins on its axis.
B. The Earth moves around the Sun.
C. The Sun moves around the Earth.
D. The Moon blocks out the Sun's light.
E. The Earth moves in and out of the Sun's shadow.

_____ (5) On which date below do you have the most hours of daylight in the Boston area?

A. June 15
B. July 15
C. August 15
D. September 15
E. all dates are the same

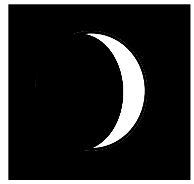
_____ (6) The **main reason** that Boston is hotter in the summer than it is in the winter is that

A. the Sun is closer to the Earth during the summer.
B. the Sun is closer to the northern hemisphere during the summer.
C. the Sun's height above the horizon is greater during the summer.
D. the Sun gives off more energy during the summer.
E. there are fewer clouds to block the Sun during the summer.

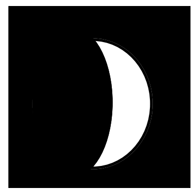
More

More Multiple Choice

_____ (7) One night you looked at the Moon and saw this:



A few days later you looked at the Moon again and saw this:



What causes this change?

A. Clouds block less of the Moon.
B. The Moon has moved out of the Earth's shadow.
C. The Moon has moved out of the Sun's shadow.
D. We're seeing less of the side of the Moon that is facing away from the Sun.
E. The Moon is black and white and rotates on its axis.

QUESTIONS 8 THROUGH 12 REFER TO THE LIST BELOW:

A. hour
B. day
C. week
D. month
E. year

Using the list above, choose the best estimate for each of the events given below. *You may use a choice more than once.*

_____ (8) The time it takes the Earth to turn once on its axis.

_____ (9) The time it takes the Earth to go once around the Sun.

_____ (10) The time it takes the Moon to go once around the Earth.

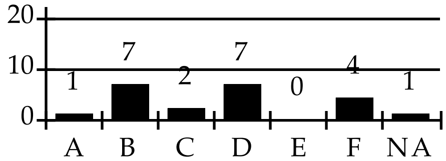
_____ (11) The time it takes the Moon to go once around the Sun.

_____ (12) The time it takes the Moon to turn once on its axis.

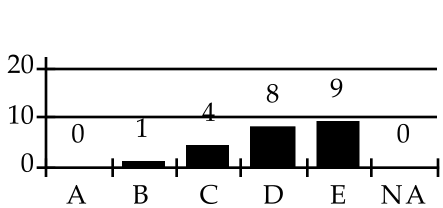
You're done...thanks

TABLE 1: Teacher Responses To Items On The Astronomy Concepts Survey

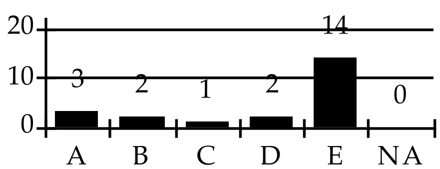
Question 1



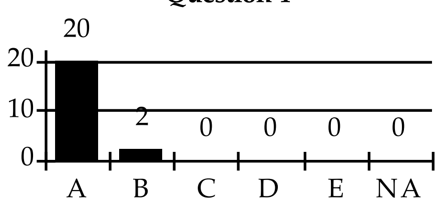
Question 2



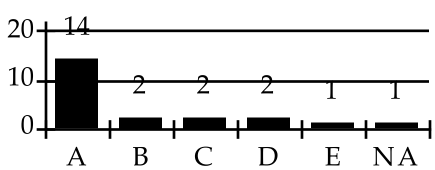
Question 3



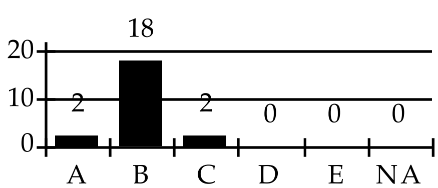
Question 4



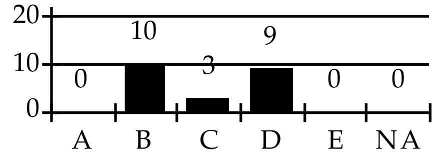
Question 5



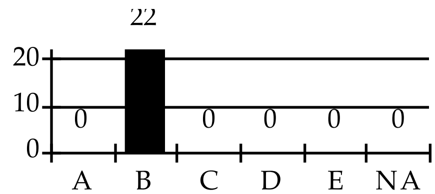
Question 6



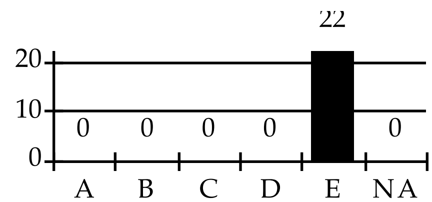
Question 7



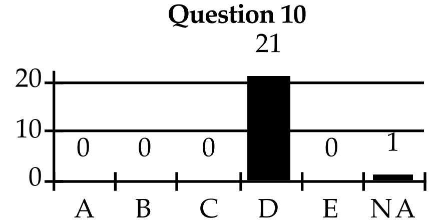
Question 8



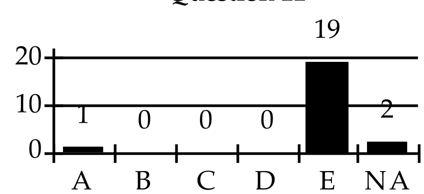
Question 9



Question 10



Question 11



Question 12