AN ANALYSIS OF THE EFFECTS OF A FIVE-DAY PROFESSIONAL

DEVELOPMENT EXPERIENCE ON IN-SERVICE K-12 TEACHERS'

CONTENT KNOWLEDGE AND SELF-REPORTED CONFIDENCE IN

THEIR ABILITY TO TEACH ASTRONOMY CONTENT

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Table of Contents

Introduction

Research has revealed that the ability of teachers to effectively teach science content is directly related to their own content knowledge (US Department of Education [USDOE],1999). Teachers who lack deep, coherent understanding of the subjects they teach tend to emphasize memorization and are limited in their ability to teach creatively (Gess-Newsome, 2001). Research has shown that teachers lack sufficient astronomy content knowledge (Brunsell & Marcks, 2005; Atwood & Atwood, 1996). A contributing aspect to a teacher's content understanding is their formal training in the subjects they are teaching. Teachers may be able to improve their content understanding by completing further coursework or attending professional development workshops (Slater, Carpenter, & Safco, 1996; National Science Board [NSB], 2010). Providers of these professional development workshops require further information about current teacher understanding of astronomy topics, how teachers can best be trained, and what types of trainings result in greatest teacher gains (Bailey & Slater, 2004; Brunsell & Marcks, 2005). This study will help to inform professional development providers who require further information about in-service teachers' understanding of astronomy content, and how teachers can best be trained.

This paper describes teachers' pre and post results on the Test of Astronomy Standards (TOAST) assessment instrument and a supplemental survey (which included self-reported confidence in their ability to teach astronomy content). The pre and post assessments were administered to sixty K-12 teachers prior to and after a five-day astronomy training workshop. Results indicate that elementary and middle-school

teachers lack sufficient astronomy content knowledge in the content areas they are currently responsible for teaching. However, these groups of teachers also experienced the greatest gains in content knowledge and self-reported confidence from a multi-day training. By comparison, high school teachers scored better on pre and post tests and experienced only slight gains in content and self-reported confidence. The implications of these findings suggest that multi-day professional development opportunities do help to develop better astronomy content understanding and self-confidence in K-8 teachers.

Review of Literature

This study is grounded in a significant body of research that affirms the relationship between student learning and teacher capability. The ability of teachers to provide high quality learning experiences for students is directly related to their own understanding and ability to communicate the subject matter (USDOE, 1999; Schmidt, 2001, Darling-Hammond & Youngs, 2002). Research has asserted the relationship between teacher quality (teacher ability, teacher education, and teacher experience) and student achievement (Greenwald, Hedges, & Laine, 1996; Croninger, Rice, Rathburn, & Nishio, 2003), and the relationship between teachers' content knowledge and student test scores (USDOE, 1999). Teachers with superficial content understanding tend to emphasize memorization of isolated facts and are limited in their ability to teach in a creative and innovative manner (Gess-Newsome, 2001). Schmidt (2001) hypothesized that teachers with weak science content background will create instructional activities for children that are science "neutered"; such as focusing on cooperative learning or manipulating physical objects. There is no shortage of research in the current literature to

confirm the clear, strong connection between what teachers know, and their ability to convey this information to their students.

Given that strong teacher content knowledge is critical for effective instruction, many studies seek to measure teachers' understanding of content through the use of standardized tests. However, other researchers have argued that using standardized tests is an insufficient measure of the range of teachers' skills that are needed for instruction, and that standardized tests can only measure teachers' basic knowledge and not their pedagogical knowledge or their teaching practice (USDOE, 1999). Furthermore, the ability of teachers to score well on standardized tests does not always translate to student understanding. For example, Sadler, Coyle, Miller, Cook-Smith, Dussault, and Gould (2010) found several test items where teachers scored perfectly, yet their student scores averaged approximately 50% correct. Thus, the ability of teachers to correctly answer test questions may not necessarily result in their students' ability to understand the same concept in their classroom. It also raises the question of whether or not improving a teacher's content understanding will ultimately translate into improved student understanding of the same concept (Sadler et al., 2010).

Another contributing aspect to a teacher's content understanding is their formal training in the subjects they are teaching. Teachers are often assigned classes in areas where they lack sufficient training or education. For example, the teacher may have a bachelor or masters degree, but their coursework may or may not include the content they are currently assigned to teach (Ingersol, 1998). In 1999, a US Department of Education survey found that virtually all teachers had a bachelor's degree, and 45 percent had a master's degree. However, 6 percent of high school science teachers had an

undergraduate or graduate major or minor that did not match their main teaching assignment (USDOE, 1999). Similarly, a study by the National Science Board (2010) found that during the 1999-2000 school year, only 55% of high school students, and only 18% of middle school students, received physical science instruction (chemistry, earth science, and physics) from a teacher with a major or minor in physical sciences. With the introduction of the federal No Child Left Behind Act in 2001 and the requirement that districts hire "highly qualified" teachers, there has been an improvement in the number of students currently receiving science instruction from teachers with a bachelor degree and demonstrated subject area competence (NSB, 2010). However, the National Science Board (2010) found that the rates of in-field science teaching (defined as teachers who taught science and had a degree major in science or science education) were still much lower at lower grade levels. For example, about 40% of fifth grade students in public schools were taught science by an in-field teacher (in 2004), but 80% of these students were taught by an in-field science teacher when they reached eighth grade (in 2007). These numbers only improved further in high school courses, with 82% of high school physical science teachers and 93% of biology teachers teaching in-field (NSB, 2010).

Although many researchers have sought to assess teacher content knowledge in various science content areas, astronomy is an area where there is a noted lack of information about the content needs of in-service teachers, as evidenced by a lack of large numbers of published studies in this area. Further research into in-service teachers' understanding of astronomy topics, as well as a need for study into effective methods for preparing teachers, is needed (Bailey & Slater, 2004). In one study, Brunsell and Marcks (2005) used the Astronomy Diagnostic Test (ADT) to assess the content understanding of

in-service K-12 teachers and found a lack of understanding of astronomy concepts, particularly in the elementary and middle school levels. The mean scores were 35% for elementary-school teachers, 50% for middle-school teachers, and 64% for high-school teachers (Brunsell & Marcks, 2005). In contrast to these low scores, another study (using a different diagnostic survey) has suggested that teachers may be reasonably proficient in the content they are teaching. Sadler et al. (2010) recently released a new instrument (the Astronomy and Space Science Concept Inventory) that is specifically aligned to the K-12 National Science Education Standards and the AAAS Benchmarks for Science Literacy. The results of a pilot of this instrument on K-12 students and their teachers suggest that teachers generally perform well on questions that address content they are currently teaching. [At the time that data was collected for this research paper, the Astronomy and Space Science Concept Inventory had not yet been released, thus the TOAST survey was used as an assessment of K-12 teacher's astronomy content knowledge].

While there remains a need for further study in the area of in-service teachers' astronomy content understanding, studies that detail the content knowledge of pre-service teachers may provide some insight. Atwood and Atwood (1996) detailed the content understanding of elementary pre-service teachers and found that only 1 in 49 had a scientific understanding of the concept of seasons. Atwood and Atwood (1995) also studied the content understanding of elementary pre-service teachers, and found that 27 of 50 teachers had alternative conceptions of the causes of day and night; the most common alternative conception being that day/night is caused by earth's revolution about the sun. Trundle, Atwood and Christopher (2002) studied the scientific understanding of

pre-service elementary teachers in the area of moon phases, and found that 61.4% did not understand that the moon revolves around the earth, and 93% did not understand that the moon is always half lit. Thus, in studies of both pre-service and in-service teachers, an alarming pattern emerges: teachers lack a deep, coherent understanding of astronomy content, and this is especially true in the elementary level. These results are consistent with other research (non-specific to astronomy content) that shows that teachers in the elementary and middle-school grades, in general, lack strong science backgrounds (Schmidt, 2001).

In addition to a deep understanding of the content they teach, teachers must also know *how* to convey that content, including how students learn best, as well as common student misconceptions. This understanding of *how* to best teach a concept (not just the concept itself), is pedagogical content knowledge. A teacher's pedagogical content knowledge (PCK) includes their repertoire of a variety of analogies, representations, strategies, examples and demonstrations, as well as an understanding of what makes a subject difficult, and what students commonly misunderstand (Shulman, 1986). When a teacher has PCK they can better communicate their knowledge in more effective and flexible ways. Teachers can gain or improve their PCK from reflecting on their own teaching practice and/or by taking specific courses (such as a course that highlights alternative student conceptions) (van Driel, Verloop, & de Vos, 1998; van Driel, De Jong, & Verloop, 2002).

When teachers find themselves teaching science content outside of their area of specialization they may or may not choose to complete additional undergraduate/graduate coursework or participate in professional development to increase their content

knowledge. The National Science Board found that in the 2003-2004 school-year almost all public middle-school and high-school science teachers participated in some form of professional development. However, this professional development tended to be in the form of short-term workshops, conferences and training sessions (NSB, 2010). These types of professional development are often criticized for ineffectiveness, largely because of their short duration and their lack of connection to the challenges teachers face in their classrooms. Research suggests that unless professional development programs are carefully designed and implemented to provide continuity between what teachers learn and what goes on in their classrooms and schools, the training is not likely to produce any long-lasting effects on either teacher competence or student outcomes (USDOE, 1999). In their study of professional development of math and science teachers, Garet, Porter, Desimone, Birman, and Yoon, (2001) concluded that there were several important factors leading to results. These included training that: 1) had an extended length of time (sustained and intensive professional development was more likely than shorter professional development to have an impact), 2) focused on a specific academic subject matter, 3) gave teachers an opportunity to learn actively ("hands-on"), 4) was integrated into the daily life of the school (had coherence), (Garet et al., 2001). The National Science Board (2010) summarized the attributes of effective professional development that was most likely to result in teachers changing their instructional practice, gaining subject matter knowledge and improving their teaching in general. The National Science Board stated that professional development is most effective when it:

- Focuses on subject content

- Provides an intensive and sustained approach

- Is presented in a format of teacher network, study group, mentoring, and coaching as opposed to a traditional workshop or conference

- Is connected or related to teachers' daily work

- Emphasizes a team approach and collaboration

- Provides opportunities for active learning (NSB, 2010, p.1-27)

Professional development providers need to take these factors into consideration when trying to design a well-planned, high quality professional development experience for in-service teachers.

Though there is considerable research in best practices for professional development in general, research regarding best practice for preparing teachers to teach astronomy topics is lacking in the extant literature, (Bailey & Slater, 2004). In one study by Slater et al. (1996) where teachers completed a 45 hour in-service course, the teachers experienced a dramatic increase in self-reported confidence levels, intentions to teach more astronomy, and cognitive scores. An important component of this training was the inclusion of training in both astronomy content and pedagogy, as well as a reflective report at the end of every class meeting. In a follow-up longitudinal questionnaire, Slater et al. (1996) found that the teachers' scores in confidence, knowledge and quality of instruction, remained high. This study suggests that teachers are best served by extended professional development experiences that provide training to improve both astronomy content knowledge and pedagogical content knowledge. Brunsell and Marcks (2005) called for better information for designers of professional development in astronomy, stating "because good teaching is dependant on, but not guaranteed by, a depth of content

knowledge, it is important that professional development designers and facilitators have an understanding of the knowledge base of their audience" (p. 44).

This study aims to improve the understanding of the astronomy content knowledge of K-12 in-service teachers, and the effects of training upon them, so as to provide empirical data to inform designers and facilitators of future astronomy workshops.

Methodology

The Test Of Astronomy STandards (TOAST) is a newly developed assessment instrument that was designed for use in an undergraduate course (Slater & Slater, 2008; Slater, 2009; Slater, Slater & Bailey, 2011). The test includes 27 multiple choice questions that were each aligned to various consensus learning goals, including those stated by the American Astronomical Society, the American Association of the Advancement of Science's Project 2061 Benchmarks, and the National Research Council's National Science Education Standards. The TOAST assessment was designed by researchers from the Cognition in Astronomy, Physics and Earth sciences Research (CAPER) Team at the University of Wyoming's Science and Math Teaching Center (UWYO SMTC), (Slater & Slater, 2008).

The TOAST assessment and a supplemental survey [Appendix A and B] was administered to sixty K-12 teachers who attended a five-day Summer Astronomy Institute conducted by the New Jersey Astronomy Center. The professional development training was offered during the summers of 2009 and 2010, with a total of 60 teachers attending (31 in summer 2009, and 29 in 2010). In this study, the TOAST was

administered to 18 elementary-school teachers (grades K-4), 40 middle-school teachers (grades 5-8) and 9 high-school teachers (grades 9 through 12). Note that a teacher who taught both grades 4 and 5 would be listed in both the K-4 category and the 5-8 category. Therefore, although 60 teachers attended, 7 teachers taught in both the elementary and middle grades, so their data was used for analysis in both categories. All of the attending teachers taught in public or private K-12 school settings within New Jersey. The teachers either attended summer 2009 or summer 2010 (no teachers attended both summers).

The TOAST was administered on the morning of the first day, so pre-test values represent the incoming knowledge of the participants. The TOAST was re-administered on the afternoon of the last day, so post-test values represent the outgoing knowledge of the teachers after five days of professional development. On the supplemental survey, data was also collected on the number of years the teachers have taught, the number of years they have taught some astronomy content, the areas of astronomy content they are currently teaching, and their stated confidence (Likert scale) in their ability to teach the astronomy content in their current teaching assignment.

The five-day professional development training was designed to include content, pedagogy and time for teachers to reflect on their current classroom practices and areas of potential improvement. During the training, teachers experienced activities similar to ones they would use in their classroom (but modified to an adult level). In total, the teachers attended over 27 hours (over 1,600 minutes) of training [see Agenda in Appendix C]. The allocation of the content of this training is summarized in Table 1. Break out sessions were provided for some of the time, thus not every teacher attended the total number of minutes provided in that content area. Note that some activities met

more than one content area, so these instructional minutes were allotted to both content areas. For example, an activity on how the size and scale of the Earth, Sun, Moon system affects the frequency of eclipses would have instructional minutes counted in both the Moon Phases and Eclipses category and the Size and Scale of the Universe category.

Table 1
Allocation of Minutes in Summer Astronomy Institute

Area of Instruction	Hours of Instruction (Minutes)
Moon Phases and Eclipses	6.25 hours (375 min)
Seasons	6.4 hours (385 min)
Gravity	4.2 hours (250 min)
Solar System*	4 hours (240 min)
Size and Scale of the Universe*	1.9 hours (115 min)
Daily/Yearly Motion*	1.9 hours (115 min)
Evolution of Stars*	1.25 hours (75 min)
Big Bang*	0.83 hours (50 min)
Light / Electromagnetic Spectrum*	0.83 hours (50 min)
Total Content Training Time	*27.6 hours (1,655 min)*
Pedagogical Training / Reflection Time	3.2 hours (190 min)
Other Activities (Opening, Closing, Review of Goals, Administration of Pre and Post Tests)	4.9 hours (295 min)

Note. Some sessions in the agenda are included in more than one category.
*Break out sessions.

Results

Pre and Post Scores

The TOAST contains 27 multiple-choice questions that assess the understanding of a variety of astronomy concepts. The pre and post TOAST assessment results and gains (Table 2) have been grouped by grade level. The pre and post results for individual TOAST assessment items are summarized in Table 3, and have been grouped by subject category. Question #4 (Position of the Sun in the Sky) and Question #24 (Origin of Atoms found on Earth) were both listed under two categories, but were only counted once in the calculation of final averages.

Overall, the elementary and middle-school teachers pre-scores were quite low (34.9% and 48.6%, respectively), while the high school teachers pre-scores were much higher (78.6%). Although this indicates a general lack of astronomy content knowledge on the part of K-8 teachers, there were some individual test questions where their scores were relatively high (>60%). These include questions on the Causes of Moon Phases (question 5), the Effect of Tilt on Seasons (question 7), the Evidence that Supports the Big Bang (question 15), and the Early Stages of Star Formation (question 16). Only some of these questions reflect content that K-8 teachers would typically teach (moon phases and seasons).

The elementary and middle-school teacher's score gains were found to be statistically significant (at 98.7% confidence and 97.3% confidence, respectively). The high school teacher's score gains were not found to be statistically significant (at 59.8% confidence). On individual questions, the middle school teachers experienced statistically

significant gains (at p<.10 level) on 9 of the 27 questions, while the elementary school

teachers experienced statistically significant gains (at p<.10 level) on 6 of the 27

questions, and a loss on 1 of 27 questions. There were several other questions where

teachers experienced a loss between the pre and the post scores, however, none of these

losses were statistically significant.

The high school teachers only had statistically significant gains (at p<.10 level) on

1 of the 27 questions. These results suggest that only K-8 teachers experienced noticeable

content gains from the five-day institute. While high school teachers may have

Table 2
Pre and Post Assessment Results and Gains

Teaching Level	Scores / Values
Elementary-School Teachers Pre Scores	34.9% (SD =3.2)
Elementary-School Teachers Post Scores	44.7% (SD =3.4)
Gain / Statistical Significance	9.8% (two-tailed T test p= 0.013)
Middle-School Teachers Pre Scores	48.6% (SD =5.0)
Middle-School Teachers Post Scores	57.8% (SD =4.5)
Gain / Statistical Significance	9.2% (two-tailed T test p= 0.027)
High-School Teachers Pre Scores	78.6% (SD =3.9)
High-School Teachers Post Scores	81.5% (SD =4.3)
Gain / Statistical Significance	2.9% (two-tailed T test p= 0.40)

Table 3

Pre and Post Scores on Individual TOAST Items

Topic	Question # / Topic	Pre-score (K-4)	Post-score (K-4)	Pre-score (5-8)	Post-score (5-8)	Pre-score (9-12)	Post-score (9-12)
Moon Phases	3. Rate of Change of Moon Phases	64.7	58.8	81.6	86.8	100	100
	5. Causes of Moon Phases	70.6*	94.1*	86.8	89.5	88.9	100
Seasons	4. Position of the Sun in the sky	47.1*	88.2*	55.3*	81.6*	100	88.9
	7. Effect of Tilt on Seasons	82.4	94.1	78.9*	94.7*	100	100
	12. Effect of the Shape of Earth's Orbit on Seasons	11.8*	58.8*	39.5*	73.7*	77.8	88.9
Solar System	18. Objects Between Sun and Pluto	58.8	47.1	71.1	76.3	100	88.9
	19. Formation of the Solar System	11.8	29.4	23.7	28.9	44.4*	77.8*
	24. Origin of Atoms Found on Earth	0	0	7.9	10.5	77.8	88.9
Gravity	20. Effects on Weight	35.3*	70.6*	71.1	76.3	100	88.9
	21. Why Astronauts Float in Shuttle	5.9	11.8	34.2	42.1	66.7	88.9
Daily / Yearly motion	1. Motion of the Sun Relative to Constellations	17.6	17.6	10.5*	31.6*	44.4	55.6
	2. Daily Motion of Constellations in the sky	17.6*	47.1*	31.6*	71.1*	44.4	66.7
	4. Position of the Sun in the sky	47.1*	88.2*	55.3*	81.6*	100	88.9
	6. Motion of Planets in the sky	17.6	29.4	18.4*	36.8*	44.4	55.6
Light / EM Spectrum	22. Energy Released From Motion of Electrons	11.8	17.6	26.3	28.9	77.8	88.9
	23. Visible and Radio Waves	11.8	35.3	28.9	18.4	88.9	77.8
	25. Absorption of Light by Atoms	47.1	41.2	47.4	42.1	66.7	55.6
	26. Emission of Light by Atoms	11.8	29.4	18.4	26.3	55.6	44.4
	27. Temperature of Object Based on Spectra	5.9*	23.5*	13.2*	31.6*	33.3	55.6
Evolution of Stars	8. Processes Within the Sun	41.2	41.2	73.7	76.3	100	100
	13. Definition of a Star	11.8	11.8	42.1	47.4	100	100
	14. Properties That Affect Stellar Evolution	41.2*	23.5*	36.8*	55.3*	88.9	77.8
	16. Early Stages of Star Formation	70.6	82.4	81.6	84.2	100	100
	17. End of Sun's Life	23.5	29.4	39.5	55.3	66.7	77.8
Size and Scale of the Universe	10. Ranking Order of Object Distance to Earth	35.3	52.9	81.6	76.3	100	77.8
	11. Ranking Order of Size of Object	47.1	41.2	63.2	60.5	88.9	77.8
Big Bang	9. Definition of the Big Bang	67.4	47.1	71.1	65.8	88.9	100
	15. Evidence That Supports the Big Bang	76.5	82.4	78.9*	92.1*	77.8	77.8
	24. Origin of Atoms Found on Earth	0	0	7.9	10.5	77.8	88.9

* Indicates that score changes (difference between pre and post) were statistically significant at the p<.10 level in a two-tailed T-test.

experienced professional growth from this training in other (non-tested areas) such as

pedagogy, the results suggest that they did not experience any significant content gain.

These preliminary results indicate that high school teachers are already quite

knowledgeable in astronomy content, and do not experience a large gain in content

knowledge from training, though they did experience a moderate growth in confidence

from training (see results section on confidence). However, another study with a larger

sample is needed in this area.

Pre and post scores disaggregated for areas currently teaching

In the pre and post survey, participants were asked to self-identify the content

they were currently teaching. These topics correlated to specific questions on the TOAST

assessment. These content areas and related questions are:

- o   Moon Phases (Questions 3, 5)

- o   Seasons (Questions 4, 7, 12)

- o   Solar System (Questions 18, 19, 24)

- o   Gravity (Questions 20, 21)

- o   Daily/Yearly Motion (Questions 1, 2, 4, 6)

- o   Light and the Electromagnetic Spectrum (Questions 22, 23, 25, 26, 27)

- o   Evolution of Stars (Questions 8, 13, 14, 16, 17)

- o   Size and Scale of the Universe (Questions 10, 11)

- o   Big Bang (Questions 9, 15, 24)

Between the pre and post tests, participants were not consistent in their self identification of the content that they were currently teaching. Despite these inconsistencies in teacher responses analysis was still possible, and was accomplished by removing the pre-test scores of any questions that fell into categories not identified by the teacher as 'currently being taught' on their pre-test, and then doing the same for post-test scores and post-survey indications of subjects taught. The results of pre and post tests, adjusted to only represent content currently taught, are presented in Table 4.

Table 4
Pre and Post Scores Adjusted for Content only in Areas being Taught

Grade Level	Adjusted Pre-Score	Adjusted Post-Score	Adjusted Gains	Gains on Entire TOAST Instrument
K-4	39.7%	47.0%	7.2%	9.8%
5-8	48.8%	55.1%	6.2%	9.2%
9-12	76.2%	76.4%	0.2%	2.9%

Number of years teaching

On both the pre and post survey, participants indicated their number of years teaching, and number of years teaching some astronomy content. The 60 teachers who attended the workshop were fairly experienced, with an overall average of 16.7 years of teaching experience and 7.8 years of experience teaching some astronomy content. (The

minimum number of teaching years was 0, the maximum was 40, and the median was 13 years.)

There was not a significant difference between the teacher groupings: the elementary-school teachers who attended the institute had an average of 16.0 years teaching experience, and 7.0 years experience teaching some astronomy content. This is compared to 14.4 years and 7.0 years for the middle school teachers, and 17.7 years and 9.1 years for the high school teachers.

Figure 1 shows the relationship between number of years of teaching and teachers' pre-scores on the TOAST. Figure 2 shows the relationship between number of years of teaching astronomy content to teachers' pre-test TOAST scores. Although it was anticipated that more experienced teachers would score better on the pre-test, this was not observed. The figure indicates that there is little to no correlation between teaching experience and pre-test score. Thus even the most experienced teachers need professional development training in astronomy content. Figure 2 indicates that the majority of teachers at the training had 10 years or less of experience teaching astronomy, whereas Figure 1 indicates that the same teachers had more teaching experience overall. Thus, participants attending the workshop were relatively new to teaching astronomy content.
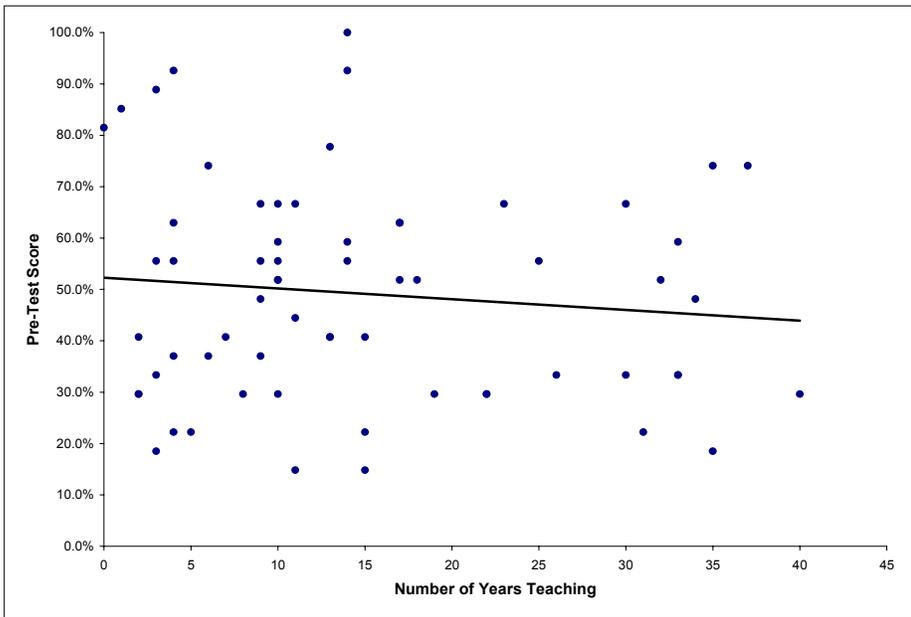
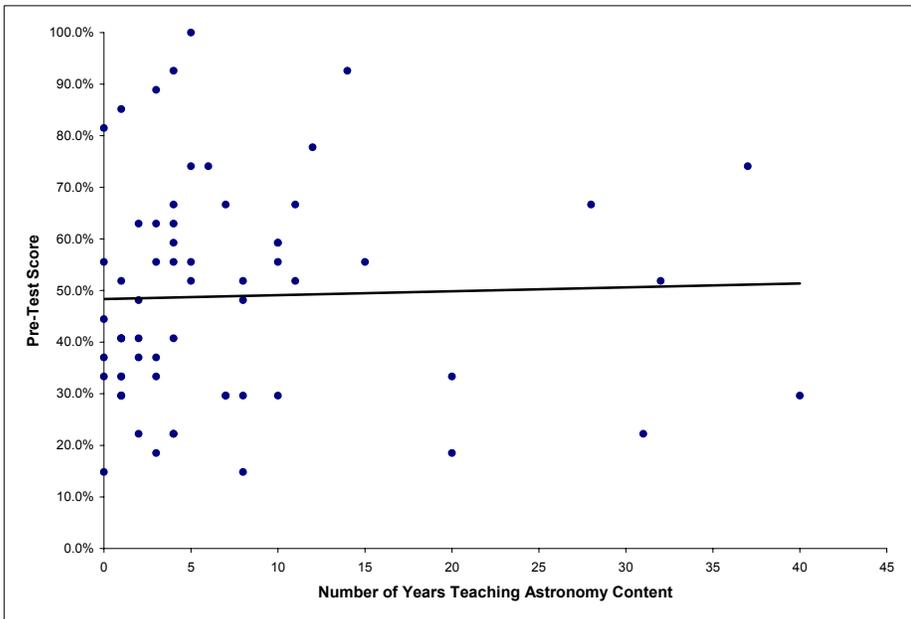*Figure 1*. Teachers' Pre-Test Scores on the TOAST as Compared to Their Years of Teaching.

Figure 2. Teachers' Pre-Test Scores on the TOAST Assessment as Compared to Their Years of Teaching Astronomy Content.

Confidence

Using a Likert Scale in the pre and post surveys, teachers were asked to respond to the statement "I am extremely confident in my ability to teach the astronomy content of my current teaching assignment" (with 5 representing Strongly Agree, and 1 representing Strongly Disagree). Overall confidence of all teachers attending rose from 3.13 on the pretest to 3.8 on the post survey, representing a gain of 0.7 points. Results grouped by grade-level taught have been summarized in Table 5.

Table 5
Results in Self-Reported Confidence in Ability to Teach Astronomy Content

Teacher Grade Level	Pre-Survey Confidence	Post-Survey Confidence	Gain	Gain as Percentage of Pre-survey Confidence
K-4	3.1	4.1	+1.0	+32%
5-8	3.1	3.8	+0.7	+23%
9-12	3.7	4.3	+0.6	+16%
Overall	**3.13**	**3.8**	**+0.7**	**+22%**

Although the elementary-school and middle-school teachers both indicated the same pre-level of confidence, the elementary-school teachers experienced a greater gain in confidence. The initial confidence of the high school teachers was much higher (3.7) and they experienced the smallest gain in confidence (16%).

When comparing TOAST assessment gains to confidence gains, the elementary -

school teachers experienced both the greatest gain in confidence (1.0 points) and greatest

TOAST score gain (9.8 percent). Conversely, the high school teachers started with the

highest pre-scores and highest initial confidence scores, and experienced the least gains

in confidence (0.6 points) and the smallest TOAST score gain (2.9 percent). The high

school teachers and middle-school teachers did not gain as much confidence as the

elementary-school teachers, who became nearly as confident as high school teachers in

the post-survey. The relationship between teachers' pre-test TOAST scores and self-

reported confidence in ability to teach astronomy content is shown in Figure 3. The

figure clearly depicts that there is relationship between teachers' confidence, and

teachers' score. However, the figure also indicates that there are a number of teachers

who vastly overestimate their abilities. There are a number of teachers who indicated a 4

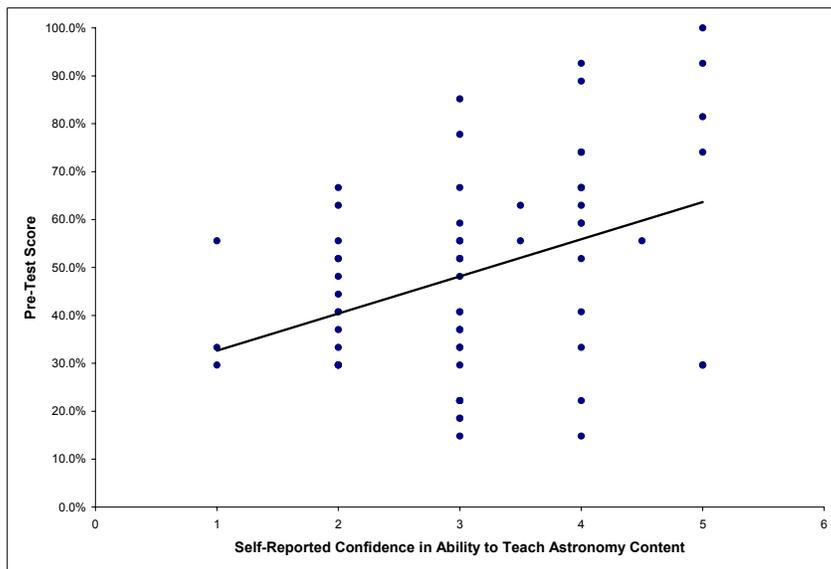or 5 value in confidence, but scored less than 50% on the pre-test.

Figure 3. Teachers' Self-reported Confidence to Teach Astronomy Content as compared to Teachers' Pre-test scores on the TOAST assessment.

Discussion

This study sought to investigate the effect of a 5-day summer astronomy institute on in-service K-12 teachers' content knowledge in astronomy. Teachers were administered a pre-test and a supplemental survey prior to the five-day Astronomy Institute. Following the professional development experience, the teachers were given the same survey, and completed a post-test. The purpose of this study was not to point out the severity of teacher's lack of content knowledge in astronomy, but rather to identify the areas of need and to examine the effects of a multi-day professional development program on teachers' content knowledge and confidence to teach astronomy content.

This study affirmed what has been described in the research literature; elementary and middle-school in-service teachers' lack sufficient content knowledge in astronomy. The pre-test TOAST instrument scores of the elementary and middle-school teachers were very low; the elementary-teachers pre-scores had a mean of 34.9%, the middle-school teachers had a mean pre score of 48.6%. The same group of teachers, when scored on just content they are currently teaching, had similarly low scores: the elementary teachers' adjusted pre-scores were 39.7%, and the middle-school teachers had a mean pre scores of 48.8%. These results are consistent with scores from other researchers, and further develop a picture of a group of teachers who, by NCLB standards, may be "highly qualified", are still clearly unprepared to teach astronomy content.

The post-test scores indicate that the K-8 teachers did experience a content knowledge gain from the training: the elementary teachers' post scores had a mean of

44.7% (a 9.8% gain), the middle school teachers had a mean post score of 57.8% (a 9.2% gain). Despite the gains, these scores remain disappointingly low and further content training would still be needed.

Results of the high school teachers differ substantially from the K-8 teachers. Their mean pre-score was much higher (78.6%), and the mean post-scores was also higher (81.5%). Thus, the high school teachers had experienced only a 2.9% content gain from the five-day institute. It is possible that the high school teachers experienced professional development gains in other non-tested areas (outside of the TOAST content test) such as pedagogy, but results indicate that they did not experience any significant content gain from this training. In addition to low score gains, the high school teachers also had lower confidence gains. These low score changes, combined with the information that the training had few high school attendees, indicate that high school teachers are already quite knowledgeable in astronomy content, and (based on their initial confidence scores) that they may not perceive that they need training.

In the area of confidence, the elementary-school teachers experienced the greatest gains (32%), followed by the middle-school teachers (23%). The elementary teachers started with the lowest pre-test scores and lowest confidence. It is not a surprising correlation: the elementary-school teachers had the most to gain from the training, they gained the most, and recognized their own need for the training. Conversely, the high school teachers started with the highest raw scores and highest confidence scores, and experienced the least gains in confidence and raw score. These teachers did not experience substantial changes in their content knowledge and, consequently, did not experience the same increase in confidence as their elementary peers. This suggests that

high school teachers perceive themselves to be quite knowledgeable, and are already quite confident. It is unclear if high-school teachers have less gains because they are over-confident, are less inclined to feel they must pay attention when attending trainings with teachers of lower grade-levels, or because the training itself does not provide training that meets their needs. Further study is needed in this area.

In the pre/post surveys, participants were asked to identify the content areas they currently teach. In the analysis, the scores were adjusted to only include questions that addressed this content, yet there was little difference between the full test scores and the adjusted scores. This suggests that there is substantial room for improvement for teacher content knowledge, both in areas taught and areas not taught. All teachers, regardless of grade level taught, experienced greatest gains on their overall score (as compared to gains only in the areas they are currently teaching), which suggests that teachers do have improved understanding of the content they are teaching, albeit only slightly better than general astronomy content. Lastly, participants were not consistent in their self identification of which content that they teach. This may have occurred as a result of instruction: after training they had a clearer picture of the content included in each area, leading them to change their minds about which content they actually teach.

On individual TOAST items, the greatest content gains were seen in areas where teachers received the most time for instruction and reflection (moon phases, seasons, daily/yearly motion). However, the number of instructional minutes was not directly related to the gain. For example, moon phases and eclipses received the largest number of instructional minutes (375 minutes), but resulted in a 23.5 percentage point gain on only one question for elementary school teachers, and no changes of statistical significance for

middle and high school teachers. In fact, the pre-test moon phase results for these groups were already quite good (~80% or better). Thus, had the professional development providers known this in advance, the instructional time devoted to this area could have been reduced, or a separate break out session for just elementary teachers could have been offered. The topic of moon phases was evidently an area where most teachers already knew the content, and in light of the pre-test results, 375 hours of instructional time seems somewhat unnecessary. Conversely, the teachers' initial scores on two of the three questions in the Seasons were quite low, and following 385 minutes of instructional time, there were substantial gains. Similarly, middle and elementary teachers experienced substantial gains in the area of gravity (250 minutes of instructional time) and daily/yearly motion (115 minutes). This non-relationship between number of minutes and change in teacher score suggests two important findings: 1) that the nature of what the teachers are doing during the training can have a dramatic effect on scores, or, in other words, a short period of training with the right activity can have a substantial effect on scores, and 2) professional development providers may be spending precious instructional minutes on unnecessary content if they do not know the needs of their teachers and adjust their agendas accordingly, or in other words, more instructional hours do not always equate to better scores, particularly if pre-scores are already high.

Unexpectedly, there were some higher pre-scores (>60%) for the elementary and middle-school teachers in content areas outside of the usual K-8 curriculum (such as the Evidence that Supports the Big Bang, and the Early Stages of Star Formation). However, since this was not known to the developers, there were no adjustments made to the instructional minutes. The teachers also had higher than anticipated pre-test scores on

areas of Moon Phases and Seasons. Again, because the teachers arrived to the training with content understanding that was not anticipated by the providers, the agenda for the week provided more minutes of training in content that might have been better spent in other areas. Although further study with larger numbers of teachers is needed, it may be that professional development providers underestimate the content knowledge of K-8 teachers in some areas, and thus, do not make best use of instructional minutes.

Overall, pre and post tests and surveys revealed that K-8 teachers have the weakest astronomy content knowledge, the lowest levels of self-reported confidence, and experienced the greatest gains in both of these areas as a result of a five-day professional development experience. Compared to their elementary and middle-school peers, high school teachers have stronger content knowledge, are more self-confident in their ability to teach astronomy content, and achieve low gains in both of these areas as a result of five days of training.

Limitations

The participants who attended this five-day professional development experience may not represent a true sample of all K-12 teachers in New Jersey. They opted to attend the training, which may indicate that they recognize their need for additional training in the content area. Conversely, the fact that these teachers opted to take 5 days from their summer vacation to attend a workshop suggests that they are eager to improve, and thus, they may actually represent a "better-than-average" cohort of their peers.

Although the training offered in both summers (2009 and 2010) was similar, it was not identical. The results of both cohorts of teachers have been lumped together for this study, but the teachers' experiences may have varied slightly from year to year.

Although results for high school teachers are discussed in this paper, there was a small sample (n=9) involved. Thus most test results were not found to be statistically significant, and any comments or conclusions discussed in the paper should be viewed as tentative in light of this small sample.

The assessment instrument used (TOAST), was intended to be an assessment for college students, and therefore, is not an ideal assessment for K-12 in-service teachers' content knowledge. As with any assessment instrument, there is an inherent limitation in the results. Furthermore, the ability of teachers to correctly answer test questions does not necessarily result in their students' ability to understand the same concept in their classroom, so we cannot assume that good TOAST scores translate directly to good instruction and student understanding. There were no other measurement instruments used, and no interviews or follow up testing was done in the weeks or months that followed. Thus, it is not clear what, if any, long term effects exist on the teachers' content understanding, their quality of classroom instruction, and any resultant effects on student understanding of content.

Recommendations

There is further research needed in several areas. Further work is needed to establish the content and pedagogical training needs of high-school teachers. More work is needed to understand if high-school teachers have gains in other areas (such as

pedagogy) from multi-day trainings, and what types of training result would provide greatest content gains. Furthermore, more study is needed to determine if the high level of confidence in high-school teachers causes them to have fewer gains because they are less inclined to feel they must pay attention, or because the training does not provide instruction that meets their needs.

There are several recommendations from this study that may be helpful to professional development designers and facilitators. Elementary and middle school teachers experience similar content gains from multi-day training, but elementary teachers become more self-confident. If professional development providers are looking to maximize the effects of their training on the content knowledge and confidence of teachers, K-8 focused trainings may have better results than K-12 trainings. Additionally, professional development providers may need to adjust the number of minutes spent in core astronomy topics (such as moon phases), as results suggest that most teachers may already have a good understanding of the topic.

If the TOAST instrument or other similar assessment (such as the Astronomy Diagnostic Test or the Astronomy and Space Science Concept Inventory) can be given as a pre-test well in advance of training, it can be used as a tool to identify teacher content knowledge gaps, and to plan the professional development offering accordingly. Furthermore, the TOAST instrument (or another similar assessment) can be administered by professional development providers to assess the efficacy of the training in specific content areas. This would give professional development providers an opportunity to maximize the time spent on areas of need, and it would give teachers a more customized training experience.

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Appendix A
Supplementary Information Survey

Introductory Astronomy Survey – Supplementary Information

Grade Level that you are currently teaching:

K   1   2   3   4   5   6   7   8   9   10   11   12

Number of Years of Teaching Experience: _____

Number of Years of Teaching some Astronomy content: _____

Please check the boxes (below) next to topics that you are currently, or have previously taught.

□ Moon Phases   □ Light and the Electromagnetic Spectrum

□ Seasons   □ Evolution of Stars

□ Solar System   □ Size and Scale of the Universe

□ Gravity   □ The Big Bang

□ Daily and Yearly Motion

Use the scale below to respond to the follow statement:
I am extremely confident in my ability to teach the astronomy content of my current teaching assignment.

5	**4**	**3**	**2**	**1**
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

Appendix B
TOAST Instrument, Page 1

Dear Teacher,

We are conducting this Introductory Astronomy Survey to help us inform the design and content of our astronomy workshop.

It will take approximately 20-30 minutes to complete the survey. Please answer all of the survey questions on the attached bubble sheet. Make sure that your name is on the answer sheet and that all answers are recorded in the correct position. Always select the BEST answer.
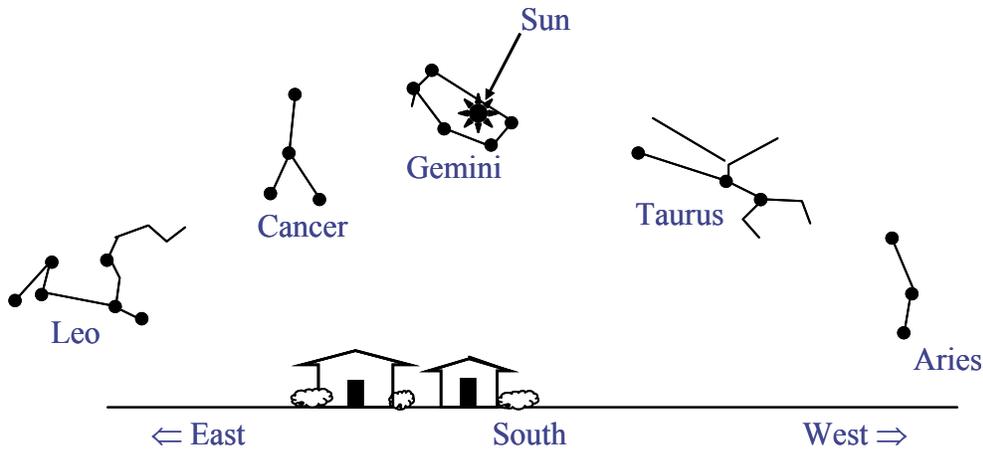
Thank you very much for your time and support. Please do not start the survey until you are instructed to do so.

I have read the survey instructions, and acknowledge my voluntary participation in this survey.

_____

Please sign your name

Appendix B
TOAST Instrument, Page 2


Use the drawing below to answer the next <u>two</u> questions.

1. If you could see stars during the day, the drawing above shows what the sky would look like at *noon* on a given day. The Sun is at the highest point that it will reach on this day and is near the stars of the constellation Gemini. What is the name of the constellation that will be closest to the Sun at sunset on this day?
   a. Leo
   b. Taurus
   c. Aries
   d. Cancer
   e. Gemini

2. This picture shows the position of the stars at *noon* on a certain day. How long would you have to wait to see Gemini at this same position *at midnight?*
   a. 12 hours
   b. 24 hours
   c. 6 months
   d. 1 year
   e. Gemini is never seen at this position at midnight.

----

3. You look to the eastern horizon as the Moon first rises and discover that it is in the new moon phase. Which picture shows what the moon will look like when it is at its high point in the sky, later that same day?
   a. A
   b. B
   c. C
   d. D
   e. E
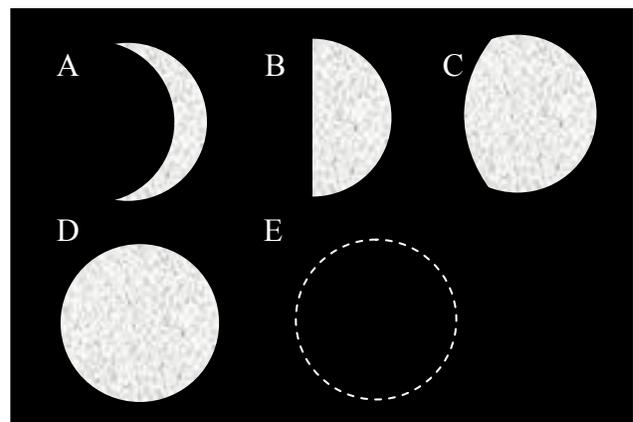
Appendix B
TOAST Instrument, Page 3

4. You are located in the continental U.S. on the first day of October. How will the position of the Sun at noon be different two weeks later?
   a. It will have moved toward the North.
   b. It will have moved to a position higher in the sky.
   c. It will stay in the same position.
   d. It will have moved to a position closer to the horizon.
   e. It will have moved toward the west.

5. Which sentence best describes why the Moon goes through phases?
   a. Earth's shadow falls on different parts of the Moon at different times.
   b. The Moon is somewhat flattened and disk-like. It appears more or less round depending on the precise angle from which we see it.
   c. Earth's clouds cover potions of the Moon resulting in the changing phases that we see.
   d. The sunlight reflected from Earth lights up the Moon. It is less effective when the Moon is lower in the sky than when it is higher in the sky.
   e. We see only part of the lit-up face of the Moon depending on its position relative to Earth and the Sun.

6. Imagine you see Mars rising in the east at 6:30 pm. Six hours later what direction would you face (look) to see Mars when it is highest in the sky?
   a. toward the north
   b. toward the south
   c. toward the east
   d. toward the west
   e. directly overhead

7. Imagine that Earth was upright with no tilt. How would this affect the seasons?
   a. We would no longer experience a difference between the seasons.
   b. We would still experience seasons, but the difference would be *less* noticeable.
   c. We would still experience seasons, but the difference would be *more* noticeable.
   d. We would continue to experience seasons in essentially the same way we do now.

8. How does the Sun produce the energy that heats our planet?
   a. The gases inside the Sun are burning and producing large amounts of energy.
   b. Gas inside the Sun heats up when compressed, giving off large amounts of energy.
   c. Heat trapped by magnetic fields in the Sun is released as energy.
   d. Hydrogen is combined into helium, giving off large amounts of energy.
   e. The core of the Sun has radioactive atoms that give off energy as they decay.

9. The Big Bang is best described as:
   a. The event that formed all matter and space from an infinitely small dot of energy.
   b. The event that formed all matter and scattered it into space.
   c. The event that scattered all matter and energy throughout space.
   d. The event that organized the current arrangement of planetary systems.

Appendix B
TOAST Instrument, Page 4

10. Which of the following ranks locations, from <u>closest to Earth to farthest from Earth</u>?
    a. the Sun, the Moon, the edge of our solar system, the North Star, the edge of our galaxy
    b. the Sun, the North Star, the Moon, the edge of our galaxy, the edge of our solar system
    c. the Moon, the North Star, the Sun, the edge of our solar system, the edge of our galaxy
    d. the Moon, the Sun, the edge of our solar system, the North Star, the edge of our galaxy
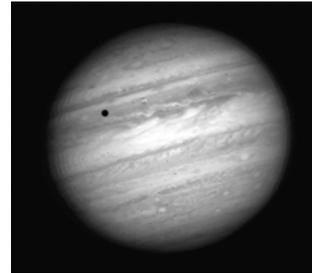   e. the North Star, the Moon, the Sun, the edge of our galaxy, the edge of our solar system

----

Consider the six different astronomical objects (A-F) shown below.
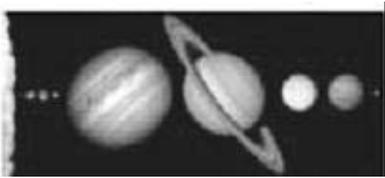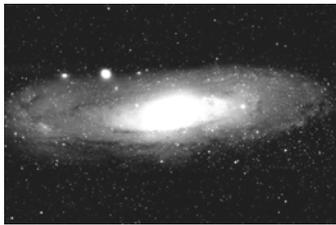

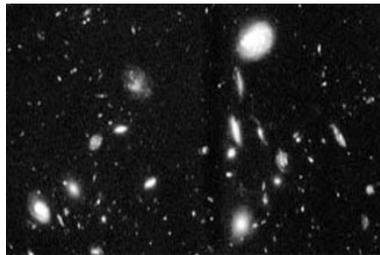**A**. The Solar System
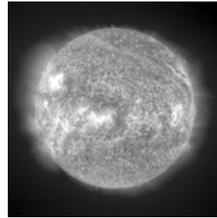
B. The Sun

C. Jupiter

D. Andromeda Galaxy

E. Galaxy Cluster

F. Nebula

11. Which of the following is the best ranking (from smallest to largest) for the size of these objects?
    a. C<F<B<A<D<E
    b. E<D<F<A<B<C
    c. C<B<A<F<D<E
    d. F<C<B<A<D<E
    e. None of the above is correct.

----

12. Imagine that Earth's orbit were changed to be a perfect circle about the Sun so that the distance to the Sun never changed. How would this affect the seasons?
    a. We would not be able to notice a difference between seasons.
    b. The difference in the seasons would be *less* noticeable than it is now.
    c. The difference in the seasons would be *more* noticeable than it is now.
    d. We would experience seasons in the same way we do now.

Appendix B
TOAST Instrument, Page 5

13. What is a star?
    a. a ball of gas that reflects light from another energy source
    b. a bright point of light visible in Earth's atmosphere
    c. a hot ball of gas that produces energy by burning gases
    d. a hot ball of gas that produces energy by combining atoms into heavier atoms
    e. a hot ball of gas that produces energy by breaking apart atoms into lighter atoms

14. Which one property of a star will determine the rest of the characteristics of that star's life?
    a. brightness
    b. temperature
    c. color
    d. mass
    e. chemical makeup

15. Current evidence about how the universe is changing tells us that
    a. We are near the center of the universe.
    b. Galaxies are expanding into empty space.
    c. Groups of galaxies appear to move away from each other
    d. Nearby galaxies are younger than distant galaxies.

16. Stars begin life as
    a. a piece off of a star or planet.
    b. a white dwarf.
    c. matter in Earth's atmosphere.
    d. a black hole.
    e. a cloud of gas and dust.

17. When the Sun reaches the end of its life, what will happen to it?
    a. It will turn into a black hole
    b. It will explode, destroying Earth
    c. It will lose its outer layers, leaving its core behind
    d. It will not die due to its mass

18. If you were in a spacecraft near the Sun and began traveling to Pluto you might pass
    a. planets.
    b. stars.
    c. moons.
   d. two of these objects.
    e. all of these objects.

19. How did the system of planets orbiting the Sun form?
    a. The planets formed from the same materials as the Sun.
    b. The planets and the Sun formed at the time of the Big Bang.
    c. The planets were captured by the Sun's gravity.
    d. The planets formed from the fusion of hydrogen in their cores.

Appendix B
TOAST Instrument, Page 6

20. Which of the following would make you weigh half as much as you do right now?
    a. Take away half of the Earth's atmosphere.
    b. Double the distance between the Sun and the Earth.
    c. Make the Earth spin half as fast.
    d. Take away half of the Earth's mass, but keep Earth the same size.

21. Astronauts "float" around in the space shuttle as it orbits Earth because
    a. There is no gravity in space
    b. They are falling in the same way as the Space Shuttle
    c. They are above earth's atmosphere
    d. There is less gravity inside of the Space Shuttle

22. Energy is released from atoms in the form of light when electrons
    a. are emitted by the atom.
    b. move from low energy levels to high energy levels.
    c. move from high energy levels to low energy levels.
    d. move in their orbit around the nucleus.

23. Which of the following would be true about comparing visible light and radio waves?
    a. The radio waves would have a lower energy and would travel slower than visible light.
    b. The visible light would have a shorter wavelength and a lower energy than radio waves.
    c. The radio waves would have a longer wavelength and travel the same speed as visible light.
    d. The visible light would have a higher energy and would travel faster than radio waves.
    e. The radio waves would have a shorter wavelength and higher energy than visible light.

24. The atoms in the plastic of your chair were formed
    a. in our Sun.
    b. by a star existing prior to the formation of our Sun.
    c. at the instant of the Big Bang.
    d. approximately 100 million years ago.
   e. in a distant galaxy in a different part of the early universe.

Appendix B
TOAST Instrument, Page 7

Use the drawings below to answer the next two questions.
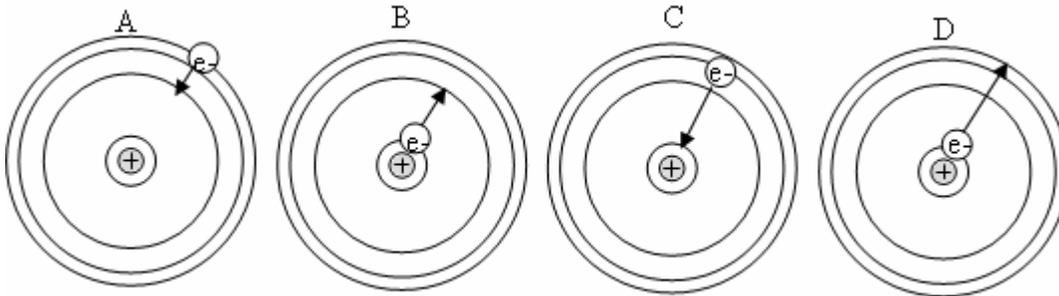
25. Which atom would be absorbing light with the greatest energy?
    a. A
    b. B
    c. C
    d. D

26. Which atom would emit light with the shortest wavelength?
    a. A
    b. B
    c. C
    d. D

----

27. The graphs below illustrate the energy output versus wavelength for three unknown objects A, B, and C. Which of the objects has the highest temperature?
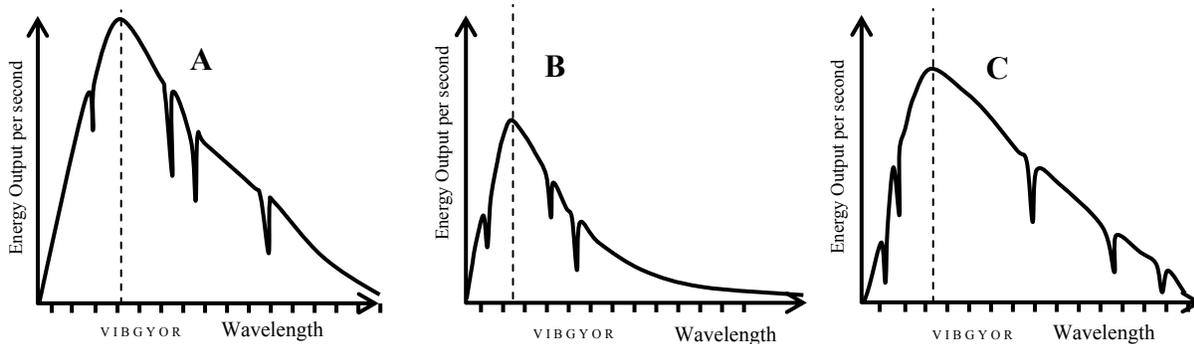
    a. A
    b. B
    c. C
    d. All three objects have the same temperature.
    e. The answer cannot be determined from this information.

Appendix C
Summer Astronomy Institute Agenda: Day 1

Summer Astronomy Institute

New Jersey Astronomy Center

Day 1 - Monday, August 9, 2010

Time

9:00 AM	Welcome, Introductions, Goals and Overview
9:25 AM	Pre-Assessment
9:55 AM	A Scale Model of the Earth, Sun, Moon System
10:30 AM	Break
10:45 AM	A Scale Model of the Earth, Moon, Sun System Con't
11:15 AM	The Four Strands of Science Learning
11:35 AM	Going Through a Phase
11:50 AM	Moon Journals
12:15 PM	Lunch (Moon Resources)
1:00 PM	Modeling Moon Phases
2:00 PM	Going Through a Phase Revisited
2:15 PM	Shadows in the Earth, Sun, Moon System
3:00 PM	Making Sense of Moon Phases and Eclipses
3:35 PM	Reflecting on the Four Strands of Science Learning
4:00 AM	Gots and Needs
End	

Appendix C
Summer Astronomy Institute Agenda: Day 2

Summer Astronomy Institute

New Jersey Astronomy Center

Day 2 - Tuesday, August 10, 2010

Time

9:00 AM	Reviewing Gots and Needs, Previewing the Day
9:15 AM	Sun-Earth Survey
9:30 AM	Collecting Data on Seasons
9:50 AM	Five Essential Features of Inquiry + Claim, Evidence and Reasoning
10:10 AM	Sun Tracking
10:40 AM	Break
10:55 AM	The Earth's Orbit
11:30 AM	Sun Tracking – Continued
11:40 AM	Seasonal Data From Around the World
12:10 PM	Final time for Sun Observation
12:15 PM	Lunch (Seasons Resources)
1:00 PM	Sun Tracking – Continued
1:15 PM	Modeling Seasons
2:25 PM	Making Sense of Seasons
3:05 PM	Reflecting on the Four Strands and Inquiry
3:30 PM	Gots and Needs
END	

Appendix C
Summer Astronomy Institute Agenda: Day 3

Summer Astronomy Institute

New Jersey Astronomy Center

Day 3 - Wednesday, August 11, 2010

Time

9:00 AM	Reviewing Gots and Needs, Previewing the Day
9:15 AM	Building Understanding of the ESM System
9:30 AM	Introduction to the Galileoscope
10:25 AM	Break
10:40 AM	Displacing the Geocentric Model / Tracking Jupiter's' Moons
12:15 PM	Lunch (Resources)
1:00 PM	Features of Planets
1:50 PM	Categorizing Solar System Objects
2:45 PM	Reflecting on Strand 2 and 3
3:30 PM END	Gots and Needs

Appendix C
Summer Astronomy Institute Agenda: Day 4

Summer Astronomy Institute

New Jersey Astronomy Center

Day 4 - Thursday, August 12, 2010

Time

9:00 AM	Reviewing Gots and Needs, Previewing the Day
9:20 AM	The Earth's Shape and Gravity
9:55 AM	Exploring Gravity
10:20 AM	Break
10:35 AM	The Earth's Shape and Gravity
10:55 AM	Exploring Gravity, Continued
11:30 AM	Revisiting Jupiter's Moons
12:00 PM	Lunch with Resources from Tom Estill
1:00 PM	Tides in the Earth Sun Moon System
2:10 PM	Structure of Knowledge of the ESM System
3:05 PM	Building Understanding of the Solar System
3:15 PM	Reflecting on Strand Four
3:30 AM END	Gots and Needs

Appendix C
Summer Astronomy Institute Agenda: Day 5

Summer Astronomy Institute

New Jersey Astronomy Center

Day 5 - Friday, August 13, 2010

Time

9:00 AM	Reviewing Gots and Needs
9:15 AM	Breakout Session 1a: Life Cycles of Stars Breakout Session 1b: Starlab Moon Phases and Seasons
10:30 AM	Break
10:45 AM	Breakout Session 2a: Formation of the Solar System Breakout Session 2b: Kinesthetic Moon Rise and Seasons
11:25 AM	Breakout Session 3a: Expanding Universe Breakout Session 3b: Counting Stars
12:15 PM	Lunch (and Resources)
1:00 PM	Changing Practice
3:00 PM End	NASA Evaluations, Post Assessment and Closing