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Assessing high school students' conceptions of the size, age, and distance of astronomical objects

Tracy Jean Lawrence

ASSESSING HIGH SCHOOL STUDENTS' CONCEPTIONS OF THE SIZE, AGE, AND DISTANCE OF ASTRONOMICAL OBJECTS

A Thesis

Presented to the

Faculty of

California State University,

San Bernardino

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

In

Education:

Science Education

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by

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ABSTRACT

Thirty-nine high school students from three different physical science courses were administered a survey instrument that attempted to assess their levels of scientific conceptualization in the areas of the size, age, and distance of seven astronomical objects. The subgroups included an AP physics class, a physical science class, and an astronomy class. It was predicted that the astronomy students would perform the best of the three groups based on the time they had spent on the subject tested. The AP Physics students were not expected to perform well despite their high academic ability levels. The results of the study supported these hypotheses and imply a need for further research related to students' conceptions in space science.

ACKNOWLEDGMENTS

I would like to thank Mary Dussault of the Science Education Department at the Harvard-Smithsonian Center for Astrophysics for her generous support with materials for this study. Dr. Bonnie Brunkhorst, of the Science, Mathematics, and Technology Department at California State University, San Bernardino, for inspiring me to be a better teacher through her love and enthusiasm for the earth sciences. And Dr. Herbert Brunkhorst, of the Science, Mathematics, and Technology Department of California State University, San Bernardino, for his consistent kindness, clarity and humor throughout this project.

I would also like to thank my children, Aidan and Abbie, and my husband Adam for unconditional love and support during this project and throughout the course of my masters' studies.

DEDICATION

To my father, Craig C. Cox, who taught me to love science, and to my mother, Beverly Jean Cox, who taught me how to write about that which I love.

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CHAPTER ONE

INTRODUCTION TO THE STUDY

Background

A considerable amount of research has been conducted to examine students' alternative conceptions in various areas of science. Educators and scientists in the field of science education have been working diligently to improve the overall state of science and mathematics achievement of students in the United States. The United States ranks well below many other industrialized nations in both math and science scores on international tests (NCES, 1996). One of the main problems identified by the researchers involved with the Third International Mathematics and Science Study (TIMSS) is the lack of a shared national vision regarding the context and number of math and science concepts to be taught in Americas' schools. With American textbook publishers attempting to market textbooks to nearly 16,000 different school districts nationwide, it is no wonder that math and science education in the United States is characterized as "a mile wide and an inch deep" (NCES, 1996).

The concepts of size, distance, and age of objects in the universe are central to students' overall conceptual understanding of space and earth science and their human place within the universe. In fact, William H. Schmidt, of the Education Policy Center, at Michigan State University, and leading researcher with TIMSS, suggests "the nature of the universe and how it and life within it are interrelated" may provide a possible organizing principal for the nations' science curriculum" (Schmidt, 2003) It may be that the subject of astronomy, the worlds' oldest science, will come to provide the nations' leading science educators with a much-needed unifying vision.

Statement of the Problem

> Many people, adults and students alike, are familiar with the names of objects in space, but have an incomplete mental model of where those objects are in space, their relative size and scale, and how they fit into the cosmic scheme of things. (Smithsonian Institution, 1999)

This study will focus on these few specific concepts and attempt to determine whether or not high school physical science students hold a scientific view about the size, distance, and age of various space objects, or perhaps harbor certain alternative conceptions about these concepts. The specific research questions used to guide this study include:

1) What are high school students' alternative conceptions about the size of seven different astronomical objects?
2) What are high school students' alternative conceptions about the age of seven different astronomical objects?
3) What are high school students' alternative conceptions about the distance of seven different astronomical objects?
4) Does participation in a yearlong high school astronomy course increase the overall score on the astronomy concept survey?
5) Based on their academic ability level, will AP Physics students score higher on the astronomy concept survey than other science students?

Based on results of past studies into students' scientific conceptions and my own work as a high school astronomy educator, I have several hypotheses related to the above research questions. I believe the results of the survey instrument will show one or more alternative conceptions related to each area, (size, age, and distance), being investigated. Due to many years of exposure to science textbooks drawn with an inaccurate size and scale of astronomical objects, I predict a majority of students will not display "mastery" of the concept of the relative sizes of the seven astronomical objects, or the relative distances between them. Additionally, I predict fewer than 10% of the students will show "mastery" of the concept of age of the astronomical objects being studied.

Research questions 4 and 5 deal with demographic school factors that may be responsible for a difference in overall score on the astronomy concepts survey. The students from the astronomy course were at the very end of an entire year of astronomy instruction, in which they were involved in hands-on projects, labs, reports and had unlimited access to astronomy websites and computer tutorials. Conceptual change takes a great deal of time (Vosniadou,1991). I believe the Astronomy students will, on the average, score 4 points higher than the Natural Science students, who have only had one astronomy unit. I also feel they will outperform the AP Physics students by an average of 4 points overall on the survey, despite the academic ability level and IQ's of the AP Physics students who have had no direct astronomy education since perhaps junior high school.

Purpose of the Study

The purpose of this research study is to identify student conceptions about the size, distance, and age of various objects associated with space science. After reviewing the literature related to this study, there seems to be a need for continued research at the high school level in the field of astronomy conceptualization. Much of the past research has focused on younger students who may not yet be at a developmental level necessary to conceptualize these difficult, abstract concepts. Only with the careful assessment of preconceptions can educators design curricula specifically aimed at reducing the number of alternative conceptions held by science students.

This study may also become the pilot for a much larger future study involving a more significant number of participants. The combined results of this study and future work in the field of astronomy conceptualization may serve as the basis for designing a semester course in high school astronomy that focuses on reducing students' alternative conceptions.

Theoretical Bases and Organization

Research has shown that even with schooling in a specific science area, students' alternative conceptions are difficult to change (Ausubel et al.1978). It is anticipated that the results of this study will show a significant lack of conceptual understanding about the size, age and distance of the seven tested astronomical objects. The physical science students studied will have completed a unit on astronomy, and the astronomy students will have completed an in-depth, yearlong astronomy curriculum. Additionally, the AP Physics students are considered to be at the highest academic level in high school sciences. Even with these apparent curricular and ability-level advantages, the research shows little in the way of improved overall reduction in the number of scientific alternative conceptions held by various subgroups (Sadler, 1992; Schoon,1988).

The American Association for the Advancement of Science had this to say in 1993 about space science education:

> If being educated means having an informed sense of time and place, then it is essential for a person to be familiar with the scientific aspects of the Universe and know something of its origin and structure. (AAAS, 1993)

In addition, typically, one quarter of earth science instruction deals with astronomy. Students are expected to know and understand the size and scale of the solar system, that the Sun is only one star amongst billions in the Milky Way Galaxy, and that there are billions of galaxies within the Universe. The magnitude of the size and scale of these objects and systems is conceptually difficult for most individuals, especially young people. In order for students to understand the structure and origin of the universe, it is essential that their conceptions related to the more basic aspects of space science, (such as gravity, and the size, age and scale distances of celestial objects), be identified. Once these alternative conceptions are revealed, the best teaching strategies can be employed to target these conceptions and gradually replace them with more scientifically acceptable ideas.

Limitations of the Study

As with most research projects involving K-12 students, there are many inherent limitations related to the quality of the results. The process of obtaining informed consent to administer the survey instrument proved to be involved and quite time consuming. The greatest difficulty actually came with getting the students to return their consent forms. Because it took so long to obtain these consent forms, the study had to be conducted rather quickly in light of the approaching end of the school year. Consequently, there came a point in time where the study had to be conducted despite the limited number of participants involved from each of the three science classes. It may also be that the most conscientious, and perhaps the higher-achieving students were the ones who returned the consent forms and therefore, the results may be slightly skewed.

One disadvantage to the instrument used for this study was the size of the seven picture images involved. Each image is 1″x ½″ in size, making it sometimes difficult for students to see the differences in appearance between the Whirlpool Galaxy, the Deep Field of Galaxies, and the Pleiades star cluster. Because the images are somewhat difficult to discern, it may mislead students into inaccurate answers they may have otherwise understood.

The reliability and validity of the eight multiple-choice questions could have been strengthened had there been more time to test the entire instrument on other students and educators.

And finally, the population size of this study, unfortunately, was not large enough to obtain statistically significant results. Therefore, a more descriptive technique was employed to analyze the data. There may have been other interesting trends identified in the data with the application of a statistics program.

Definition of Terms

An 'alternative conception' is defined as: An explanation of a physical idea or process, which is different from, or in conflict with, the standard scientific explanation.

CHAPTER TWO

REVIEW OF THE LITERATURE

Summary of the Literature

Children's everyday experiences with the natural world lead them to construct synthetic mental models that are not consistent with scientific information (Vosniadou, 1991). It has been said that children do not require the criteria for coherence among perceived physical phenomena in the same way that a scientist does (Driver, Guesne, & Tiberghien, 1985). Furthermore, these alternative conceptions are highly resistant to change. Often, when presented with scientific explanations the student ignores the counter-evidence or modifies it to fit into their previously held model. The correct acquisition of many science concepts may require radical, long-term restructuring of students' prior knowledge. Consequently, science curricular materials and teaching techniques must reflect a sequence consistent with the order in which students acquire their concepts (Vosniadou, 1991). This study will provide data on actual student conceptions related to the distance of astronomical objects from Earth, the age of these objects and their relative sizes. With a clearer understanding of student ideas about these concepts, it would eventually be possible to design and sequence astronomy curriculum, as well as employ the finest inquiry lessons, to target any inaccurate concepts revealed by this survey.

William W. Cobern, affiliated with Western Michigan University, Adrienne T. Gibson and Scott A. Underwood, both affiliated with Cave Creek Unified School District in Cave Creek, Arizona, collaborated to conduct a study of sixteen ninth graders. The purpose of their study was to gain an understanding of students' fundamental beliefs about the world on the basis that developing scientific literacy can be successful only to the extent that science finds a place in the cognitive and cultural environment of students.

The participants in the study were sixteen ninth graders who lived and attended a semi-rural high school in the central desert region of Arizona. The groups of participating students were typical science students found in this high school from middle to upper-middle income homes. The researchers conducted structured interviews with these students. The final conclusions of the study indicated that these ninth grade students tend to discuss the natural world using numerous perspectives. These perspectives included aesthetic, conversational, religious, and sometimes scientific. These perspectives were linked only some of the time. There appeared to be a low level of science integration within their daily thinking. There was no correlation between high or low science grades and the concepts these ninth graders chose to use in discussion during the interviews. The majority of students who were interviewed placed strong importance on personal experiences with nature.

Herein lies the major stumbling block for science teachers attempting to convey concepts that are often times far more complicated and counterintuitive when compared to children's innate ideas about the way the universe operates. For example, for any observer, including children, the Sun does indeed appear to rise in the east, travel across Earth's sky, and set in the west. In order for a child to accept a new idea from their teacher, such as 'the Earth is spinning at 1000 mph on its axis making it look like the Sun is moving', the student must first come to terms with their alternative conceptions and then, most importantly, become discontent enough with their conceptions to allow a teachers' scientific notion to replace their own (Posner et al. 1982).

Children's Ideas and the Learning of Science is an article by Rosalind Driver, Edith Guesne and Andree Tiberghien that summarizes the types of conceptions students hold with regards to a variety of areas in science. The article is an introduction to a book of related articles about students' acquisition of science concepts entitled: "Children's Ideas in Science". The article does not describe a particular type of research design but rather it contains a series of conclusions about students' ideas derived from the authors' previous research and studies presented in later chapters of the book. The author refers to students' alternative conceptions simply as 'children's ideas'. Children's ideas are said to be derived from everyday experiences, to be personal to the individual child, and are considered to be quite stable in spite of attempts by a teacher to challenge the ideas. In order to accomplish the reorganization of these entrenched ideas the authors conclude that science teachers must take the time to provide students a wide variety of experiences relating to a specific concept.

The implications presented in this article focus on suggestions for science teachers that may be helpful in an attempt to restructure children's nonscientific conceptions. Teachers are asked to carefully decided which concepts to teach and how best to present the information because students at different stages of development may have a fragmented understanding of the world around them (Palmer, 1999). The authors do recognize the difficulty in addressing each child's unique set of conceptions and suggest that the teacher plan learning activities that reflect general trends in children's thinking. The conclusions drawn in <u>Children's Ideas and the Learning of Science</u> are consistent with the findings of other researchers in the area of student conceptual development. This article provides a solid basis for continued research in the methods and practices necessary to bring about conceptual change in the minds of science students.

In, "Earth as a Cosmic Body", Joseph Nussbaum describes a series of primitive mental models that children hold with regards to planet Earth. According to Nussbaum, the single largest factor limiting a child's scientific conceptualization is Piaget's theory of egocentrism (1929). Children tend to interpret reality only the way they perceive it. Piaget would say that young children lack the capability to imagine reality from a different perspective, such as one presented by a teacher or a textbook. Piaget's idea of egocentrism is consistent with current cognitive research which maintains that conceptual change is less of a case of replacement and more a part of a developmental process (Strike & Posner, 1992). With respect to children's naïve ideas and their resistance to change, Nussbaum's primitive mental models are consistent with the conclusions mentioned in the previous article (Driver, Guesne, & Tiberghien, 1985).

Nussbaum employed an interview procedure aimed at revealing children's concepts of Earth. Questions such as: "What is the shape of the Earth?" and "How do we know that the Earth is round?" and "Which way do we have to look in order to see the Earth?" were asked in the interview. Later the children were given pictures and models of Earth and asked to predict directions for falling objects. Ultimately, these tasks led the author to identify five different notions children possess about Earth.

Notion 1 is that Earth is flat and not round like a ball. Notion 2 is that a flat ground exists at the bottom of a hollow sphere with the sky towards the top. Students that hold Notion 3 believe Earth is a sphere but do not grasp the concept of gravity and think that things will fall off the bottom of Earth. Notion 4 describes a more advanced concept of Earth that correctly describes objects falling at Earth's surface but is still limited in its relationship to gravitation towards Earth's center. And finally, students that have advanced to Notion 5 demonstrate a satisfactory notion of these aspects of the scientific Earth: (1) a spherical planet, (2) surrounded by space, and (3) with objects falling toward its center.

The author attempted to apply the findings of this conceptual study in an experiment with 8-year-old students. His method involved a pre and post-test with a series of audio-tutorial lessons designed to address the three aspects of a scientific world-view. Nussbaum's experiment showed a 30% increase in the number of students who held Notions 4 and 5. From these results the author implies that with a focused curriculum, conceptual change can take place much earlier than Piaget would predict. The implication of this study is that curriculum must be designed to directly confront children's incomplete notions of concepts related to science. This study supports the need for research into related alternative conceptions of astronomical bodies and asserts conceptual change can be accelerated with focused curriculum.

Research conducted by W. C. Cobern, A. T. Gibson, and S. A. Underwood (1999), examined third grade students' ideas about lunar phases. Over a three-week period, students' received 6 instructional lessons designed to promote conceptual change. A qualitative approach was used to ascertain and make sense of children's understanding of lunar phases. The study was driven by 3 main questions:

1. What are third-grade students' conceptions about lunar phases?
2. In what ways are the third-grade students' ideas inconsistent with the scientifically accepted perspective?
3. Do third-grade students' conceptions of the lunar phases change after participating in activities featuring the scientific view?

This study took place in a third-grade classroom at an elementary school in a mid-western city located near a major university. Four students who were representative of the population were selected. Interviews were conducted and surveys given to students prior to instruction in order to ascertain pre-constructed ideas concerning the lunar phases. Interviews were also conducted after the final lesson was presented. Students' explanations were analyzed and compared with pre-instructional and post instructional responses.

The results of this study indicated some students were able to integrate the scientific concepts about lunar phases. However, as previously indicated by other reviewed research, many students continued to hold onto their unscientific notions about lunar phases even after instruction. It may be that the complexity of this topic was inappropriate for the developmental level of third-graders, and as suggested by Piaget and others, more success may be achieved with older students.

One of the leading researchers in the field of conceptual change in astronomy is Stella Vosniadou. Her study entitled: "Designing curricula for conceptual restructuring: Lessons from the study of knowledge acquisition in astronomy"(1991) directly supports further research in the areas of alternative conceptions in astronomy. The author cautions that conceptual restructuring is a long-term process. This admission is in agreement with the work of Rosalind Driver. As with two previously reviewed articles, Vosniadou believes that in spite of the obstacles involved with restructuring students' conceptions, carefully designed curricula and instruction can produce a significant change in students' thinking.

Vosniadou describes the methods of a research project designed at conceptual restructuring in the domain of astronomy. The subjects included pre-school, elementary and high school students, college undergraduates and adult illiterates from the United States, India, Samoa, and Greece. These varied groups were administered interview questions very similar to the types of questions posed in Nussbaum's study. In fact, the author used mental models derived from the work of Nussbaum and Novak (1976), to investigate the degree to which the participants used mental models in a consistent way.

Vosniadou identifies three mental models: intuitive, scientific, and synthetic in which participants were grouped based on their answers to interview questions. The intuitive model, similar to Nussbaum's Notion 1, deviates little from the child's phenomenally experienced world. The model includes a flat concept of Earth and the idea that day/night cycles are caused by the Sun going below the horizon. Scientific models are those that are most in accordance with current scientific views and would be equivalent to Nussbaum's Notion 5. Vosniadou describes "synthetic mental models" as misrepresentations of scientific information. She believes that these synthetic models are formed because children lack the meta-conceptual awareness necessary to question the accuracy of their entrenched beliefs.

Vosniadou also argues that an interrelationship exists between concepts in astronomy. For example, a child cannot fully understand Earth's shape without some understanding of the concept of gravity. The implication is that the curriculum must be sensitive to the order of concept acquisition in the domain of astronomy. The author notes that the concepts of day/night cycles and moon phases are very poor starting points for lower-elementary astronomy lessons. She feels that units on Earth's shape, gravity, and light reflection are better basic concepts to introduce prior to lessons on astronomical events. Another implication of the study is the need for textbooks and curricula that are sensitive to students' mental models. It is imperative that written materials and diagrams of celestial objects not inadvertently reinforce misconceptions. Curricula must be designed to avoid presenting counter-intuitive ideas, such as, 'the Sun is a star', or 'the Earth rotates on its axis' as simple facts to be accepted. Children must be given varied activities that confront their existing mental structures and force them to give up their previous ideas.

Once again, the author believes these synthetic mental models are entrenched and require maturation of the students in order to be reconstructed. Conversely, this research is another example of the idea that these deeply entrenched notions can be successfully advanced with the quality implementation of well-designed curricula that is sensitive to astronomy concept acquisition.

In his dissertation entitled, "The Initial Knowledge State of High School Astronomy Students", Philip Sadler of the Harvard Smithsonian Center for Astrophysics, describes the development and administration of a multiple-choice instrument designed to illuminate high school students astronomical misconceptions. The instrument was given to 1,414 high school earth science and astronomy students and revealed fifty-one different misconceptions in the area of space science. Nineteen of the misconceptions were actually preferred by students over the correct scientific answer.

The sixty-item test, developed in association with the Harvard-Smithsonian Center for Astrophysics' Project STAR (Science Teaching through its Astronomical Roots), a long-term curriculum development project funded by the National Science Foundation (NSF), was given to subjects during the first two weeks of their high school astronomy or earth science courses. Sadler sought the answers to various research questions such as, "For students enrolling in a course where astronomical concepts are taught, for which concepts will students initially hold concepts that are at odds with accepted scientific views?" and "Are differences in the quantity of misconceptions related to students' grade level or age?" Additionally, several other demographic factors were analyzed. The results of Sadler's misconception study were quite interesting. Not only were fifty-one different misconceptions defined, showing the magnitude of inaccurate scientific conceptualization by high school science students, but the overall variance among subgroups was quite low. Of the many demographic factors considered, only one highly significant schooling factor was uncovered. Students with several years of mathematics held fewer misconceptions in astronomy-related science. Grade-level, age, parental education levels, and even exposure to a previous earth science course, (which are typically 25% astronomy curriculum), did not significantly reduce the number of astronomical misconceptions held by high school students. Sadler describes the overall conceptual understanding of the students in this study as, "appalling" and limiting the "students' ability to integrate new concepts into their already well-developed frameworks of understanding" (Sadler, 1992). He calls on earth science and astronomy educators to assess the astronomical concepts of their students. Along with the previously mentioned authors, Sadler believes students must be given the time to elucidate and test their conceptions before significant conceptual change can be expected.

Each of the articles critiqued for this project support the notion that conceptual change is possible after the illumination and analysis of students' alternative conceptions in science. Joseph Nussbaum's experiment with 8-year-old students showed a 30% increase in the number of students holding a more scientific world-view after focused instruction. Vosniadou believes, "there is an interdependency among various concepts that comprise the domain of astronomy" (Vosniadou, 1991). She agrees that if the connections are discovered between these interdependent entities then conceptual change can take place. And Philip Sadler suggests that when students realize their misconceptions cannot explain natural phenomena or the results of experiments, they will then be open to the scientific concepts presented by their teachers.

CHAPTER THREE

METHODOLGY

Design of the Investigation

The research questions posed in this study were derived from the instrument used in the study, which was found on the Harvard-Smithsonian Center for Astrophysics, web site: Universe! An Educational Forum. The website is open domain to educators who wish to gain a better understanding of their students' conceptions about the size, age and distance of seven common objects associated with astronomy. The first three research questions in this study are designed to investigate these same three concepts of size, age, and distance of astronomical objects. It is expected that common patterns will be found in the data that reveal students' alternative conceptions. In addition to these three questions, eight multiple-choice questions related also to the concepts of size, age and distance of astronomical objects were written in order to illuminate any additional alternative conceptions students may be harboring.

In order to investigate questions four and five, which deal with school-related demographic factors, the overall scores from the survey were compared and analyzed descriptively.

Population

The subjects for this study included 39 science students from Santiago High School in Corona California. The students were chosen for convenience purposes from three physical science classes: Advanced Placement (AP) Physics (n=11), Astronomy (n=12), and Natural Science (n=16).

AP Physics is a yearlong, laboratory physics course taught in the eleventh and twelfth grade, where students can earn college credit. Although the subjects of physics and astronomy are related, these students did not receive specific instruction on astronomy concepts during this school year. AP Physics is considered to be one of the most advanced science courses offered at Santiago High School. Students taking AP Physics tend to be at the highest academic ability levels and they were chosen to participate in this study in order to determine if academic ability is related to the number of alternative conceptions held by science students.

The twelve Astronomy students, grades 11 and 12, involved in this study can be characterized as average to above average ability level. They were at the end of a yearlong laboratory astronomy curriculum that covered all of the State of California space science standards as well as additional topics such as space exploration and the history of astronomy.

Natural Science is a yearlong laboratory physical science course, aligned with state science standards in basic chemistry, basic physics, and earth science. Most students in this course could be described as average ability with a few below average and a few above, ranging in grade level from 9^{th} to 12^{th} grades. These students received a one-month unit of instruction on astronomy standards at the beginning of the school year.

Treatment

Over a two-day period during the last two weeks of the school year, the data for this research project was collected. Each of the three classes, AP Physics, Astronomy, and Natural Science, was administered the test separately during the first 15 minutes of class. Students were asked to cut out seven images of celestial objects and place them in order according to: 1) distance from Earth, 2) age (most recently formed to oldest), and 3) size (largest to smallest).

Students were instructed not to discuss their ideas or answers with others. They were asked to do their best work and told the assignment would not affect their grade. Students were able to manipulate the cut out images until they were satisfied with their order before committing their answers in writing on the questionnaire. Students were asked to write down any questions of their own that may have occurred to them as they contemplated their survey answers. This additional meta-cognitive information was optional for students but it was included to provided additional insight into the students' thought processes. And lastly, the students were instructed to circle the answer they felt best answered each of the eight multiple-choice questions.

During an Internet search for research in support of this study, an instrument called the Cosmic Survey was discovered on the Harvard-Smithsonian Center for Astrophysics website. The website is maintained by the Science Education Department at Harvard University and the research project entitle: Universe! An Educational Forum is supported by a grant from NASA (National Aeronautics and Space Administration). The instrument is a three-part survey, which asks students to physically manipulate pictures of seven common astronomical objects (Moon, Whirlpool galaxy, Deep-field galaxies, Hubble telescope, Pleiades star cluster, Saturn, Sun) in order to represent their mental models of objects in the universe as well as space and time. The instrument used for this study included these three Cosmic Survey questions as well as eight multiple-choice questions also related to the size, age and distance of astronomical objects. (See Appendix A)

A version of this instrument, without the eight multiple-choice questions, was administered to a different group of 56 Natural Science students, earlier in the year by their classroom teacher as a post-test to determine the levels of conceptualization following an astronomy unit. The data from that administration was collected and analyzed in the same manner as for this study and provides a basic level of reliability to this portion of the instrument. In addition, the Cosmic Survey has been administered online for several years and the data collected by the Science Education Department, reveals results consistent with this study, which provide reliability and validity to the first three questions of the instrument used in this study. However, the eight multiple-choice questions were not administered prior to this study to determine their reliability or validity.

Instructors of the Astronomy, Natural Science, and AP Physics classes found the instrument to be a valid indicator of student learning and conceptualization of the topics surveyed. There were no problems mentioned with reading level or design of the questions by the instructors who reviewed the instrument.

Data Analysis Procedures

A set of 39 surveys was collected as data from this study. Because each survey included answers to eight multiple-choice questions, in addition to the three Cosmic Survey questions, (which each contained seven pictures to be ordered), the possible number of combinations of answers presented quite a difficult challenge in analysis. A descriptive approach was applied to the data. With regard to the Cosmic Survey portion of the data, each of the three questions was totaled separately, as well as the three classes of students' answers to those questions. The number of correct answers ranging from 0 correct to 7 correct was calculated manually. Then the totals for each of the three Cosmic Survey questions were bar graphed.

A scale to define student conceptual understanding as it relates to the Cosmic Survey questions was developed and used as a guide for analyzing the surveys. The students that correctly ordered all seven pictures on any one question were considered to have "mastery of the concept" of that question. The students that correctly ordered five or six of the pictures were considered to have a "basic conceptual understanding" of that question. A student that ordered 3 or 4 pictures correctly was said to show "limited conceptual understanding". And any student that placed two or fewer pictures in the correct order, was considered to "lack conceptual understanding" on that particular question.

The overall score out of a possible 29 points on the entire instrument was tabulated for each student and a range of scores was determined. In addition, the average overall score for each of the three science classes was determined and graphed for comparison.

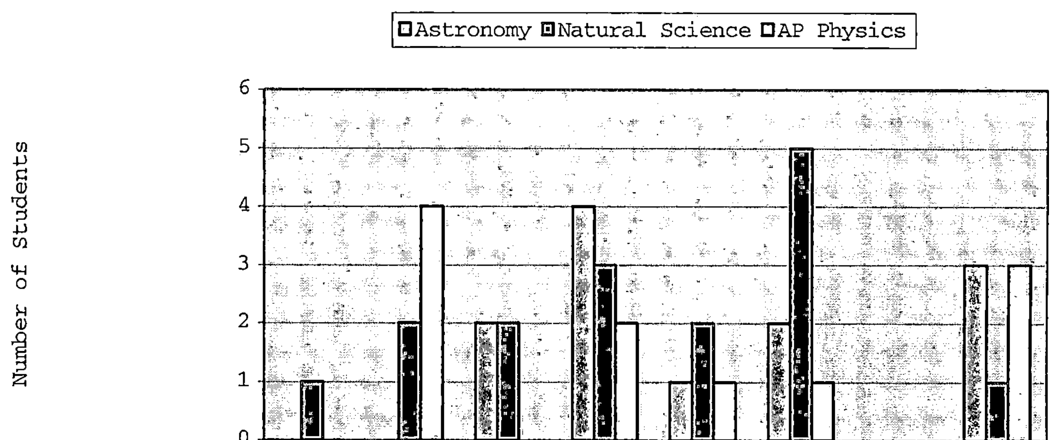
CHAPTER FOUR

RESULTS AND DISCUSSION

Presentation and Discussion of the Findings

The results of question one (How Far?) are presented in Table 1 below, which compares the results of each of the three physical science classes:

Table 1. Comparison of 3 Classes: Question #1 How Far?



	0	1	2	3	4	5	6	7
Astronomy	0	0	2	4	1	2	0	3
Natural Science	1	2	2	3	2	5	0	1
AP Physics	0	4	0	2	1	1	0	3

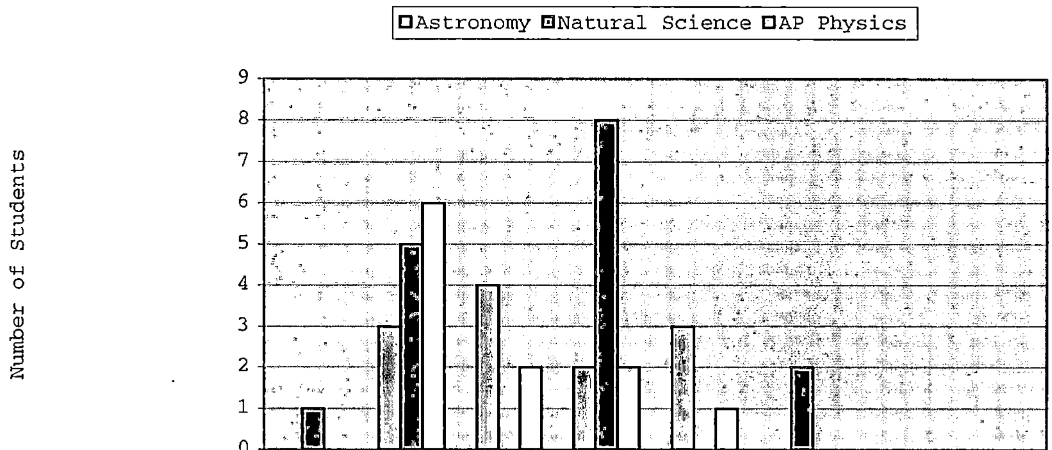
Number of Correctly Placed Pictures

With regard to question one, (How Far?), seven students ordered all seven pictures correctly and could be considered to display mastery of this concept. This represents 18% of the students surveyed. Another 21% of students displayed a basic conceptual understanding of question one and 33% showed a limited conceptual understanding. Of the 39 students surveyed, 11 or 28% could be said to lack conceptual understanding of the distances to the seven celestial objects. These findings support the hypothesis that a majority of the 39 students would not display mastery of the concept of relative distance of the seven celestial objects.

Patterns emerged in the data, which were also identified and analyzed. The patterns included: a) the first series of pictures placed correctly, b) the last series of pictures placed correctly, c) both the first and last series of pictures placed correctly. For question one, (How Far?) twenty-three students correctly ordered the last few pictures. Eight students of this group ordered both the first and last few pictures correctly, indicating possible confusion between the difference in distance from the Earth to the Sun and the Earth to Saturn.

The patterns that emerged with question two, (How Old?) were similar to that of question one, with 21 students getting the first and last few pictures placed correctly. Only six students of the 39 students tested, correctly placed three or more pictures; two of these students placed five pictures correctly and no one placed either six or seven pictures correctly to represent a mastery level of conceptualization for question two. Forty-one percent of the students demonstrated a limited conceptual understanding on question two, and a dismal twenty-one students (54%) displayed a total lack of conceptual understanding of the age of the celestial objects. The hypothesis for this concept predicted fewer than 10% of the 39 students surveyed would display mastery of the concept of age of the seven astronomical objects. Sadly, the hypothesis was overwhelmingly supported. The results of question two are displayed in Table 2 below:

Table 2. Comparison of 3 Classes: Question #2 How Old?

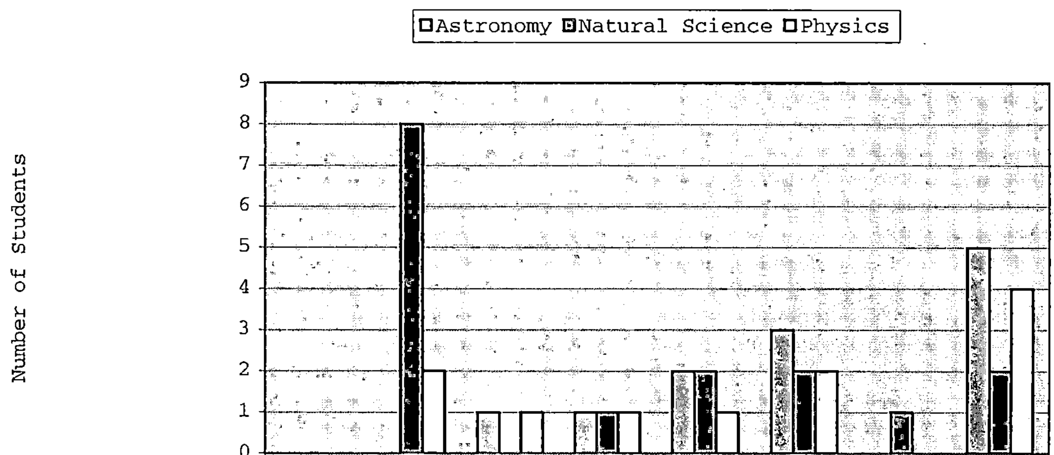


	0	1	2	3	4	5	6	7
Astronomy	0	3	4	2	3	0	0	0
Natural Science	1	5	0	8	0	2	0	0
AP Physics	0	6	2	2	1	0	0	0

Number of Correctly Placed Pictures

The results of question three, (How Big?) were more promising with 11 students displaying mastery of the concept of size of the celestial objects. And another 16 students scored between limited and basic conceptual understanding of the concept of the size of the celestial objects. Although students seemed to grasp the concept of size of the objects better than age or distance, 12 of the 39 students (31%) still displayed a lack of conceptual understanding by placing two or fewer pictures correctly. Once again 26 students correctly placed the first, last or first and last pictures correctly, but struggled with the middle portion of the survey. Again, the prediction that fewer than half of the 39 subjects would display mastery on this concept was supported by the data. The results of Question #3 are presented in Table 3 on the following page.

Table 3. Comparison of 3 Classes: Question #3 How Big?

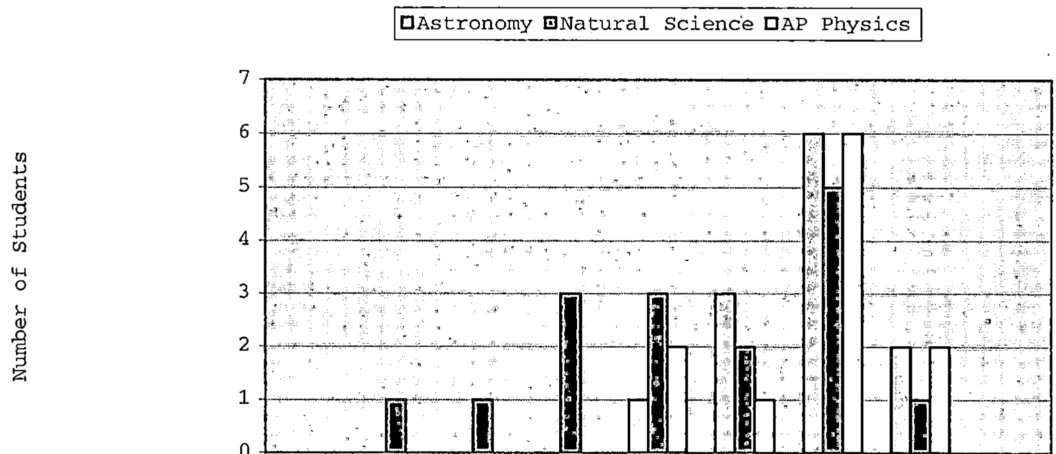


	0	1	2	3	4	5	6	7
Astronomy	0	0	1	1	2	3	0	5
Natural Science	0	8	0	1	2	2	1	2
Physics	0	2	1	1	1	2	0	4

Number of Correctly Placed Pictures

Because the eight multiple-choice questions had never been administered to a group of students in the past, the results were most interesting. Table 4, comparing the results of the three classes on the multiple-choice potion of the instrument follows on the next page.

Table 4. Comparison of 3 Classes: 8 Multiple-Choice Questions



	0	1	2	3	4	5	6	7	8
Astronomy	0	0	0	0	1	3	6	2	0
Natural Science	0	1	1	3	3	2	5	1	0
AP Physics	0	0	0	0	2	1	6	2	0

Number of Correct Answers Out of 8

Overall, it is quite apparent from Table 4 that each of the three subgroups performed considerably better on the multiple-choice questions than on the Cosmic Survey portion of the instrument. Some reasons for this may include: teacher-made questions often tend to be easier than most standardized test questions, students are more familiar with the format of multiple-choice questions, and because science textbooks emphasize vocabulary over concepts, these questions may have better addressed the students' fact-based knowledge (Roth, 1985b).

Students on the average scored 5.3 out of 8 (66%)on the multiple-choice portion of the survey as opposed to 54% on average for the entire survey. The Astronomy and AP Physics students did essentially, the same on the multiple-choice questions with an average of 72%, while the Natural Science students averaged only a 54% on this part of the test.

It was interesting to see that no one missed all eight questions and no one answered all eight correctly. Questions (#2) and (#8) were missed by 23 and 29 students, respectively, out of a total of 36 students. Question (#2) asked, "How many Earth's could fit in the Sun?" The correct answer, (d) about one million, was chosen 41% of the time. However, incorrect answers (b) about one hundred, and (c) about one thousand, were chosen by a combined 55% of students. This shows that the majority of students in this sample have very little concept of the relative size of the Earth or Sun. Seventy-four percent of the students surveyed answered question eight incorrectly. This question was chosen purposely to test the subjects' higher-order abstract thinking skills by attempting to determine to what extent students associate objects at great distances with relatively young age of formation. The concept of looking back in time by looking out into space is very challenging for most adults, let alone high school students. The question could have been worded to provide more information, such as: (True or False)"Because the galaxies in the deep field are very far away, we see them as they were when they were young."

Questions (#1) and (#4) dealt with the concept of what a galaxy is as compared to a solar system or universe. The Astronomy and AP Physics students were quite successful with these questions. Oddly, Natural Science did very well on question four but very poorly on question one. It may be the concepts of solar systems or black holes that students do not strongly grasp. Seventeen out of 36 subjects (47%), answered question six incorrectly. Although the astronomy students did slightly better, all three subgroups, once again, displayed a lack of conceptual understanding about the ages of celestial objects.

Research questions four and five dealt with demographic school factors such as, the Astronomy student's time-spent on space science concepts, and the AP Physics students perceived ability levels. It was predicted that the Astronomy students, due to their yearlong exposure to astronomy curricula, would score 4 points higher overall than both of the other subgroups surveyed. The data supports this prediction for the Natural Science students but the AP Physics students scored only 2 points lower on average than the Astronomy students. The Astronomy students' mean score on the survey was 17.67 out of a possible 29, for an average of 61%. While the AP Physics students mean score was 15.64/29, (54%) and Natural Science averaged 13.38/29, or 46%, overall. The AP Physics students in this study obviously did not score significantly higher on the survey based on their apparent academic ability levels. It seems as though advanced ability level, age and/or advanced IQ's, do not prevent our best students from holding alternative conceptions in science, and certain misconceptions may actually appear more frequently among higher-performing students (Sadler, 1992).

So, what possible alternative conceptions may these high school students be harboring related to the concepts of size, age and distance of astronomical objects? The results of this survey suggest several areas where students seem to lack a concept at all to explain many of the items discussed on the survey. For example, even the absolute highest scoring students had no idea how old something like the Pleiades Star cluster might be. In fact, had the cluster not been one of the choices, often, the following series of pictures would have been placed correctly. Surprisingly, students from all three subgroups showed a lack of conceptual understanding about the size, age and distance of the Hubble Space Telescope. Many students placed the moon closer to the Earth than the Hubble Telescope. One student wrote on his paper, "Where is the Hubble Telescope?"

Most students placed the Pleiades Star cluster, Whirlpool Galaxy, and Hubble Deep Field of galaxies far away from Earth but in varying orders. This suggests that students struggle with the concept of relative distances in space. They know these things are far away but they do not hold a conceptual framework that allows them to order distances or sizes, relatively.

The results of multiple-choice question #8 suggest students believe far away objects must be very old, or perhaps, they believe all celestial objects are very old. Although they are "old", once again, we see difficulty with the concept of relativity; this time associated with the age of objects in the universe. The results of multiple-choice question #2 indicate many students may hold an alternative conception that either the Sun is smaller than it actually is, or that the Earth is larger. In most textbooks, the Sun is drawn much smaller, and closer, to Earth than in reality, reinforcing these misconceptions related to the relative size and distance of the Sun. There was also consistent confusion about whether the Sun or Saturn was closer to Earth. However, students did well when this question was posed in a multiple-choice format, suggesting many of our students lack the ability to apply information in a more challenging format.

And lastly, it appears, due to the results of multiple-choice question #6, (Which objects are about the same age?), that many students do not hold the scientific conception that the entire solar system formed at roughly the same time. Consequently, 44% of the subjects chose an answer other than choice C (the Sun, the Moon, and Saturn), which was correct.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

This quantitative study was conducted to assess the levels of conceptualization various groups of high school physical science students may possess about the size, age, and distance of seven astronomical objects. Research shows that when students harbor alternative, non-scientific concepts, these ideas inhibit further learning (McDermott, 1984). Furthermore, a clear conceptual understanding of earth and space science standards is essential for all high school students (NSES, 1995), including our most advanced science students who often miss out on astronomy entirely.

Thirty-nine high school students from three different physical science classes were administered the survey instrument. The results were tabulated and descriptively analyzed to reveal patterns, alternative conceptions, and levels of conceptualization among the various subgroups.

The results of this study indicate a lack of conceptual understanding in all three conceptual areas surveyed. The area students seemed to struggle with most was the age of the various astronomical objects. Although they scored the lowest on this question, with some basic teacher input and investigation activities, this may prove to be the easier area of the three investigated, to change conceptually with instruction.

The range of conceptual understanding related to the size of the seven astronomical objects, was quite varied. Some students displayed a basic conceptual understanding in this area, which could be built upon with a quality set of instructional activities. The distances in the universe are difficult to comprehend for most individuals. It takes many years to develop a mental structure that can imagine the scale of stars, solar systems within galaxies of billions of stars, and billions of galaxies within an ever-expanding universe.

Because several students ordered the first and last few pictures correctly on the distance question, it is likely that they better understand the objects near Earth and conceive of objects such as galaxies as being very far away. The challenge will be to design lessons to bridge this gap in their mental structures and help students make the needed connections between the closer and farther objects in the universe.

It is unfortunate that obtaining a larger sample size proved to be so difficult. The low numbers of participants, especially within each subgroup, make it difficult to claim the results of the study as statistically significant. Even with this major limitation, this study illuminated several important points of interest upon which further research may be conducted. These high school students performed very poorly, overall, on the instrument. Even the brightest Advanced Placement Physics students averaged only 54% on the survey. The implication here, is not one of lack-of-ability, but rather, lack-of-exposure to space science concepts.

Although, the Astronomy students clearly were more successful on the survey than the other subgroups, a 61% is considered a D- on most high school science teachers' grading scales. Although a survey specifically designed to assess students' misconceptions will invariably have lower averages than other standardized tests (Sadler, 1992), it is clear that this research has assessed this group of high school students with an overall lack of conceptualization in the areas tested. It seems obvious that more work is needed within the context of earth and space science classes in order to help students improve their overall scores on space science assessments. None-the-less, the results of this study are consistent with larger-scale research endeavors, such as the Harvard-Smithsonian's A Private Universe project, which showed some of the nation's highest ability college graduates (Harvard), sharing similar alternative science conceptions with high school students (Sadler, 1988).

Much of the research related to altering students' misconceptions in science involves lower grade students. There still remains a need for further research targeted at the secondary levels involving student conceptions in various other areas of space science. Likewise, most of the articles reviewed for this study suggest that students must be at a more advanced developmental stage in order to acquire the complexities of a subject such as astronomy. A focused, research-informed space science curriculum developed specifically for high school astronomy classes could be designed. The curricula designed will be informed by the suggestions of the authors reviewed here as well as other current research in the field of science education. This survey could also be given as a pre-test and post-test after the curriculum was taught to gauge the students' conceptual changes.

This study may serve as a basis for further research regarding a probable disconnect between our nation's top students and their conceptualizations within the earth sciences. Another major implication of this study is that courses should be designed to address one science subject at a time. Despite a low average score on the survey, it is clear that the Astronomy students, who were immersed in a yearlong curriculum related to the concepts investigated, displayed a higher level of conceptualization than the other subgroups. Given a quality space science curriculum and the necessary time to fully explore that curriculum, students at all academic levels can begin to replace their alternative conceptions with scientific conceptions.

APPENDIX

INSTRUMENT

UNIVERSE!

COSMIC SURVEY: WHAT ARE YOUR IDEAS ABOUT THE UNIVERSE?

QUESTION #1: HOW FAR?

You have been provided with images of seven different objects in space. Try arranging the pictures side by side in a row, in order of distance of the object from Earth. Order the objects so that the object closest to Earth is on the left, farthest on the right. Write down and keep track of questions that arise as you order the images.

When you are satisfied that you have the best order, record the names of the objects in the spaces below.

OBJECTS ORDERED BY DISTANCE FROM EARTH

1.	2.	3.	4.	5.	6.	7.

Closest to Earth   Farthest from Earth

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UNIVERSE!

COSMIC SURVEY: WHAT ARE YOUR IDEAS ABOUT THE UNIVERSE?

QUESTION #2: HOW OLD?

You have been provided with images of seven different objects in space. Try arranging the pictures side by side in a row, in order of age, beginning with the youngest (most recently formed) object, and moving in order to the oldest. Write down and keep track of questions that arise as you order the images.

When you are satisfied that you have the best order, record the names of the objects in the spaces below.

OBJECTS ORDERED BY AGE

_______	_______	_______	_______	_______	_______	_______
1.	2.	3.	4.	5.	6.	7.

Youngest (Most Recently Formed) Oldest

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COSMIC SURVEY: WHAT ARE YOUR IDEAS ABOUT THE UNIVERSE?

QUESTION #3: HOW BIG?

You have been provided with images of seven different objects in space. Try arranging the pictures side by side in a row, in order of actual size of the object (or field of objects) pictured. Order the objects so that the smallest is on the left, largest on the right. Write down and keep track of questions that arise as you order the images.

When you are satisfied that you have the best order, record the names of the objects in the spaces below.

OBJECTS ORDERED BY ACTUAL SIZE

______	______	______	______	______	______	______
1.	2.	3.	4.	5.	6.	7.

Smallest in Actual Size — Largest in Actual Size

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CIRCLE YOUR ANSWER FOR THE FOLLOWING QUESTIONS.

1) What is a galaxy?
   a) a cluster of a few hundred stars
   b) the same thing as a solar system
   c) a cluster of billions of stars
   d) a black hole

2) How many Earth's could fit in the Sun?
   a) about ten
   b) about one hundred
   c) about ten thousand
   d) about one million

3) Which is closer to Earth: the Sun or Saturn?
   a) Sun
   b) Saturn

4) What is the difference between a galaxy and a universe?
   a) they are two words for the same thing
   b) there are billions of galaxies within a universe
   c) there are billions of universes in a galaxy
   d) a universe contains stars

5) When you look up at the night sky, the stars you see...
   a) are all part of our Milky Way Galaxy
   b) are part of another galaxy
   c) are part of many different galaxies

6) Which objects are about the same age?
   a) the Whirlpool Galaxy and the Pleiades star cluster
   b) the Hubble Space Telescope and the Moon
   c) the Sun, the Moon, and Saturn

7) (True or False) The galaxies in the Hubble Deep Field picture are very far away.
   a) True
   b) False

8) (True or False) The galaxies in the Hubble Deep Field are very young galaxies.
   a) True
   b) False

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