THE USE OF NEW LEARNING MODALITIES IN THE TEACHING OF CORE CONCEPTS IN INTRODUCTORY COLLEGE ASTRONOMY CLASSES

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ABSTRACT

This study had, three distinct purposes, and as such, explored several different innovative new educational concepts. One purpose was to find out how many students in college astronomy did not understand the basic concepts and models concerning what causes the seasons on the earth and the understanding of why the moon goes through phases as one of the examples. A pre-test was given to find out the level of understanding the students had concerning these concepts. The students that did not show an understanding of the basic concepts were then used in

the study to try several new learning modalities of teaching and understanding the basic concepts.

A second purpose was to contrast instructional techniques by dividing the group that had trouble with the concepts into two groups. One was given a learning modality of teaching using manipulatives and models (earth and moon as an example). The other group was given a different learning modality, which involved more formal lecturing and audio-visuals to help understand the concepts. This division of understanding was done for both of the astronomy-based models incorporated within the study.

A third purpose was to contrast tactile modality instruction with a straight lecture method using visual and auditory learning modalities, examining two concept models presented to the subjects. The purpose was to see which of the methods, employing different learning modalities was more effective in teaching the students, and their related understanding of the concepts.

Results of the study indicated that the students over the semester showed very large increases in general understanding as assessed by a conceptually based multiple-choice measuring device. In addition, attitudes toward the course at the beginning were slightly positive and changed to slightly negative at the end. Implications were then made from the study related to the instruction of astronomy-based concepts within college coursework.

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CHAPTER 1

INTRODUCTION

At many colleges the introductory astronomy class is often used by non-science majors to get the studies they need in order to fulfill certain pre-requisites in their majors(National Academy of Sciences 1996). The classes are usually taught out of the physics/astronomy departments of most colleges.

Most students, and in fact over 200,000 in 1997(Zeilik, 1997) take this class to meet their general science requirements. Many of the students are non-science major's (i.e. they will be business leaders, computer programmers, or politician). For example, the highest enrollment in the classes used as a sample for the study, came from the business majors.

The basic purpose of an astronomy class of this type then must be focused to help students develop a general understanding of basic concepts and processes in science(Astronomical Society of Pacific, 1996). As many astronomical organizations suggest, this is perhaps the only opportunity we have of teaching students in college to appreciate science and learn its value to society as a whole.

Many studies have shown that the manner of instruction (Penner 1984), what is taught, and what the instructor wants learned in the modality of instruction can create many problems for the student. Thus, if we as instructors in basic science wish to improve the general understanding and literacy of related concepts and learning outcomes as most studies show; we need to change correspondingly our methods of teaching the courses to help target these outcomes.

The overall objective in this particular study was to try and improve the basic understanding of specific models in astronomy through different instructional modalities. These objectives also need to interact with the size of the class or sample within the study, which can be routinely over 100 students. Thus, several group instructional modalities were also examined in the classroom to see their effectiveness. The approach is based on educational theories(Sawyer and Prichard, 1994) and research on how students learn and retain knowledge within this context.

STATEMENT OF THE PROBLEM

What is the relationship between a specific learning modality and the improvement in the understanding of basic concepts and models in a large college course associated with the subject of astronomy?

OPERATIONAL DEFINITIONS:

Learning Modality: Visual, auditory, or tactical preference in learning model.

Visual-the student prefers to learn by sight, slides, video, or overheads.

Auditory-the student prefers sound; lecture and discussion is common mode.

<u>Tactile</u>-the student wants to touch models and things to learn; models of the planets and moons are common.

<u>Introduction to Astronomy(PHY1350)</u>: is a fifteen-week class taught on a college level at the University of Nebraska at Omaha. It is used to teach the student basic concepts in the following;

1) History
2) Light and telescopes
3) Earth and moon
4) Terrestrial planets
5) Jovan planets
6) The sun
7) Stars
8) Stellar evolution
9) Galaxies
10) Cosmology

HYPOTHESES

The focus areas in this study are outlined below in the following hypotheses:

Hypothesis I: Students using tactile learning models of seasons will do better on content post-tests than students, which are only taught through the auditory or visual method.

Hypothesis II: Students using tactile learning models of moon phases will do better on post-tests than students, which are only taught through the auditory or visual method.

Hypothesis III: Students that work in small groups in the class will score higher than students that do not work in small groups learning certain astronomy concepts.

Hypothesis IV: Attitudes toward science and its value will increase from pre-test and post-test results in the groups using new concepts of teaching modalities.

SIGNIFICANCE OF PROBLEM

By examining the use of manipulatives and the related tactile processes in learning as well as the use of group learning process an enhanced understanding of the learning of basic astronomy concepts and models may occur. In addition, an increase of basic understanding of science and its relative values may become an added benefit to such instruction. Several groups(National Science Education Standards, 1996) such as NSES, has emphasized conceptual learning and process learning for basic models and values in science.

There is little doubt, that students are leaving our schools at all levels with an extreme lack of understanding in the most basic of science methods. The Third International Mathematics and Science Study(TIMSS, 1997) showed that the United States is woefully lacking in some basic understandings of science. As stated by the president Clinton after this study was released;

> "There is no excuse for this." President Clinton went on to chide; "These results are entirely unacceptable," admonishing the secretary of education. He went to say; "this report; shows all the elements of an education tragedy"(TIMSS, 1997)

It has been shown(Zeilik, 1997) that new methods of teaching basic science can have a dramatic effect on the students and their learning of concepts that such reports deem as critically important for our students to function in an international society.

New teaching and learning styles are indeed important to the successful instruction of today's students. This was expressed several years ago by Sims and Sims(1993). They stated;

> Higher education administrators responsible for the success of their teaching efforts can no longer afford to assume that all

> students learn through whichever strategy the teacher prefers to use. Why gamble the potential successes of the teaching effort? For the student who has been unsuccessful with previous teaching style, learning is miserable and there is little chance that in the next course or class the student will suddenly adjust his/her learning style or even be capable of adjusting. Higher education needs to decide whether they want students to adjust to learning or to learn. If learning is the objective, then new mind capturing techniques must be developed and applied for teaching to be successful.

New college students today can shop for the instructor, and sometimes even an institutional provider of the needed class. The idea of success in the class or their perception of success is known to be a major deciding factor in how they proceed with their college education. Thus, the effective use of appropriate teaching methods and an emphasis on successful learning by the students is paramount in this introductory level of class, and its relative success within a college today.

SUMMARY:

Science reform in the 1990's suggest that students first have the basic concepts taught by methods that are more educationally effective and that also use several different learning modalities, particularly since different students will learn better by different methods.

Varied instructional methods by manipulatives or by group method may help students learn the concepts that we as instructors believe are important. This is perhaps the only chance we will get to teach basic science and its values, as they may never take another science class.

To investigate such instructional approaches is indeed an important step in institutionalizing such instruction in the classroom. Past efforts and insights related to previous research is now described in Chapter Two.

CHAPTER II

REVIEW OF LITERATURE

The purpose of this chapter is to provide a look at the base of information on which the project and thesis was predicated upon.

A focus of the research is to examine what is the relationship between using tactile modalities to teach core concepts in astronomy to the traditional methods of lecture only teaching methods.

Another focus is the relationship of small group teaching methods to large lecture traditional methods. This will also include a look at attitudes and their change as it relates to teaching methods and student participation.

The educational reform movement over the last 20 to 25 years has questioned the effectiveness of teaching methods of basic science in our schools and this review is to look at the various ideas that have been expressed as problems. The literature will be broken down to look at:

a) Science education reforms

b) A look at conceptual learning methods

c) Use of new models to teach basic concepts

Science Education Reform:

It was noted in Democracy and Education (Dewey, 1926) that

> "Information severed from thoughtful action is dead, a mind crunching load"(p.179)

In today's society the national standards that have been established are to address the long-standing problem of teaching methods and teaching modalities. New standards in science education encourage the use of new modalities, manipulative, and radical changes in paradigms (National Science Standards, 1996). These standards incorporate both models and concepts together, such that;

other content standards in the early grades, instruction should establish the meaning and use of unifying concepts and processes--for example, what it means to measure and how to use measurement tools. At the upper grades, the standard should facilitate and enhance the learning of scientific concepts and principles by providing students with a big picture of scientific ideas--for example, how measurement is important in all scientific endeavors"(NSES, Chapter 6).

Although this national standard was created for the K-12 students, it has a direct influence on the potential source of college bound students. K-12 students have created models and a concept based on the way science was taught to them. If the materials and methods were incorrect or incomplete then students will have their own private misconceived universe, which is incorrect, and may struggle in future college courses.

A new standard, such as the one below that puts a tremendous emphasis on scientific inquiry. For students in the K-12 grades there is a special emphasis on earth science and the solar system.

K-4 .4. EARTH AND SPACE SCIENCE STANDARDS

LEVELS K-4	LEVELS 5-8	LEVELS 9-12
Properties of earth materials	Structure of the earth system	Energy in the earth system
Objects in the sky	Earth's history	Geochemical cycles
Changes in earth and sky	Earth in the solar system	Origin and evolution of the earth system
		Origin and evolution of the universe

(NSES, Chapter 6)

A main inquiry topic with students within introductory astronomy is to assess whether they have learned this standard based approaches and how well they learned them. The new standards put a large emphasis on standards and inquiry of the subject.

The National Science Education Standards envision change throughout the educational system. The science content standards encompass the following changes in such emphases:

CHANGING EMPHASIS ON CONTENT

LESS EMPHASIS ON

1) Knowing scientific facts.

2) Studying subject matter disciplines (physical, life, and earth sciences) for their own sake.

3) Separating science knowledge and science process.

4) Covering many science topics.

5) Implementing inquiry as a set of processes.

MORE EMPHASIS ON

1) Understanding scientific concepts and developing information abilities of inquiry.

2) Learning subject matter disciplines in the context of inquiry, technology, science in personal and social perspectives, and history and nature of science.

3) Integrating all aspects of science content.

4) Studying a few fundamental science concepts.

5) Implementing inquiry as instructional strategies, abilities, and ideas to be learned.

CHANGING EMPHASIS TO PROMOTE INQUIRY

LESS EMPHASIS ON

1) Activities that demonstrate and verify science content.

2) Investigations confined to one class period

3) Process skills out of context.

4) Emphasis on individual process skills such as observation or inference.

5) Getting an answer.

6) Science as exploration and experiment.

7) Providing answers to questions about science content.

8) Individuals and groups of students analyzing and synthesizing data without defending a conclusion.

9) Doing few investigations in order to leave time to cover large amounts of content.

10) Concluding inquiries with the result of the experiment.

11) Management of materials and equipment.

12) Private communication of student ideas and conclusions to teacher.

MORE EMPHASIS

1) Activities that investigate and analyze science questions.

2) Investigations over extended periods of time.

3) Process skills in context.

4) Using multiple process skills-- manipulation, cognitive, procedural.

5) Using evidence and strategies for developing or revising an explanation.

6) Science as argument and explanation.

7) Communicating science explanations.

8) Groups of students often analyzing and synthesizing data after defending conclusions.

9) Doing more investigations in order to develop understanding, ability, and values of inquiry and knowledge of science content.

10) Applying the results of experiments to scientific arguments and explanations.

11) Management of ideas and information.

12) Public communication of student ideas and work to classmates.

The above information suggests how we should teach science to K-12 students, and states that we should be doing more inquiry and conceptual teaching. Thus the focus of my research in this particular college level class of this thesis was to see if such a teaching emphasis would have a more positive outcome on the learning expectations of college students in an introductory astronomy class.

The use of core concepts and the inquiry of those concepts appears from all previous research to be more essential to today's students and their ability to be better students inquiring about the world around them.

Conceptual learning methods in astronomy

Let us first look at the standard models used in astronomy classes at the introductory level. The following are characteristics that have been outlined by the Astronomical Society of the Pacific (1997). These are by no way comprehensive and inclusive of all colleges but give a basic guide for our further discussions.

Characteristics:

1) Covers the whole cosmos in one semester
2) Descriptive (phenomenological) rather than conceptual
3) Large classes 50-200
4) Well polished lecture
5) Heavy use of audio-visual materials
6) Occasional interactions with students
7) Student tests by multiple choices.

The many reasons for this instructional focus can be outlined by

1) Severe resource limitations
2) Limited teaching assistants
3) No discussions
4) No required laboratory.

Lecturing has been the mode of instruction at universities for a long time(Ekeler,1994). For example, in math and science classes it was found that 89% of the professors, regardless of the size of the class, lecture exclusively. However, it is also found that a well-done lecture may have some advantages for informational delivery (Thielens, 1987). In addition it was found that students have an attention span of 10 to 20 minutes at the beginning of the lecture. After this time span their minds wander(Bonwell and Eison, 1991). It was also found by Bonwell and Eison that other strategies interwoven with lecture may be a more effective tool than lecture alone. Many teachers in introductory science classes conclude that many, if not most, of the novice learners miss the big picture; no matter how well structured the content(Zeilik, 1997).

Since it has been found that all students have such a short attention span other methods to teach and keep the students focused and on task must be found. It then is imperative to find first what is important to teach in astronomy, and then learn other ways to deliver its message.

The purpose of the study was to find if manipulatives and groups size would play a role in how well students learned identify concepts in the introductory astronomy class.

USE OF NEW MODELS TO TEACH BASIC CONCEPTS

The foundation for the model of Zeilik(1994) is founded in cognitive and educational psychology theories and research that have been conducted about science education(Farnahm-Diggory, 1992). Many models and educational theories often are predicated on cognitive theory. There are discussions of short term and long-term memories and how this gives the student access to problem solving ideas. This model of Zeilik(1994) uses the idea that the learning needs to be an active participant in the process. In learning abstract ideas through being an active participant it was found that cognitive skills increased and better memory structures were formed to aid the student(Zeilik, 1997).

One of the instructional problems found in such studies that instruction is having instruction, which takes what the student already knows into consideration. Students enter a science course and typically already have some misconceptions. This can also be viewed as alternative conceptions about science based on daily experience wrapped in scientifically misunderstood theories(Franneck, 1994). Often the students try to memorize content to take the typical multiple-choice testing concepts of the introductory class. But since no concerted effort was made to undo the misconceptions they have---they often then leave with the same contorted views of nature overall, that they came with into the college classrooms. So college astronomy instructors need to identify students that have such misconceptions and then design instruction around their deficiencies (Carey, 1991).

Another instructional job is to identify the most important concepts in our knowledge domain and then elaborate on how to intertwine other cognitive domains to these concepts. The interconnection in a variety of ways is important to the proper development of the knowledge domain. It has been found that students using active training in class are more likely to recognize their problems in the cognitive learning and their own deficiencies. They are also better able to apply their learning to real-life situations, and this then strengthens their learning even more(Reddish, 1991).

The assessment within such coursework also needs to be tied to the new goals laid out in this type of instruction. The goal is to have the student understand those concepts that have been keyed into the curriculum and try and form connections in their knowledge domain to the concepts being taught in astronomy(Lane, 1989). So assessment asked the students key concepts and how they are related to the subject that was being taught.

SUMMARY:

In summary it has been found through studies in many science classes that a different method of teaching our basic astronomy classes must be addressed. Based on research, the attention span of students is short and the information that is being taught is woefully lacking based on tests that have been given to our students at all grade levels.

Consequently the students in the introductory astronomy class in college must be given new techniques to learn core concepts since it has been shown that earlier approaches for the most part missed have their marks.

In the next chapter the instructional approach used within the study will be described as it includes the changing of the methods of teaching the introductory astronomy course and the assessment of the instructional outcomes, within the design of the study itself.

CHAPTER III

METHODOLOGY

Introduction

This chapter will describe and outline the methods used in the development of the thesis study. This includes the research designs, subjects covered and researched, materials used, procedures and data collection used and how the data was analyzed. The idea behind this research was to see if using tactile manipulatives and small groups in teaching of core concepts in an introductory college astronomy class would make a difference on how well students learned those concepts.

Subjects:

The basic subject groups with the study were three 5 introductory astronomy college classes that enrolled in the course in the fall of 1995 through summer of 1996.

The students that participated in this study were extracted from two sections of astronomy over three semesters at Creighton University. The class size normally was 120 in the morning section and 125 in the evening section. This gave a total of 245 subjects to test the conceptual understanding that has been presented at each of three semesters.

The students in the morning section in the fall 1995 semester were 55% freshmen, 25% sophomore, and 20% juniors. The night section in the same semester was 35% freshmen, 45% sophomore, 10% juniors and 10% seniors. The Night class had 15 non-traditional students that were mainly an older adult group. These are typical numbers for all three semesters. The course is cataloged as NSC107 or PHY107. It is considered an introductory course and the course is in the catalog as a Core Course at Creighton so the students take this class to fulfill a required science requirement. There is no pre-requisite to take the class.

Research Design:

The course development and the teaching methods within the course were based on three related tasks.

1) Identify Core Concepts and create a concept cluster to cover
2) Assess students prior knowledge and prior experience
3) Develop and implement appropriate pedagogical techniques aimed at testing the improvement of the students conceptual understanding of the subject

After the students were identified that had trouble with the core concepts they were then taught by different pedagogical techniques to see which were more effective in teaching the core concepts that had been identified. The number of core concepts that have been looked at and identified in astronomy is 200; which is based upon Zeilik(1993).

Students that were identified as lacking the basic understanding were then put into to on of four groups Group A, Group B, Group C and Group D. Group E was considered the group of students that had shown on the pre-test a basic understanding of the subject so they became the control group and are excluded from the study as it pertained to this research.

Group A was given manipulative and tactical tools to work with as they studied that core concept. A posttest was given to test their understanding of the core concept. This was a large group task letting the students work on the task as an individual way.

Group B was not given manipulative tools but was lectured to and was shown audio-visual components to help them understand the core concept. Again a post-test was used to see what materials were mastered concerning the core concept.

Group C was given manipulative and tactile tools but was put into small groups consisting of 3 to 4 students. The same post-test method was used top see what results were gained.

Group D was only shown the same audio-visuals and lectures as in Group B. However they had a lecture size of only 5-6. The same post-test method was used to see what results were gained.

Materials:

The book used was "Astronomy" by Chiasson. It was the book's second edition. The core concepts that were identified were in Section 1 and Section 2 of the book. The students were then broken into discussion sections. The students as a core class had to have outside activities so they signed up for different times available to them to come to another discussion. It was during the discussion that the students were tested by the various assessment methods of this research project. The students had to do all their work in discussion so could not leave with any materials or manipulatives.

Procedures:

The study was conducted over a 16-week semester as prescribed by the college. The research used a large formal lecture and also did the instruction at all the discussion to assure consistency in the research. Graduate students in the physic department were used as helpers in grading and keeping class decorum. The pre-tests on the core concepts were given in the first lecture week of the semester that the students went to. They were then broken down based on the results into Group A through Group E.

During the manipulative groups students used tools and manipulatives to demonstrate the core concepts. In group A manipulatives were used by the instructor and shown to the students and then used by the student in a large group. In group C the students were shown the manipulative and then used the manipulative in small groups within the discussion section. Group B was taught the core concept by lecture again in a discussion section of 15 to 20 students and Group D was lectured to in small groups of 4 to 6 students.

Sample Concept:

This group was extracted from the astronomy class based on the student's results on pre-test showing how well they understood how moon phases occurred.

Moon Phases:

Show why the moon goes through phases and be able to name the various phases of the moon and show their position in an earth, moon, and sun diagram.

Manipulatives used in this concept included Styrofoam balls, markers to show directions, trapezium models for the earth, moon, and sun positions. It should be noted that when the students were assessed at the end no maipulatives were available. Zeilik based tests created on assessment of core concepts of astronomy in 1993 were used as a model of assessment(Appendix C).

The test was given after each section of the book was covered and there were a total of four tests given and proctored in the astronomy class. This did not include the pre-test and post-test conducted in each discussion group over the semester.

Instrumentation:

The pre and posttest given for the core concepts were developed by Wiley publishers in 1993 to test for competency of core astronomy concepts. The researcher created the one-hour exams with input from the Michael Zelik in order to test the core concepts that had been identified for research.

Copies of the pre and posttests samples are shown in Appendix A and B.

Data Collection:

Because of the large number of students enrolled in these introductory astronomy courses, an evaluation method using scantron techniques had to be used. So the use of the pre-test and post test (Misconception Measure) scores from the discussion groups helped to evaluate how the students improved in their knowledge. A survey was also done concerning the attitudes towards astronomy over the semester(Attitude Survey Appendix D).

The size of the Groups varied from concept to concept as the pre-test would change the number of students that had misconceptions. It should be noted that this made Group A through D vary by about 2 to 4 percent, which is not considered problematic.

In addition, often in courses such as these, two types of students may skew the group results. They are non-participants and statistical outliers. The non-participants are students that do not complete the full assessment battery or fail to complete part of a test series(i.e. forgot last page). They for this study were removed form the final analysis of the data.

Statistical outliers are those students whose scores are very different from the 'usual' scores. These are students with 2 to 3 standard deviations above the normal student. Some students have an extensive background in astronomy and may score higher than normal on the pretest. These are the students that go into Group E so they did not participate in the manipulative tests and group tests, and thus had no effect on the results.

Data Analysis:

After the tests were given and collected the data was analyzed for each hypothesis.

Analysis of Hypothesis 1:

Hypothesis I: Students using tactile learning models of seasons will do better on content post-tests than students, which are only taught through the auditory or visual method.

A t-test was run in order to determine if the difference between the pre-test pooled test scores data and the pooled test scores data for the post test was statistically significant at α=.05.

H_1= Post-test>pre-test

H_0=Post-test=pre-test

Analysis for Hypothesis II:

Hypothesis II: Students using tactile learning models of moon phases will do better on post-tests than students, which are only taught through the auditory or visual method.

A t-test was run in order to determine if the difference between the pre-test pooled test scores data and the pooled test scores data for the post test was statistically significant at α=.05.

H_1= Post-test>pre-test

H_0= Post-test=pre-test

Analysis for Hypothesis III:

Hypothesis III: Students that work in small groups in the class will score higher than students that do not work in small groups learning certain astronomy concepts.

A t-test was run in order to determine if the difference between the pre-test pooled test scores data and the pooled test scores data for the post test was statistically significant at α=.05.

H_1=small group > normal size group

H_0= small group = normal size group

Analysis for Hypothesis IV:

Hypothesis IV: Attitudes toward science and its value will increase from pre-test and post-test results in the groups using new concepts of teaching modalities.

A t-test was run in order to determine if the difference between the pre-test pooled attitude scores and the pooled attitude scores for the post test was statistically significant at α=. 05.

H_1= attitude at end of class > attitude at beginning of class

H_0=atttude at end of class = attitude at beginning of class.

In the next chapter the results of the three semesters of research will be discussed and how well the hypothesis was or was not proven will be examined based on the data.

CHAPTER IV

DATA ANALYSIS

Presentation of Results:

The purpose of this investigation was to examine the misconceptions that students hold about certain core concepts in astronomy, and the effective methods of teaching the students so that the misconceptions can be relearned. It was also hypothesized that there would be a relationship between the learning modalities and methods and the size of the groups used in the modalities.

An initial effort for the analysis was to compare change in the pre-test to the post-test that the students took for the misconceptions. The way this was done was by <g>, which is a normalized gain index; the ratio of the actual average student gains to the maximum average gain. It is given by the following formula:

$$<g>=(post\%-pre\%)/(100-pre\%)$$

This type of index has been used for physics testing since 1985(Hestrenes, 1985, 1992). In this index, a relationship 0 means no gain while a g of 1 indicates that all possible gain has occurred. In physics it was found that a <g>=.23+-.04(SD) was typical while in interactive courses the gain was found to be <g>=.48+-.14(SD).

In introductory astronomy classes there is no established standard and so this study was in new territory related to gains of normal teaching methods Vs interactive methods as it concerns core concepts. It should be noted that the t-test and p values for many of the groups are well below .01. This is for Group A through Group D. Group would have proved all the hypothesis of this study for A through D so the gain formula gives a better perspective on student improvement.

The following results are only for students that completed both the pre and posttests and fell below g=.38. Statistical outliers and the non-participants were removed so as not to skew the results of the research.

Statistical significance of change in the mean scores on each concept was analyzed by a dependent-samples t-test. This test is used for inferential statistics to calculate the probability that the two means from the two samples show a significant change. A significant statistical t-value indicates that the sample mean difference of this size or larger could have occurred because of sampling error at the probability level(p value) associated with the specific t-test value. When probability is small we can then conclude that the population means differ very little. Using the traditional level of $\alpha=.05$ we have a 95% chance of being correct in our conclusion.

In the first table below is the result of the misconception pre-test and posttest comparison. This test is used to make further groupings for this research. The students that at or below 38% on this test are then put into Group a through Group D. The ones above this score are put into group E and are considered statistical outliers.

TABLE I. This is result of the overall Misconception Achievement Measure Differences were significant at p=.05 using the t-test

Item (misconceptions)	Semester Fall1995 (%)	SD (%)	Gain<g>
	n=134		
Group A (manipualtives) -Pre	37	14	0.54
Post	71	16	
Group B (lecture) -Pre	37	13	0.13
Post	45	11	
Group C (manipulative-sm groups) -pre	40	12	0.48
Post	69	18	
Group D (small group lecture) - Pre	38	11	0.21
Post	51	13	
	Semester Sp 1996 (%)	**SD (%)**	**Gain<g>**
	n=155		
Group A (manipualtives) -Pre	35	11	0.54
Post	70	13	
Group B (lecture) -Pre	30	15	0.29
Post	50	13	
Group C (manipulative-sm groups) -pre	41	11	0.51
Post	71	12	
Group D (small group lecture) - Pre	39	9	0.25
Post	54	10	

	Semester Summer 1996(%)	SD(%)	Gain< g>
	n=83		
Group A(manipualtives)-Pre	32	14	0.53
Post	68	13	
Group B(lecture)-Pre	29	15	0.23
Post	45	14	
Group C(manipulative-sm groups)-pre	35	16	0.71
Post	81	17	
Group D(small group lecture)-Pre	30	15	0.27
Post	49	12	

As was noted that the index<g> gain was defined above.

In the table following misconceptions in Group A through Group D are examined. Note the <g> level for Group A averaged 60%, Group B 27%, Group C 56% and Group D 33.The t-test and p values for all the groups show a very positive value and this is in the Appendix. In Appendix G shows the most gain for Group A and C. Group B and D also show p-values, which are significant, but the other two groups are much higher. The <g> value is a better marker for gain in this study.

TABLE II. Misconception on the seasons test when the students had mean pretest scores less than 38%. The last column includes the percentage of students who gave the indicated incorrect response on the posttests. Appendix G as T-Test and p values

	Mean pre-score	Mean post	Mean gain<g>
FALL OF 1995			
Group A(manipualtives) n=19	17	68	61.45%
Group B(lecture) n=17	11	36	28.09%
Group C(manipulative-sm groups) n=19	10	59	54.44%
Group D(small group lecture) n=16	11	45	38.20%
SPRING 1996			
Group A(manipualtives) n=25	15	65	58.82%
Group B(lecture) n=26	13	40	31.03%
Group C(manipulative-sm groups) n=19	13	66	60.92%
Group D(small group lecture) n=16	11	47	40.45%
SUMMER 1996			
Group A(manipualtives) n=16	19	68	60.49%
Group B(lecture) n=14	21	38	21.52%
Group C(manipulative-sm groups) n=14	18	62	53.66%
Group D(small group lecture) n=15	17	49	38.55%

In the table following misconceptions in Group A through Group D are examined. Note the <g> level for Group A averaged 53%, Group B 28%, Group C 62% and Group D 29%. The t-test and p values for all the groups show a very positive value and this is in the included Appendix. In Appendix H shows the most gain for Group A and C. Group B and D also show p-values, which are significant, but the other two groups are much higher. The <g> value is a better marker for gain in this study.

TABLE III. Misconception on the moon phase test when the students had mean pretest scores less than 38%. The last column includes the percentage of students who gave the indicated incorrect response on the posttests. Appendix H has t-test and p values

	Mean pre-score	Mean post	Mean gain<g>
FALL OF 1995			
Group A(manipualtives) n=19	12	55	48.86%
Group B(lecture) n=17	14	35	24.42%
Group C(manipulative-sm groups) n=19	13	65	59.77%
Group D(small group lecture) n=16	11	42	34.83%
SPRING 1996			
Group A(manipualtives) n=25	13	57	50.57%
Group B(lecture) n=26	12	38	29.55%
Group C(manipulative-sm groups) n=19	11	66	61.80%
Group D(small group lecture) n=16	10	45	38.89%
SUMMER 1996			
Group A(manipualtives) n=16	18	66	58.54%
Group B(lecture) n=14	16	41	29.76%
Group C(manipulative-sm groups) n=14	18	70	63.41%
Group D(small group lecture) n=15	19	39	24.69%

The formal hypotheses of the study were then examined.

Hypothesis I Analysis:

H_1: The students with tactile learning modalities concerning the concept of seasons will score significantly higher on the achievement post-test than the pretest.

The null hypothesis is as follows:

H_0: There will be no significant difference in the test scores of the students who have manipulative instruction.

The t-test and <g> both show a significant gain of group A from the pre-test to the posttest. The gain of <g> was 61% and the t value was .99 with $p<.05$. This shows a significant gain through the use of manipulatives so H1 is supported.

Hypothesis II Analysis:

H_1: The students with tactile learning modalities concerning the concept of moon phases will score significantly higher on the achievement post-test than the pretest.

The null hypothesis is as follows:

H_0: There will be no significant difference in the test scores of the students who have manipulative instruction.

The t-test and <g> both show a significant gain of group A from the pre-test to the posttest. The gain of <g> was 60% and the t value was .99 $p<.05$. This shows a significant gain through the use of manipulatives so H1 is shown to be supported.

Hypothesis III Analysis:

H_1: The students taught in small groups will do better on the post-test than the pre-test on the two core concepts; moon phases and seasons.

The null hypothesis is as follows:

H_0: There will be no significant difference in the test scores of the students who are in small groups being taught the two core concepts.

The t-test and <g> both show a significant gain of group C over Group D from the pre-test to the posttest. The gain of <g> was 53% and the t value was .99 $p<.05$. This shows a significant gain through the use of manipulatives so H1 is shown to be significant.

The last hypothesis to be tested was an attitude change in the students. The survey of attitudes was only conducted in the three semesters of the study. The data is in the table below.

Table IV: Results from the Attitude Survey. Based on the dependent-samples t-test only spring of 1996 was statistically significant.(.05). Scores are normalized so 50% in neutral response

Appendix I has t-test and p values

SURVEY	Semester	mean	SD	Gain<g)
Pre	F1995	65	10	none
Post	n=51	64	11	
Pe	SP1996	64	10	0.11
Post	n=62	66	11	
Pre	Su1996	57	13	none
Post	n=31	56	17	

Hypothesis IV Analysis:

H_1: The students will have better attitudes about astronomy at the end of class than at the beginning

The null hypothesis is as follows:

H_0: There will be no significant change in attitudes of the students from the beginning of the course to the end of the class.

The t-test, <g> and p value do not show significant difference on a consistent basis in

Appendix I the t scores and p values are above and below in different semester. So the attitudes of the class cannot be shown to have changed based on the t, <g> and p test in any particular direction. The null hypothesis then is accepted, as there is no change in attitudes of the students.

Qualitative Data:

In addition to the quantitative results, interviews were also made with a randomly picked group of students from the Group A through Group E. The main idea was to find what the students thought of the new systems of teaching and see what they wanted to see done differently.

Group A:

Based on selective interviews the students that used the manipulatives overall felt that they got a better concept and grasp of the core concept that was being taught. Many said when they took the test they pretended they still had the manipulatives in their hands to solve and answer the question. They felt that lecture and manipulatives were very useful.

Group B:

Based on selective interviews; the students that had lecture based only felt cheated that they did not get to use the manipulatives that the other class used. However, it seemed that they got coaching from the other students In-Group A and probably used their own tools to understand.

Group C:

Based on selective interviews; overall the students in small groups using manipulatives seamed to have the best response of the groups. They really liked the ability to bounce ideas off other students and pool ideas until the best model and method was found.

Group D:

Based on selective interviews this was the small group lecture group and they felt it was nice to be in smaller groups to ask questions they also felt they wanted the manipulatives not just lecture.

SUMMARY:

The analysis of the data presented in this chapter was intended to statistically examine the hypotheses listed in Chapter 1 and to provide insight into future discussions outlined in Chapter 5.

Discussion of Research Results:

It was a surprise to see that Group A and C did so much better using manipulatives and small groups. There appears to be a strong potential relationship in teaching core concepts in introductory astronomy by small groups and tactile modalities. It might additionally strengthen the investigation by trying other core concepts in astronomy classes at the college level and also use this in high schools that teach astronomy to see it the results are as strong. It is encouraging to see the results and the differences in teaching style through the groups. The small group and tactile manupulatives is very strong in the concepts that were tested.

The primary findings of this study appear to support the idea of small group and use of manipulatives over lecture only classes. This concept could be used in many classes similar to astronomy and perhaps the results would be just as encouraging. It might also work even better; to possibly have students take different sensory tests to see how they might learn best. Then they might be assigned into the proper Group based on the sensory testing.

This study suggests that hands on instruction in college, at least freshman astronomy classes, works, and probably has a fundamental place in many more classes.

Some additional points of interests were also suggested by the study results:

1) Manipulative based instruction seems to help students draw new concept maps of knowledge in their knowledge domain.
2) Many students using manipulative modes of study appear to feel they have a much deeper view of the studies and core concept that was being studied.
3) The visual and auditory group appeared to leave with some of the same misconceptions that they came to the class with, no matter how much they were lectured to within the class instruction.

Limitations to the study:

1) This was the first time the researcher tried to take a large group and make small discussion groups from my astronomy class. As with any first experience, the first semester was sometimes confusing and not flowing very well. This changed by the third semester.
2) There were some adults in the night class Vs the day class of typical college students. This may have changed some of the data but analysis did remove the outliers and non-participants.

Suggestions for Further Study:

Recommendations for further study to this research would be to include this study in other types of science classes that do not necessarily have a lab component. Meteorology and Environmental Geology could be used as other research potential areas. Also the use of core concept research could be moved into high schools that offer astronomy classes, to examine the approach there.

The design of the research could be modified such that the Groups based on the preferred mode of learning by the student, could be established and then students would learn core concepts through the semester based on those preferred methods.

It would be interesting to see further how the groups might break down based on, sex, age, and educational background. This may help us catalog what students may do best based upon the learning modes presented. This would also provide further potential justification to have more modes of learning for students based on their backgrounds.

These recommendations for further investigation are but a few of the many possible considerations for research in related areas of science education. With the new pressures in education for better results new ways to teach the learner must be reviewed for all possible outcomes.

Some additional thoughts will be presented in Chapter 5 concerning future research implications and other perceptions pertaining to this study.

CHAPTER V

Discussion, Perceptions, and The Future

Introduction:

In this chapter the results of the research from the previous chapters will be examined in an overall perspective as it pertains to education in beginning astronomy classes at the college level.

This study looked at a few core concepts of astronomy and how instructors are presenting materials in the classroom. Three semesters worth of classes were tested covering two core concepts of astronomy. This approach could easily be expanded to more concepts and further research could further strengthen the present results of this research.

From chapter four the data show that all the groups usually improved on the posttest, however the greatest gain was shown in Group A and Group C. This seems to indicate that manipulatives and manipulatives in small groups maybe more effective in teaching core concepts in an introductory college astronomy class. The methods of teaching show by the research to have a very strong influence on how students learn in a large class.

PERCEPTIONS:

In conducting this research and in reviewing research going on in this field of study, it appears that our present way of teaching needs to be drastically changed.

The traditional classroom today is based in college on a 1 hour to 1-hour 15-minute block. This time has been traditionally spent giving long lectures with very little feed back from the students. The tests are usually multiple choices or true false in nature due to the size of the class and the instructor's lack of time/help or both. This then leaves very little ability of the instructor to interact directly with the student and address the weaknesses that the student may have in the learning process.

In today's classroom many students appear to not be compatible with these traditional approaches to instruction because:

1) Students may have a short span of attention of (15 minutes) as it pertains to lecture.

2) Students often come to class ill prepared as it pertains to basic science concepts that should have been taught in grades K-12.

3) Students need to learn in a variety of ways, and instructors, not using different modalities of teaching in the astronomy class may not be teaching concepts so that most students can understand and learn effectively.

It appears that students in introductory astronomy classes need to have different teaching modalities offered to them in smaller groups, away from lecture or during lecture, using different teaching techniques. By the research espoused on in this study and other research in the field it appears we need to drastically change the way we teach, or else the students may leave with the same misconceptions that they had when they entered the class.

Tips for Effective Classroom Instruction in Astronomy:

Based upon experiences within this study, and the current professional perceptions, tips are offered for instruction of basic astronomy classes:

1) Reduce lecture in the classroom to 15 to 20 minute blocks.
2) Identify core concepts in each section taught in astronomy and develop new methods to teach them.
3) Identify the core concepts in each section and develop modalities and manipulatives to teach the concepts.
4) Get the college administration to support discussion for classes on an ongoing basis so small groups may be used more effectively.

5) Test all students on how they learn best and use these results to best teach that particular student.
6) Create concept maps for each core concept and use this to help the student trace their mastery of the subject.
7) Develop cost analysis to create smaller discussion groups and present this to administration.
8) Let go of the egocentric lecture and center stage to a more chaotic and productive classroom.

New Strategies:

In studying instructional problems, many concepts have not been studied in any depth. It would be very beneficial to test many more concepts to see which ones best are taught by tactile methods, audio-visual or other methods yet explored. It seems that the numbers of concepts that have been identified number more than 200, but one might classify each of these as more or less important. The most important concepts then could by researched and then be classified as which method is best to teach the students those particular core materials.

Also, in reviewing the literature it also as become apparent that few standards for assessments in introductory astronomy classes have not been established nor have many rubrics been attempted at this time.

Finally, it is indeed important to consider such instructional aspects within the learning of basic college level astronomy classes. The importance is confirmed in this study, as the results of the students mastery of basic concepts was greatly enhanced. As we have more and more discussions in or public forum on the effectiveness of education, this concept, and alternative ways of teaching could and should be considered in all levels of education and all subjects, including astronomy.

REFERENCES

Dewey, J. (1926). Democracy and Education. New York, NY: MacMillian.

National Education Standards, (1996). National Research Council. (National Academy of Science Press, Washington D.C. 1996)

W.J. Ekeler, (1994) "The Lecture Method," in Handbook of College Teaching: Theory and Applications, edited by K. W. Prichard and R.M. Sawyer: Greenwood, Westport, CT, pp84-89.

W. Thielens, (1987) "The disciplines and undergraduate lecturing," in American Educational Research Association. Washington Press, D.C. (April, 1987, pp34-45.

Astronomical Society of Pacific (1996), "Astronomy in the National Science Education Standards," edited by Jeffrey Adams and Tim Slater: ASP Press; pp67-89.

Zeilik, M. (1997). "Conceptual Astronomy: A novel model for teaching postsecondary science course," American Journal of Physics, 65(10), pp987-996

Penner, J. G. (1984). "Why College Teachers Cannot Lecture," Thomas Springfield Press, Il., pp126-131.

Bonwell, C.C. and Eiason, J.A., (1991). "Active Learning: Creating Excitement in the Classroom," The George Washington University Press: School of Education and Development Annual, Washington.

Farnham-Diggory, S. (1992). "Cognitive Processes in Education," HarperCollins: New York, NY. Pp200-234.

Sawyer R.M. and Prichard S. (1994) "Cognitive retention theories and effectiveness," in Handbook of College Teaching: Theory and Applications, edited by K. W. Prichard and R.M. Sawyer: Greenwood, Westport, CT, 1994,pp23-56.

Sims, R. R. & Sims, S.J. (1995). The importance of Learning Styles. West Port, CT: Greenwood Press.

Zeilik, M. (1994). "Active Learning in Large Astronomy Classes," A symposium on Teaching Astronomy to Non-Science Majors, Albuquerque, New Mexico ASP 106th Meeting: June, 1994.

Carey, S. (1991). "Cognitive Science and Science Education," American Psychology, 41, 1123-1130.

Reddish, E.F. (1994). "Implications of cognitive studies teaching physics," American Journal of Physics, 62, pp796-803.

Lane, S. (1995). "Implications of cognitive psychology fro measurements tests: Diagnosis of procedural errors, Educational Measurements'" Issues Practice 8(4), pp17-20.

Zeilik, M. (1993). "Creation of Core Concepts for Large Post-Secondary Astronomy Classes," A symposium on Teaching Astronomy to Non-Science Majors, Pasadena, Ca: ASP 105th Meeting: July, 1993.

Hestrenes, D. (1985). "The initial knowledge state of college physics students," American Journal of Physics, 53, 1043-1055.

Hestrenes, D. (1992). "A mechanics Test Baseline," American Journal of Physics, 66, 64-74.

TIMSS, (1997). "Third International Math and Science Survey", NCES 1999081 Publication

APPENDIX A
PRE-TEST EXAMPLES

SEASON PRE-TEST (VER2)

1. What makes the seasons change?
A) The wind B) The earth's changing position in relation to the sun C) The temperature

2. When is it summer in the Northern Hemisphere?
A) When the North Pole slants toward the sun B) When the North Pole slants away from the sun C) When the North Pole is perpendicular to the sun

3. What is an equinox?
A) A time when day and night are about equal throughout the world B) A time when a day without night is followed by a night without day C) A year when all 4 seasons are of equal length

4. How many equinoxes occur each year?
A) 4 B) 3 C) 2

5. When does an equinox occur?
A) When the sun is directly above one of the earth's poles B) When the sun is directly above the equator C) When each of the seasons begins

6. In what 2 months do the equinoxes occur?
A) June and December B) June and July C) March and September

7. What is a solstice?
A) The moment each year when the sun reaches its northernmost and southernmost points B) The moment each year when the sun is directly above the equator C) The moment each year when the sun is directly over the north and south poles

8. In what seasons do solstices occur?
A) Summer and winter B) Spring and fall C) Spring and summer

9. In the Northern Hemisphere, what is the shortest day of the year?
A) The day of the summer solstice B) The day of the winter solstice C) There is no shortest day--all days are of equal length

10. What regions of the earth do not have four climatic seasons?
A) All regions in the Northern Hemisphere B) All regions in the Southern Hemisphere C) Polar regions

Phases of the Moon-PRE-TEST

Name ______________________ Date ___________________

1. Describe the appearance of your moon.

2. Raise the moon slightly so that you can just see the sun under the moon. Describe the appearance of your moon.

3. Slowly move the moon counterclockwise around your head. You may need to move your hand so that the shadow of your hand does not fall on the moon. Notice the edge of the shadow as it moves across the softball. This edge is called the terminator: the line that divides the illuminated side from the dark side of the moon. Describe what happens to the appearance of your moon as you turn through one/quarter of a turn.

4. Below, make a diagram of the relative position of the Earth (your head), the sun (the light source), and the moon (the softball) at this position.

5. What time of day would this moon appear to be highest in the sky?

6. Continue moving the moon counterclockwise until the sun is behind your head. You will need to raise the moon slightly so that the shadow of your head does not fall on the moon. How does the angle between the sun and the moon relate to the amount of the moon that you see as illuminated?

7. How much of the moon is actually illuminated as you do this activity?

8. Continue moving the moon until it is again in the same direction as the sun. Describe its appearance.

9. Below, make a diagram showing the moon when it is between one-half and three-quarters the way around from the sun, and when it is between one-half and all the way around your head.

10. Which of the moons that you have seen would be found in the morning sky?

APPENDIX B
POSTTEST EXAMPLES

SEASON POSTTEST (VER2)

1. What makes the seasons change?
A) The wind B) The earth's changing position in relation to the sun C) The temperature

2. When is it summer in the Northern Hemisphere?
A) When the North Pole slants toward the sun B) When the North Pole slants away from the sun C) When the North Pole is perpendicular to the sun

3. What is an equinox?
A) A time when day and night are about equal throughout the world B) A time when a day without night is followed by a night without day C) A year when all 4 seasons are of equal length

4. How many equinoxes occur each year?
A) 4 B) 3 C) 2

5. When does an equinox occur?
A) When the sun is directly above one of the earth's poles B) When the sun is directly above the equator C) When each of the seasons begins

6. In what 2 months do the equinoxes occur?
A) June and December B) June and July C) March and September

7. What is a solstice?
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9. In the Northern Hemisphere, what is the shortest day of the year?
A) The day of the summer solstice B) The day of the winter solstice C) There is no shortest day--all days are of equal length

10. What regions of the earth do not have four climatic seasons?
A) All regions in the Northern Hemisphere B) All regions in the Southern Hemisphere C) Polar regions

Phases of the Moon-POSTTEST

Name ______________________ Date ___________________

1. Describe the appearance of your moon.

2. Raise the moon slightly so that you can just see the sun under the moon. Describe the appearance of your moon.

3. Slowly move the moon counterclockwise around your head. You may need to move your hand so that the shadow of your hand does not fall on the moon. Notice the edge of the shadow as it moves across the softball. This edge is called the terminator: the line that divides the illuminated side from the dark side of the moon. Describe what happens to the appearance of your moon as you turn through one/quarter of a turn.

4. Below, make a diagram of the relative position of the Earth (your head), the sun (the light source), and the moon (the softball) at this position.

5. What time of day would this moon appear to be highest in the sky?

6. Continue moving the moon counterclockwise until the sun is behind your head. You will need to raise the moon slightly so that the shadow of your head does not fall on the moon. How does the angle between the sun and the moon relate to the amount of the moon that you see as illuminated?

7. How much of the moon is actually illuminated as you do this activity?

8. Continue moving the moon until it is again in the same direction as the sun. Describe its appearance.

9. Below, make a diagram showing the moon when it is between one-half and three-quarters the way around from the sun, and when it is between one-half and all the way around your head.

10. Which of the moons that you have seen would be found in the morning sky?

APPENDIX C
MISCONCEPTION
SURVEY

Introductory Astronomy Survey

1. As seen from your current location, when will an upright flagpole cast no shadow because the Sun is directly above the flagpole?
   A. Every day at noon.
   B. Only on the first day of summer.
   C. Only on the first day of winter.
   D. On both the first days of spring and fall.
   E. Never from your current location.

2. When the Moon appears to completely cover the Sun (an eclipse), the Moon must be at which phase?
   A. Full
   B. New
   C. First quarter
   D. Last quarter
   E. At no particular phase

3. Imagine that you are building a scale model of the Earth and the Moon. You are going to use a 12-inch basketball to represent the Earth and a 3-inch tennis ball to represent the Moon. To maintain the proper distance scale, about how far from the surface of the basketball should the tennis ball be placed?
   A. 4 inches (1/3 foot)
   B. 6 inches (1/2 foot)
   C. 36 inches (3 feet)
   D. 30 feet
   E. 300 feet

4. You have two balls of equal size and smoothness, and you can ignore air resistance. One is heavy, the other much lighter. You hold one in each hand at the same height above the ground. You release them at the same time. What will happen?
   A. The heavier one will hit the ground first.
   B. They will hit the ground at the same time.
   C. The lighter one will hit the ground first.

5. How does the speed of radio waves compare to the speed of visible light?
   A. Radio waves are much slower.
   B. They both travel at the same speed.
   C. Radio waves are much faster.

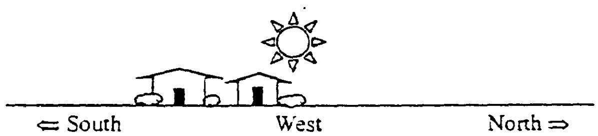
6. Astronauts inside the Space Shuttle float around as it orbits the Earth because
   A. there is no gravity in space.
   B. they are falling in the same way as the Space Shuttle.
   C. they are above the Earth's atmosphere.
   D. there is less gravity inside the Space Shuttle.
   E. more than one of the above.

PLEASE TURN THE PAGE

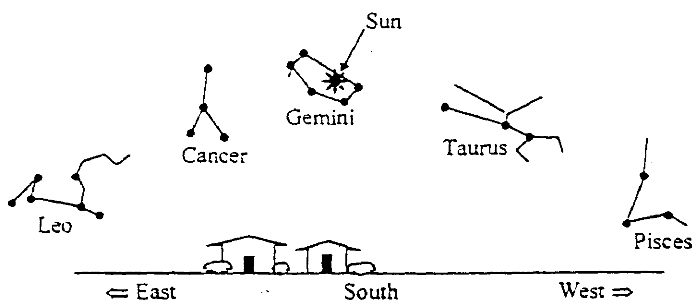
7. Imagine that the Earth's orbit were changed to be a perfect circle about the Sun so that the distance to the Sun never changed. How would this affect the seasons?
   A. We would no longer experience a difference between the seasons.
   B. We would still experience seasons, but the difference would be much LESS noticeable.
   C. We would still experience seasons, but the difference would be much MORE noticeable.
   D. We would continue to experience seasons in the same way we do now.

8. Where does the Sun's energy come from?
   A. The combining of light elements into heavier elements
   B. The breaking apart of heavy elements into lighter ones
   C. The glow from molten rocks
   D. Heat left over from the Big Bang

9. On about September 22, the Sun sets directly to the west as shown on the diagram below. Where would the Sun appear to set two weeks later?
   A. Farther south   B. In the same place   C. Farther north



10. If you could see stars during the day, this is what the sky would look like at noon on a given day. The Sun is near the stars of the constellation Gemini. Near which constellation would you expect the Sun to be located at sunset?
   A. Leo
   B. Cancer
   C. Gemini
   D. Taurus
   E. Pisces



11. Compared to the distance to the Moon, how far away is the Space Shuttle (when in space) from the Earth?
    A. Very close to the Earth
    B. About half way to the Moon
    C. Very close to the Moon
    D. About twice as far as the Moon

12. As viewed from our location, the stars of the Big Dipper can be connected with imaginary lines to form the shape of a pot with a curved handle. To where would you have to travel to first observe a considerable change in the shape formed by these stars?
    A. Across the country
    B. A distant star
    C. Europe
    D. Moon
    E. Pluto

13. Which of the following lists is correctly arranged in order of closest-to-most-distant from the Earth?
    A. Stars, Moon, Sun, Pluto
    B. Sun, Moon, Pluto, stars
    C. Moon, Sun, Pluto, stars
    D. Moon, Sun, stars, Pluto
    E. Moon, Pluto, Sun, stars

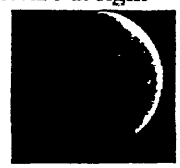
14. Which of the following would make you weigh half as much as you do right now?
    A. Take away half of the Earth's atmosphere.
    B. Double the distance between the Sun and the Earth.
    C. Make the Earth spin half as fast.
    D. Take away half of the Earth's mass.
    E. More than one of the above

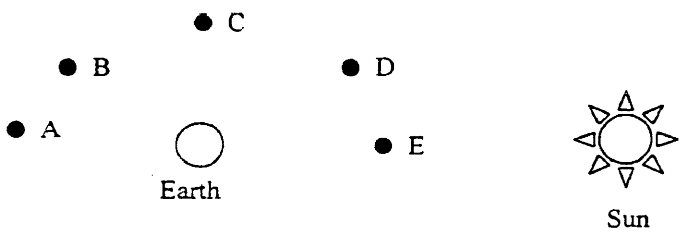
15. A person is reading a newspaper while standing 5 feet away from a table that has on it an unshaded 100-watt light bulb. Imagine that the table were moved to a distance of 10 feet. How many light bulbs in total would have to be placed on the table to light up the newspaper to the same amount of brightness as before?
    A. One bulb.
    B. Two bulbs.
    C. Three bulbs.
    D. Four bulbs.
    E. More than four bulbs.

16. According to modern ideas and observations, what can be said about the location of the center of the Universe?
    A. The Earth is at the center.
    B. The Sun is at the center.
    C. The Milky Way Galaxy is at the center.
    D. An unknown, distant galaxy is at the center.
    E. The Universe does not have a center.

17. The hottest stars are what color?
    A. Blue
    B. Orange
    C. Red
    D. White
    E. Yellow

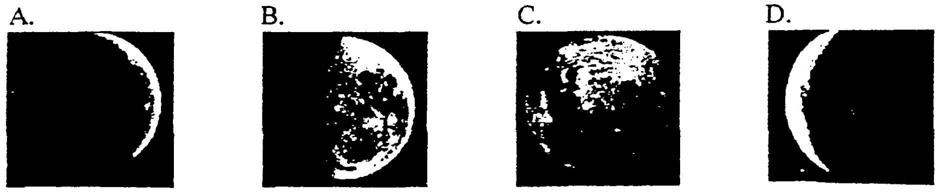
18. The diagram below shows the Earth and Sun as well as five different possible positions for the Moon. Which position of the Moon would cause it to appear like the picture at right when viewed from Earth?





19. You observe a full Moon rising in the east. How will it appear in six hours?

A. B. C. D.



20. With your arm held straight, your thumb is just wide enough to cover up the Sun. If you were on Saturn, which is 10 times farther from the Sun than the Earth is, what object could you use to just cover up the Sun?
  A. Your wrist
  B. Your thumb
  C. A pencil
  D. A strand of spaghetti
  E. A hair

21. Global warming is thought to be caused by the
  A. destruction of the ozone layer.
  B. trapping of heat by nitrogen.
  C. addition of carbon dioxide.

22. In general, how confident are you that your answers to this survey are correct?
  A. Not at all confident (just guessing)
  B. Not very confident
  C. Not sure
  D. Confident
  E. Very confident

PLEASE TURN THE PAGE

23. What is your college major (or current area of interest if undecided)?
    A. Business
    B. Education
    C. Humanities, Social Sciences, or the Arts
    D. Science, Engineering, or Architecture
    E. Other

24. What was the last math class you completed prior to taking this course?
    A. Algebra
    B. Trigonometry
    C. Geometry
    D. Pre-Calculus
    E. Calculus

25. What is your age?
    A. 0-20 years old
    B. 21-23 years old
    C. 24-30 years old
    D. 31 or older
    E. Decline to answer

26. Which best describes your home community (where you attended high school)?
    A. Rural
    B. Small town
    C. Suburban
    D. Urban
    E. Not in the USA

27. What is your gender?
    A. Female
    B. Male
    C. Decline to answer

28. Which best describes your ethnic background?
    A. African-American
    B. Asian-American
    C. Native-American
    D. Hispanic-American
    E. None of the above (see question 29 below)

29. Which best describes your ethnic background?
    A. African (not American)
    B. Asian (not American)
    C. White, non-Hispanic
    D. Multicultural
    E. None of the above (see question 28 above)

PLEASE TURN THE PAGE

30. How good at math are you?
    A. Very poor
    B. Poor
    C. Average
    D. Good
    E. Very good

31. How good at science are you?
    A. Very poor
    B. Poor
    C. Average
    D. Good
    E. Very good

32. Which best describes the level of difficulty you expect/experienced from this course?
    A. Extremely difficult for me
    B. Difficult for me
    C. Unsure
    D. Easy for me
    E. Very easy for me

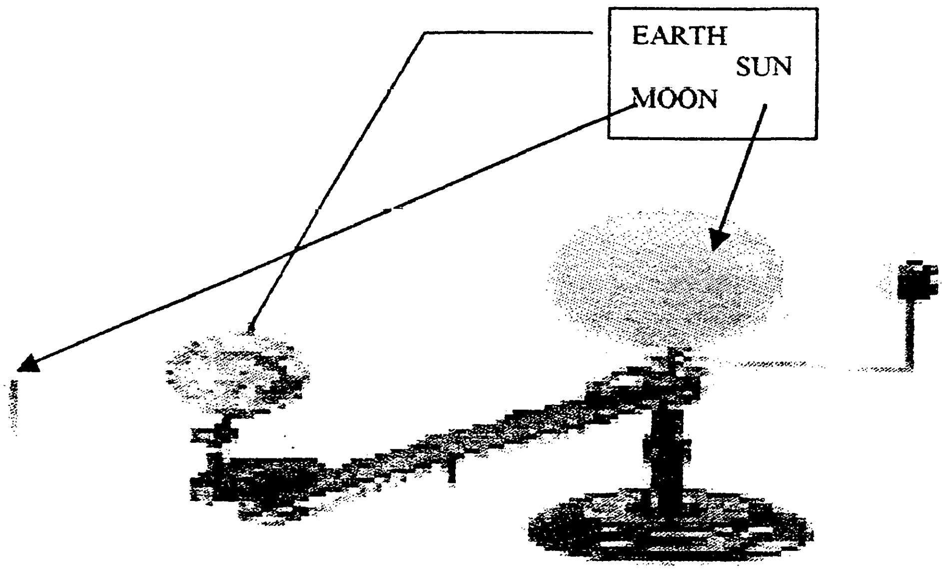
33. How many astronomy courses at the college level have you taken?
    A. I'm re-taking this course.
    B. This is my first college-level astronomy course.
    C. This is my second college-level astronomy course.
    D. I've completed more than two other college-level astronomy courses.

END OF SURVEY

APPENDIX D
MANIPULATIVES

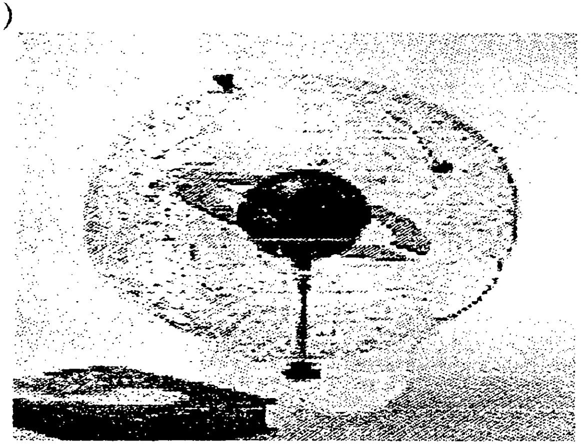
This section shows some of the manipulative tools that were used in the two core concepts that were explored in this research project:

1)



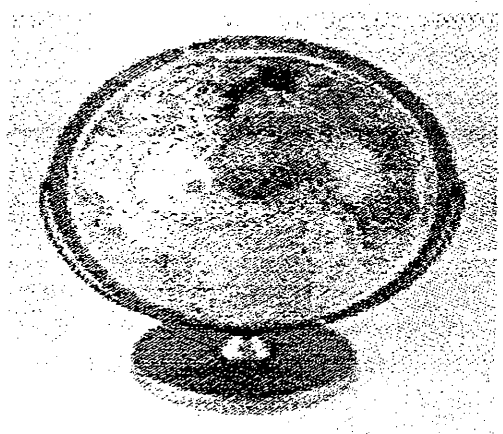
The above apparatus helps demonstrate the motion of the earth, moon and sun. This demonstration is particularly good at showing moon phases and the position of the other bodies to each other.

2)



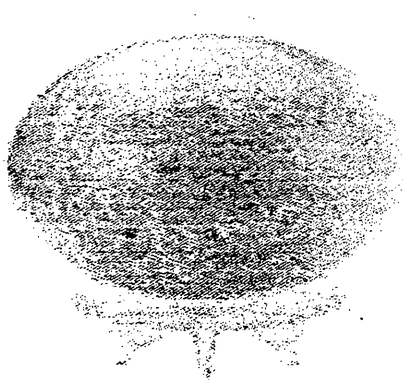
The above globe can be used for season manipulative as well as the moon phase manipulatives.

3)



A simple globe lets the student demonstrate to others and themselves how seasons work and how the tilt effects the seasons.

4)



The moon globe and the earth globe together let the students demonstrate moon phases and with an overhead projector in the classroom lets the students demonstrate moon phases to each other.

5)

These are the students working in groups with the manipulatives and overhead projector to demonstrate moon phases.

APPENDIX E
ATTITUDE SURVEY

The items fall into four subscales: affect (attitude), cognitive competence, value, and difficult. Affect relates to positive and negative attitudes about astronomy and science (8 items). Cognitive competence describes attitudes about the students' intellectual knowledge and skills when applied to astronomy and science (9 items). Value involves attitudes about the usefulness, relevance, and worth of astronomy and science in personal and professional life (9 items). Difficulty entails attitudes about the difficulty of astronomy and science as subjects (8 items).

Survey of Attitudes Toward Astronomy (Pre)

The questions below are designed to identify your attitudes about astronomy and science. The item scale has 5 possible responses; the responses range from 1 (strongly disagree) through 3 (neither agree nor disagree) to 5 (strongly agree). Please read each question. From the 5-point scale mark the response that most clearly represents your agreement with the statement. Use the entire 5-point scale. Try not to think too deeply about each response; there are no correct or incorrect answers.

1. Astronomy is a subject learned quickly by most people.	1	2	3	4	5
2. I will have trouble understanding astronomy because of how I think.	1	2	3	4	5
3. Astronomy concepts are easy to understand.	1	2	3	4	5
4, Astronomy is irrelevant to my life.	1	2	3	4	5
5. I will get frustrated going over astronomy tests in class.	1	2	3	4	5
6. I will be under stress during astronomy class.	1	2	3	4	5
7. I will understand how to apply analytical reasoning to astronomy.	1	2	3	4	5
8. Learning astronomy requires a great deal of discipline.	1	2	3	4	5
9. I will have no idea of what's going on in astronomy.	1	2	3	4	5
10. I will like astronomy.	1	2	3	4	5
11. What I learn in astronomy will not be useful in my career.	1	2	3	4	5
12. Most people have to learn a new way of thinking to do astronomy.	1	2	3	4	5
13. Astronomy is highly technical.	1	2	3	4	5
14, I will feel insecure when I have to do astronomy homework.	1	2	3	4	5
15. I will find it difficult to understand astronomy concepts.	1	2	3	4	5
16. I will enjoy taking this astronomy course.	1	2	3	4	5
17. I will make a lot of errors applying concepts in astronomy.	1	2	3	4	5

18. Astronomy involves memorizing a massive collection of facts.	1	2	3	4	5
19. Astronomy is a complicated subject.	1	2	3	4	5
20. I can learn astronomy.	1	2	3	4	5
21. Astronomy is worthless.	1	2	3	4	5
22. I am scared of astronomy.	1	2	3	4	5
23. Scientific conclusions are rarely presented in everyday life.	1	2	3	4	5
24. Scientific concepts are easy to understand.	1	2	3	4	5
25. Science is not useful to the typical professional.	1	2	3	4	5
26. The thought of taking a science course scares me.	1	2	3	4	5
27. I like science.	1	2	3	4	5
28. I find it difficult to understand scientific concepts.	1	2	3	4	5
29. I can learn science.	1	2	3	4	5
30. Scientific skills will make me more employable.	1	2	3	4	5
31. Science is a complicated subject.	1	2	3	4	5
32. I use science in my everyday life.	1	2	3	4	5
33. Scientific thinking is not applicable to my life outside my job.	1	2	3	4	5
34. Science should be a required part of my professional training.	1	2	3	4	5

The items fall into four subscales: affect (attitude), cognitive competence, value, and difficult. Affect relates to positive and negative attitudes about astronomy and science (8 items). Cognitive competence describes attitudes about the students' intellectual knowledge and skills when applied to astronomy and science (9 items). Value involves attitudes about the usefulness, relevance, and worth of astronomy and science in personal and professional life (9 items). Difficulty entails attitudes about the difficulty of astronomy and science as subjects (8 items).

Survey of Attitudes Toward Astronomy (Post)

The questions below are designed to identify your attitudes about astronomy and science. The item scale has 5 possible responses; the responses range from 1 (strongly disagree) through 3 (neither agree nor disagree) to 5 (strongly agree). Please read each question. From the 5-point scale mark the response that most clearly represents your agreement with the statement. Use the entire 5-point scale. Try not to think too deeply about each response; there are no correct or incorrect answers.

1. Astronomy is a subject learned quickly by most people.	1	2	3	4	5
2. I had trouble understanding astronomy because of how I think.	1	2	3	4	5
3. Astronomy concepts were easy to understand.	1	2	3	4	5
4, Astronomy is irrelevant to my life.	1	2	3	4	5
5. I got frustrated going over astronomy tests in class.	1	2	3	4	5
6. I was under stress during astronomy class.	1	2	3	4	5
7. I understood how to apply analytical reasoning to astronomy.	1	2	3	4	5
8. Learning astronomy required a great deal of discipline.	1	2	3	4	5
9. I had no idea of what's going on in astronomy.	1	2	3	4	5
10. I like astronomy.	1	2	3	4	5
11. What I learned in astronomy will not be useful in my career.	1	2	3	4	5
12. Most people have to learn a new way of thinking to do astronomy.	1	2	3	4	5
13. Astronomy was highly technical.	1	2	3	4	5
14, I felt insecure when I have to do astronomy homework.	1	2	3	4	5
15. I found it difficult to understand astronomy concepts.	1	2	3	4	5
16. I enjoyed taking this astronomy course.	1	2	3	4	5
17. I made a lot of errors applying concepts in astronomy.	1	2	3	4	5
18. Astronomy involved memorizing a massive collection of facts.	1	2	3	4	5
19. Astronomy was a complicated subject.	1	2	3	4	5
20. I can learn astronomy.	1	2	3	4	5
21. Astronomy is worthless.	1	2	3	4	5
22. I was scared of astronomy.	1	2	3	4	5
23. Scientific conclusions are rarely presented in everyday life.	1	2	3	4	5
24. Scientific concepts are easy to understand.	1	2	3	4	5
25. Science is not useful to the typical professional.	1	2	3	4	5
26. The thought of taking a science course scares me.	1	2	3	4	5
27. I like science.	1	2	3	4	5
28. I find it difficult to understand scientific concepts.	1	2	3	4	5
29. I can learn science.	1	2	3	4	5
30. Scientific skills will make me more employable.	1	2	3	4	5
31. Science is a complicated subject.	1	2	3	4	5
32. I use science in my everyday life.	1	2	3	4	5

33. Scientific thinking is not applicable to my life outside my job.	1	2	3	4	5
34. Science should be a required part of my professional training.	1	2	3	4	5

APPENDIX F
MISCONCEPTION
T-TEST AND P VALUES

GROUP A-MISCONCEPTION TEST RESULTS
T-TEST CALCULATIONS AND P-VALUE RESULTS
FALL OF 1995 N=34 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	10	40	30
S2	12	67	55
S3	14	57	43
S4	16	39	23
S5	18	67	49
S6	20	55	35
S7	21	78	57
S8	22	56	34
S9	24	45	21
S10	31	54	23
S11	34	78	44
S12	34	87	53
S13	34	55	21
S14	34	69	35
S15	35	69	34
S16	35	50	15
S17	36	55	19
S18	37	67	30
S19	37	81	44
S20	38	96	58
S21	39	89	50
S22	39	90	51
S23	42	66	24
S24	43	90	47
S25	45	70	25
S26	45	67	22
S27	45	75	30
S28	47	85	38
S29	50	89	39
S30	50	80	30
S31	56	78	22
S32	56	80	24
S33	67	79	12
S34	67	94	27
COUNT	34	34	34
AVERAGE	36	71	34
ST-DEV	14	16	13
T-TEST	15.46267053		
PVALUE	P<.001		

GROUP A-MISCONCEPTION TEST RESULTS
T-TEST CALCULATIONS AND P-VALUE RESULTS
SPRING OF 1996 N=34 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	37	67	30
S2	38	54	16
S3	39	80	41
S4	39	76	37
S5	42	80	38
S6	43	80	37
S7	45	85	40
S8	45	56	11
S9	45	60	15
S10	47	67	20
S11	50	80	30
S12	50	46	-4
S13	45	56	11
S14	56	89	33
S15	55	76	21
S16	54	80	26
S17	20	70	50
S18	21	85	64
S19	21	78	57
S20	20	67	47
S21	21	75	54
S22	24	65	41
S23	24	68	44
S24	31	69	38
S25	34	57	23
S26	34	65	31
S27	34	85	51
S28	36	35	-1
S29	35	46	11
S30	35	54	19
S31	36	67	31
S32	37	80	43
S33	19	85	66
S34	18	80	62
S35	19	78	59
S36	23	60	37
S37	18	56	38
S38	25	78	53
S39	25	89	64
S40	26	67	41

COUNT	40	40	40
AVERAGE	34	70	36
ST-DEV	11	13	18
T-TEST	12.66793392		
PVALUE	P<.001		

GROUP A-MISCONCEPTION TEST RESULTS
T-TEST CALCULATIONS AND P-VALUE RESULTS
SUMMER OF 1996 N=21 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	25	54	29
S2	30	80	50
S3	28	56	28
S4	45	60	15
S5	22	67	45
S6	18	80	62
S7	9	46	37
S8	25	56	31
S9	55	78	23
S10	33	67	34
S11	37	65	28
S12	25	67	42
S13	12	54	42
S14	23	89	66
S15	25	76	51
S16	34	80	46
S17	33	70	37
S18	55	85	30
S19	25	78	53
S20	58	68	10
S21	55	45	-10
COUNT	21	21	21
AVERAGE	32	68	36
ST-DEV	14	13	18
T-TEST	9.296067144		
PVALUE	P<.001		

GROUP B-MISCONCEPTION TEST RESULTS
T-TEST CALCULATIONS AND P-VALUE RESULTS
FALL OF 1995 N=36 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	12	28	16
S2	12	20	8
S3	14	32	18
S4	20	35	15
S5	20	36	16
S6	21	34	13
S7	22	22	0
S8	24	34	10
S9	25	45	20
S10	28	38	10
S11	29	39	10
S12	29	39	10
S13	30	45	15
S14	30	45	15
S15	32	54	22
S16	32	42	10
S17	35	45	10
S18	38	45	7
S19	38	40	2
S20	42	45	3
S21	43	53	10
S22	45	54	9
S23	45	55	10
S24	45	56	11
S25	46	60	14
S26	47	50	3
S27	47	49	2
S28	48	68	20
S29	49	58	9
S30	50	60	10
S31	50	50	0
S32	50	50	0
S33	51	56	5
S34	55	50	-5
S35	55	60	5
S36	60	55	-5
COUNT	36	36	36
AVERAGE	37	46	9
ST-DEV	13	11	7
T-TEST	8.101641305		
PVALUE	P<.01		

GROUP B-MISCONCEPTION TEST RESULTS
T-TEST CALCULATIONS AND P-VALUE RESULTS
SPRING OF 1996 N=38 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	37	32	-5
S2	38	36	-2
S3	22	44	22
S4	23	45	22
S5	42	47	5
S6	43	55	12
S7	45	51	6
S8	45	71	26
S9	34	60	26
S10	47	57	10
S11	50	58	8
S12	45	68	23
S13	43	67	24
S14	55	70	15
S15	54	35	-19
S16	20	32	12
S17	21	36	15
S18	31	36	5
S19	44	44	0
S20	34	45	11
S21	19	47	28
S22	46	55	9
S23	25	51	26
S24	35	61	26
S25	14	55	41
S26	54	57	3
S27	11	34	23
S28	21	34	13
S29	10	58	48
S30	21	78	57
S31	13	55	42
S32	19	56	37
S33	21	78	57
S34	12	40	28
S35	19	34	15
S36	15	45	30
S37	8	44	36
S38	9	45	36
COUNT	38	38	38
AVERAGE	30	50	20

ST-DEV	15	13	17
T-TEST	7.488337153		
PVALUE	P<.01		

GROUP B-MISCONCEPTION TEST RESULTS
T-TEST CALCULATIONS AND P-VALUE RESULTS
SUMMER OF 1996 N=21 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	19	36	17
S2	25	45	20
S3	29	44	15
S4	33	50	17
S5	55	45	-10
S6	25	67	42
S7	52	45	-7
S8	40	42	2
S9	45	77	32
S10	20	30	10
S11	26	38	12
S12	40	57	17
S13	22	28	6
S14	8	35	27
S15	14	58	44
S16	17	37	20
S17	40	70	30
S18	9	35	26
S19	8	32	24
S20	45	36	-9
S21	20	44	24
COUNT	21	21	21
AVERAGE	28	45	17
ST-DEV	14	13	15
T-TEST	5.25205286		
PVALUE	P<.01		

GROUP C-MISCONCEPTION TEST RESULTS T-TEST CALCULATIONS AND P-VALUE RESULTS FALL OF 1995 N=51 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	20	65	45
S2	22	40	18
S3	25	50	25
S4	25	35	10
S5	25	35	10
S6	25	50	25
S7	26	40	14
S8	28	50	22
S9	28	75	47
S10	28	75	47
S11	28	55	27
S12	30	40	10
S13	30	85	55
S14	30	60	30
S15	30	60	30
S16	32	65	33
S17	35	82	47
S18	37	52	15
S19	37	85	48
S20	38	48	10
S21	38	55	17
S22	38	88	50
S23	38	65	27
S24	42	80	38
S25	42	65	23
S26	45	90	45
S27	45	80	35
S28	45	75	30
S29	45	48	3
S30	45	55	10
S31	46	85	39
S32	47	57	10
S33	48	85	37
S34	50	75	25
S35	50	80	30
S36	50	90	40
S37	50	90	40
S38	52	56	4
S39	52	85	33
S40	52	82	30

S41	53	82	29
S42	54	90	36
S43	54	90	36
S44	54	85	31
S45	55	95	40
S46	55	80	25
S47	55	50	-5
S48	58	90	32
S49	60	50	-10
S50	60	85	25
S51	60	90	30
COUNT	51	51	51
AVERAGE	42	69	28
ST-DEV	12	18	15
T-TEST	13.46449136		
PVALUE	P<.001		

GROUP C-MISCONCEPTION TEST RESULTS T-TEST CALCULATIONS AND P-VALUE RESULTS SPRING OF 1996 N=39 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	35	50	15
S2	58	67	9
S3	43	80	37
S4	54	67	13
S5	35	67	32
S6	56	78	22
S7	45	87	42
S8	42	65	23
S9	46	67	21
S10	25	75	50
S11	58	80	22
S12	55	80	25
S13	55	60	5
S14	37	75	38
S15	38	67	29
S16	42	80	38
S17	40	80	40
S18	45	85	40
S19	44	66	22
S20	55	60	5
S21	45	77	32
S22	41	85	44
S23	35	67	32
S24	35	46	11
S25	64	89	25
S26	38	85	47
S27	36	70	34
S28	20	85	65
S29	35	84	49
S30	23	69	46
S31	17	52	35
S32	34	60	26
S33	38	85	47
S34	40	45	5
S35	36	77	41
S36	38	61	23
S37	35	78	43
S38	34	65	31
S39	55	70	15

COUNT	39	39	39
AVERAGE	41	71	30
ST-DEV	11	12	14

T-TEST	13.23431462
PVALUE	P<.001

GROUP C-MISCONCEPTION TEST RESULTS T-TEST CALCULATIONS AND P-VALUE RESULTS SUMMER OF 1996 N=20 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	27	96	69
S2	20	97	77
S3	25	57	32
S4	34	94	60
S5	25	90	65
S6	19	67	48
S7	33	78	45
S8	65	90	25
S9	25	26	1
S10	58	93	35
S11	60	83	23
S12	54	77	23
S13	34	70	36
S14	26	89	63
S15	49	80	31
S16	12	65	53
S17	26	90	64
S18	25	90	65
S19	33	90	57
S20	58	93	35
COUNT	20	20	20
AVERAGE	35	81	45
ST-DEV	16	17	20
T-TEST	10.2253119		
PVALUE	P<.001		

GROUP D-MISCONCEPTION TEST RESULTS T-TEST CALCULATIONS AND P-VALUE RESULTS FALL OF 1995 N=33 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	18	35	17
S2	20	33	13
S3	22	34	12
S4	22	45	23
S5	22	35	13
S6	25	30	5
S7	25	65	40
S8	28	35	7
S9	29	40	11
S10	30	55	25
S11	32	57	25
S12	32	45	13
S13	32	55	23
S14	35	60	25
S15	35	51	16
S16	36	55	19
S17	38	54	16
S18	38	45	7
S19	40	40	0
S20	45	56	11
S21	45	52	7
S22	45	55	10
S23	45	56	11
S24	45	55	10
S25	45	47	2
S26	48	56	8
S27	48	67	19
S28	50	65	15
S29	50	65	15
S30	52	67	15
S31	55	58	3
S32	55	55	0
S33	58	67	9
COUNT	33	33	33
AVERAGE	38	51	13
ST-DEV	11	11	8
T-TEST	9.188818046		
PVALUE	P<.001		

GROUP D-MISCONCEPTION TEST RESULTS
T-TEST CALCULATIONS AND P-VALUE RESULTS
SPRING OF 1996 N=38 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	45	55	10
S2	37	51	14
S3	38	71	33
S4	42	60	18
S5	39	57	18
S6	35	58	23
S7	56	68	12
S8	45	67	22
S9	40	70	30
S10	46	35	-11
S11	35	58	23
S12	39	58	19
S13	36	57	21
S14	58	36	-22
S15	43	44	1
S16	54	45	-9
S17	30	47	17
S18	40	55	15
S19	45	51	6
S20	42	61	19
S21	56	60	4
S22	20	57	37
S23	29	45	16
S24	42	47	5
S25	40	55	15
S26	45	51	6
S27	44	61	17
S28	35	55	20
S29	41	57	16
S30	30	34	4
S31	35	55	20
S32	45	56	11
S33	38	78	40
S34	36	45	9
S35	20	44	24
S36	35	45	10
S37	18	61	43
S38	39	55	16
COUNT	38	38	38
AVERAGE	39	54	15

ST-DEV	9	10	13
T-TEST	7.122441821		
PVALUE	P<.001		

GROUP D-MISCONCEPTION TEST RESULTS
T-TEST CALCULATIONS AND P-VALUE RESULTS
SUMMER OF 1996 N=20 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	35	67	32
S2	49	78	29
S3	20	50	30
S4	8	34	26
S5	17	34	17
S6	25	58	33
S7	22	78	56
S8	37	67	30
S9	49	70	21
S10	51	35	-16
S11	15	32	17
S12	30	36	6
S13	18	44	26
S14	60	45	-15
S15	17	47	30
S16	28	55	27
S17	29	51	22
S18	25	71	46
S19	50	60	10
S20	20	57	37
COUNT	20	20	20
AVERAGE	30	53	23
ST-DEV	15	15	17
T-TEST	5.984337778		
PVALUE	P<.001		

APPENDIX G
SEASONS
T-TEST AND P VALUES

GROUP A-TABLE 2 SEASONS
T-TEST CALCULATIONS AND P-VALUE RESULTS
FALL OF 1995 N=19 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	10	78	68
S2	20	77	57
S3	8	58	50
S4	8	48	40
S5	19	59	40
S6	16	78	62
S7	30	80	50
S8	30	87	57
S9	17	68	51
S10	19	66	47
S11	8	65	57
S12	35	45	10
S13	23	87	64
S14	25	69	44
S15	17	70	53
S16	12	72	60
S17	6	45	39
S18	5	80	75
S19	17	70	53
COUNT	19	19	19
AVERAGE	17	69	51
ST-DEV	9	13	14
T-TEST	16.11388459		
PVALUE	P<.001		

GROUP A-TABLE 2 SEASONS
T-TEST CALCULATIONS AND P-VALUE RESULTS
SPRING OF 1996 N=24 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	19	55	36
S2	12	58	46
S3	5	57	52
S4	19	65	46
S5	14	66	52
S6	14	53	39
S7	18	50	32
S8	17	76	59
S9	15	67	52
S10	8	59	51
S11	18	60	42
S12	21	80	59
S13	19	87	68
S14	17	66	49
S15	12	60	48
S16	16	57	41
S17	15	54	39
S18	16	60	44
S19	9	80	71
S20	18	87	69
S21	18	74	56
S22	17	71	54
S23	15	58	43
S24	19	52	33
COUNT	24	24	24
AVERAGE	15	65	49
ST-DEV	4	11	11
T-TEST	22.43352737		
PVALUE	P<.01		

GROUP A-TABLE 2 SEASONS
T-TEST CALCULATIONS AND P-VALUE RESULTS
SUMMER OF 1996 N=15 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	17	72	55
S2	18	62	44
S3	22	75	53
S4	23	78	55
S5	15	77	62
S6	22	67	45
S7	20	62	42
S8	20	65	45
S9	18	55	37
S10	19	78	59
S11	20	59	39
S12	14	65	51
S13	22	72	50
S14	25	66	41
S15	10	65	55
COUNT	15	15	15
AVERAGE	19	68	49
ST-DEV	4	7	8
T-TEST	24.85510904		
PVALUE	P<.001		

GROUP B-TABLE 2 SEASONS
T-TEST CALCULATIONS AND P-VALUE RESULTS
FALL OF 1995 N=17 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	8	33	25
S2	9	30	21
S3	10	40	30
S4	13	45	32
S5	20	40	20
S6	11	30	19
S7	6	45	39
S8	8	36	28
S9	9	26	17
S10	12	36	24
S11	13	23	10
S12	15	45	30
S13	14	40	26
S14	20	40	20
S15	8	37	29
S16	6	40	34
S17	11	35	24
COUNT	17	17	17
AVERAGE	11	37	25
ST-DEV	4	6	7
T-TEST	14.73127672		
PVALUE	P<.001		

GROUP B-TABLE 2 SEASONS
T-TEST CALCULATIONS AND P-VALUE RESULTS
SPRING OF 1996 N=26 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	12	46	34
S2	19	39	20
S3	12	37	25
S4	5	45	40
S5	17	42	25
S6	14	30	16
S7	17	37	20
S8	25	56	31
S9	10	50	40
S10	19	28	9
S11	12	47	35
S12	14	48	34
S13	23	45	22
S14	12	50	38
S15	12	28	16
S16	11	40	29
S17	12	35	23
S18	10	40	30
S19	16	35	19
S20	9	40	31
S21	19	42	23
S22	12	47	35
S23	5	35	30
S24	7	33	26
S25	14	50	36
S26	11	28	17
COUNT	26	26	26
AVERAGE	13	41	27
ST-DEV	5	8	8
T-TEST	16.67516241		
PVALUE	P<.01		

GROUP B-TABLE 2 SEASONS
T-TEST CALCULATIONS AND P-VALUE RESULTS
SUMMER OF 1996 N=14 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	22	37	15
S2	23	45	22
S3	30	28	-2
S4	22	44	22
S5	17	44	27
S6	18	35	17
S7	21	45	24
S8	20	46	26
S9	23	39	16
S10	22	37	15
S11	17	36	19
S12	25	35	10
S13	20	37	17
S14	15	25	10
COUNT	14	14	14
AVERAGE	21	38	17
ST-DEV	4	6	8
T-TEST	8.36326186		
PVALUE	P<.01		

GROUP C-TABLE 2 SEASONS
T-TEST CALCULATIONS AND P-VALUE RESULTS
FALL OF 1995 N=19 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	6	50	44
S2	8	40	32
S3	4	40	36
S4	20	60	40
S5	22	80	58
S6	4	87	83
S7	8	70	62
S8	8	71	63
S9	7	58	51
S10	8	48	40
S11	13	47	34
S12	28	50	22
S13	4	65	61
S14	6	45	39
S15	8	67	59
S16	5	69	64
S17	28	70	42
S18	4	58	54
S19	6	55	49
COUNT	19	19	19
AVERAGE	10	59	49
ST-DEV	8	13	15
T-TEST	14.63981015		
PVALUE	P<.001		

GROUP C-TABLE 2 SEASONS
T-TEST CALCULATIONS AND P-VALUE RESULTS
SPRING OF 1996 N=19 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	13	60	47
S2	8	65	57
S3	9	72	63
S4	15	45	30
S5	12	75	63
S6	13	60	47
S7	19	65	46
S8	14	45	31
S9	20	78	58
S10	13	78	65
S11	10	77	67
S12	11	77	66
S13	11	65	54
S14	14	50	36
S15	10	55	45
S16	13	75	62
S17	12	78	66
S18	13	70	57
S19	14	68	54
COUNT	19	19	19
AVERAGE	13	66	53
ST-DEV	3	11	12
T-TEST	19.72955158		
PVALUE	P<.001		

GROUP C-TABLE 2 SEASONS
T-TEST CALCULATIONS AND P-VALUE RESULTS
SUMMER OF 1996 N=14 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	18	67	49
S2	15	53	38
S3	15	65	50
S4	34	65	31
S5	17	50	33
S6	21	75	54
S7	22	68	46
S8	19	67	48
S9	23	62	39
S10	15	61	46
S11	20	75	55
S12	12	60	48
S13	15	58	43
S14	11	45	34
COUNT	14	14	14
AVERAGE	18	62	44
ST-DEV	6	9	8

T-TEST	21.27089294
PVALUE	P<.01

GROUP D-TABLE 2 SEASONS
T-TEST CALCULATIONS AND P-VALUE RESULTS
FALL OF 1995 N=16 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	7	49	42
S2	14	56	42
S3	16	55	39
S4	5	46	41
S5	7	39	32
S6	14	37	23
S7	17	56	39
S8	25	50	25
S9	4	50	46
S10	6	30	24
S11	8	47	39
S12	12	44	32
S13	10	35	25
S14	6	43	37
S15	9	33	24
S16	19	45	26
COUNT	16	16	16
AVERAGE	11	45	34
ST-DEV	6	8	8
T-TEST	16.78500526		
PVALUE	P<.001		

GROUP D-TABLE 2 SEASONS
T-TEST CALCULATIONS AND P-VALUE RESULTS
SPRING OF 1996 N=16 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	11	46	35
S2	13	33	20
S3	15	40	25
S4	14	40	26
S5	9	41	32
S6	15	45	30
S7	7	44	37
S8	17	35	18
S9	9	43	34
S10	5	67	62
S11	19	56	37
S12	12	69	57
S13	11	55	44
S14	13	52	39
S15	8	45	37
S16	5	50	45
COUNT	16	16	16
AVERAGE	11	48	36
ST-DEV	4	10	12
T-TEST	12.12119229		
PVALUE	P<.001		

GROUP D-TABLE 2 SEASONS
T-TEST CALCULATIONS AND P-VALUE RESULTS
SUMMER OF 1996 N=15 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	11	51	40
S2	19	48	29
S3	22	57	35
S4	19	44	25
S5	17	45	28
S6	15	42	27
S7	18	46	28
S8	17	39	22
S9	15	47	32
S10	20	45	25
S11	16	51	35
S12	17	59	42
S13	13	44	31
S14	19	43	24
S15	22	67	45
COUNT	15	15	15
AVERAGE	17	49	31
ST-DEV	3	7	7
T-TEST	17.46213086		
PVALUE	P<.01		

APPENDIX H
MOON PHASES
T-TEST AND P VALUES

GROUP A-TABLE 3 MOON PHASES
T-TEST CALCULATIONS AND P-VALUE RESULTS
FALL OF 1995 N=19 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	8	40	32
S2	12	45	33
S3	10	35	25
S4	6	50	44
S5	9	65	56
S6	19	57	38
S7	12	53	41
S8	5	50	45
S9	7	50	43
S10	14	40	26
S11	17	40	23
S12	25	60	35
S13	10	80	70
S14	8	87	79
S15	12	70	58
S16	14	71	57
S17	6	58	52
S18	14	48	34
S19	12	47	35
COUNT	19	19	19
AVERAGE	12	55	43
ST-DEV	5	14	15
T-TEST	12.45194688		
PVALUE	P<.001		

GROUP A-TABLE 3 MOON PHASES
T-TEST CALCULATIONS AND P-VALUE RESULTS
SPRING OF 1996 N=24 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	19	45	26
S2	12	35	23
S3	5	50	45
S4	19	65	46
S5	14	57	43
S6	14	53	39
S7	20	50	30
S8	17	50	33
S9	15	40	25
S10	8	40	32
S11	20	60	40
S12	20	80	60
S13	18	87	69
S14	15	50	35
S15	12	50	38
S16	6	40	34
S17	5	40	35
S18	16	60	44
S19	14	80	66
S20	18	87	69
S21	18	70	52
S22	17	71	54
S23	15	58	43
S24	8	48	40
COUNT	24	24	24
AVERAGE	14	57	43
ST-DEV	5	15	13
T-TEST	15.70187638		
PVALUE	P<.01		

GROUP A-TABLE 3 MOON PHASES
T-TEST CALCULATIONS AND P-VALUE RESULTS
SUMMER OF 1996 N=16 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	19	65	46
S2	17	72	55
S3	18	50	32
S4	22	75	53
S5	17	78	61
S6	15	77	62
S7	22	67	45
S8	20	48	28
S9	20	65	45
S10	18	55	37
S11	12	78	66
S12	15	60	45
S13	14	65	51
S14	17	72	55
S15	25	56	31
S16	10	65	55
COUNT	16	16	16
AVERAGE	18	66	48
ST-DEV	4	10	11
T-TEST	16.74502198		
PVALUE	P<.01		

GROUP B-TABLE 3 MOON PHASES
T-TEST CALCULATIONS AND P-VALUE RESULTS
FALL OF 1995 N=17 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	19	26	7
S2	12	36	24
S3	5	23	18
S4	19	40	21
S5	14	40	26
S6	18	40	22
S7	22	35	13
S8	17	40	23
S9	15	35	20
S10	8	33	25
S11	20	30	10
S12	20	37	17
S13	18	40	22
S14	15	40	25
S15	12	27	15
S16	6	45	39
S17	5	36	31
COUNT	17	17	17
AVERAGE	14	35	21
ST-DEV	6	6	8
T-TEST	11.33442165		
PVALUE	P<.001		

GROUP B-TABLE 3 MOON PHASES
T-TEST CALCULATIONS AND P-VALUE RESULTS
SPRING OF 1996 N=26 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	9	46	37
S2	19	39	20
S3	12	37	25
S4	5	45	40
S5	7	42	35
S6	14	47	33
S7	17	48	31
S8	25	45	20
S9	10	50	40
S10	8	28	20
S11	12	47	35
S12	14	42	28
S13	6	47	41
S14	14	48	34
S15	12	45	33
S16	8	50	42
S17	12	28	16
S18	10	40	30
S19	6	35	29
S20	9	40	31
S21	19	35	16
S22	12	40	28
S23	5	35	30
S24	7	33	26
S25	14	30	16
S26	17	37	20
COUNT	26	26	26
AVERAGE	12	41	29
ST-DEV	5	7	8
T-TEST	16.17459613		
PVALUE	P<.01		

GROUP B-TABLE 3 MOON PHASES
T-TEST CALCULATIONS AND P-VALUE RESULTS
SUMMER OF 1996 N=14 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	5	45	40
S2	19	48	29
S3	14	28	14
S4	15	47	32
S5	17	44	27
S6	17	35	18
S7	15	45	30
S8	20	46	26
S9	17	39	22
S10	22	37	15
S11	17	45	28
S12	15	35	20
S13	20	45	25
S14	15	40	25
COUNT	14	14	14
AVERAGE	16	41	25
ST-DEV	4	6	7
T-TEST	13.44427615		
PVALUE	P<.01		

GROUP C-TABLE 3 MOON PHASES
T-TEST CALCULATIONS AND P-VALUE RESULTS
FALL OF 1995 N=19 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	21	70	49
S2	17	80	63
S3	19	68	49
S4	8	60	52
S5	20	65	45
S6	20	45	25
S7	13	78	65
S8	15	60	45
S9	12	65	53
S10	6	72	66
S11	5	45	40
S12	17	75	58
S13	10	78	68
S14	20	77	57
S15	8	50	42
S16	8	48	40
S17	15	50	35
S18	10	78	68
S19	9	75	66
COUNT	19	19	19
AVERAGE	13	65	52
ST-DEV	5	12	12
T-TEST	18.20902546		
PVALUE	P<.001		

GROUP C-TABLE 3 MOON PHASES
T-TEST CALCULATIONS AND P-VALUE RESULTS
SPRING OF 1996 N=19 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	21	70	49
S2	17	80	63
S3	19	68	49
S4	8	60	52
S5	20	65	45
S6	20	45	25
S7	13	78	65
S8	15	60	45
S9	12	65	53
S10	6	72	66
S11	5	45	40
S12	17	75	58
S13	10	78	68
S14	20	77	57
S15	8	50	42
S16	8	48	40
S17	15	50	35
S18	10	78	68
S19	9	75	66
COUNT	19	19	19
AVERAGE	13	65	52
ST-DEV	5	12	12
T-TEST	27.07288558		
PVALUE	P<.01		

GROUP C-TABLE 3 MOON PHASES
T-TEST CALCULATIONS AND P-VALUE RESULTS
SUMMER OF 1996 N=19 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	11	60	49
S2	8	65	57
S3	9	45	36
S4	10	78	68
S5	12	60	48
S6	13	65	52
S7	15	72	57
S8	14	45	31
S9	20	75	55
S10	8	78	70
S11	6	77	71
S12	11	50	39
S13	8	55	47
S14	9	75	66
S15	10	78	68
S16	13	77	64
S17	12	65	53
S18	13	70	57
S19	14	68	54
COUNT	19	19	19
AVERAGE	11	66	55
ST-DEV	3	11	12
T-TEST	20.75210498		
PVALUE	P<.01		

GROUP D-TABLE 3 MOON PHASES
T-TEST CALCULATIONS AND P-VALUE RESULTS
FALL OF 1995 N=16 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	12	50	38
S2	13	46	33
S3	15	39	24
S4	14	37	23
S5	20	45	25
S6	8	42	34
S7	6	47	41
S8	11	48	37
S9	8	45	37
S10	9	50	41
S11	10	28	18
S12	13	47	34
S13	20	44	24
S14	11	35	24
S15	6	42	36
S16	8	34	26
COUNT	16	16	16
AVERAGE	12	42	31
ST-DEV	4	6	7
T-TEST	16.85129777		
PVALUE	P<.001		

GROUP D-TABLE 3 MOON PHASES
T-TEST CALCULATIONS AND P-VALUE RESULTS
SPRING OF 1996 N=16 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	12	50	38
S2	13	46	33
S3	15	39	24
S4	14	37	23
S5	20	45	25
S6	8	42	34
S7	6	47	41
S8	11	48	37
S9	8	45	37
S10	9	50	41
S11	10	28	18
S12	13	47	34
S13	20	44	24
S14	11	35	24
S15	6	42	36
S16	8	34	26
COUNT	16	16	16
AVERAGE	12	42	31
ST-DEV	4	6	7
T-TEST	16.85129777		
PVALUE	P<.001		

GROUP D-TABLE 3 MOON PHASES
T-TEST CALCULATIONS AND P-VALUE RESULTS
SUMMER OF 1996 N=16 P=.05

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	12	36	24
S2	13	23	10
S3	15	40	25
S4	14	40	26
S5	20	40	20
S6	8	35	27
S7	6	40	34
S8	11	35	24
S9	13	43	30
S10	15	67	52
S11	14	56	42
S12	20	69	49
S13	9	50	41
S14	10	52	42
S15	13	45	32
S16	12	50	38
COUNT	16	16	16
AVERAGE	13	45	32
ST-DEV	4	12	11
T-TEST	11.5258231		
PVALUE	P<.01		

APPENDIX I
ATTITUDE SURVEY
T-TEST AND P VALUES

FALL OF 1995
T-TEST CALCULATIONS AND P-VALUE RESULTS
ATTITUDE SURVEY

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	67	66	-1
S2	54	57	3
S3	70	72	2
S4	76	76	0
S5	70	67	-3
S6	71	67	-4
S7	51	52	1
S8	56	53	-3
S9	60	58	-2
S10	67	63	-4
S11	67	67	0
S12	80	81	1
S13	76	77	1
S14	69	71	2
S15	71	68	-3
S16	63	60	-3
S17	56	55	-1
S18	60	60	0
S19	67	67	0
S20	70	71	1
S21	67	68	1
S22	78	79	1
S23	67	70	3
S24	75	70	-5
S25	65	62	-3
S26	68	65	-3
S27	45	56	11
S28	45	44	-1
S29	46	42	-4
S30	54	58	4
S31	67	60	-7
S32	80	77	-3
S33	85	84	-1
S34	80	84	4
S35	70	74	4
S36	65	75	10
S37	78	70	-8
S38	70	65	-5
S39	64	54	-10
S40	63	59	-4

S41	50	44	-6
S42	51	45	-6
S43	54	50	-4
S44	60	55	-5
S45	56	60	4
S46	67	62	-5
S47	56	56	0
S48	67	87	20
S49	67	72	5
S50	67	67	0
S51	57	62	5
COUNT	51	51	51
AVERAGE	64.80392157	64.39215686	-0.411764706
ST-DEV	9.625008276	10.65284644	5.087932667
T-TEST	-0.577953438		
PVALUE	0.28		

SPRING OF 1996
T-TEST CALCULATIONS AND P-VALUE RESULTS
ATTITUDE SURVEY

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	67	70	3
S2	56	56	0
S3	60	60	0
S4	67	69	2
S5	70	76	6
S6	56	66	10
S7	60	76	16
S8	69	70	1
S9	76	71	-5
S10	66	51	-15
S11	76	56	-20
S12	70	60	-10
S13	71	67	-4
S14	51	56	5
S15	56	60	4
S16	60	67	7
S17	67	70	3
S18	67	56	-11
S19	80	60	-20
S20	76	69	-7
S21	69	76	7
S22	71	59	-12
S23	63	67	4
S24	56	75	19
S25	60	65	5
S26	67	68	1
S27	70	69	-1
S28	67	52	-15
S29	65	65	0
S30	68	50	-18
S31	45	60	15
S32	45	67	22
S33	46	78	32
S34	59	78	19
S35	67	79	12
S36	65	70	5
S37	78	85	7
S38	70	50	-20
S39	64	55	-9
S40	63	60	-3

S41	50	62	12
S42	51	56	5
S43	65	87	22
S44	85	72	-13
S45	35	67	32
S46	46	62	16
S47	54	77	23
S48	75	89	14
S49	54	55	1
S50	60	65	5
S51	56	40	-16
S52	67	44	-23
S53	56	67	11
S54	64	76	12
S55	75	70	-5
S56	70	72	2
S57	65	70	5
S58	78	85	7
S59	70	88	18
S60	60	76	16
S61	56	60	4
S62	67	60	-7
COUNT	62	62	62
AVERAGE	63.51612903	66.35483871	2.838709677
ST-DEV	9.694923355	10.53035701	12.7654677
T-TEST	1.750975592		
PVALUE	0.04		

SUMMER OF 1996
T-TEST CALCULATIONS AND P-VALUE RESULTS
ATTITUDE SURVEY

STUDENT #	PRE-TEST MISCONCEPTIONS	POSTTEST MISCONCEPTIONS	DIFFERENCE PRE-POST
S1	60	46	-14
S2	67	60	-7
S3	70	77	7
S4	36	41	5
S5	56	66	10
S6	41	37	-4
S7	56	79	23
S8	60	87	27
S9	77	67	-10
S10	67	70	3
S11	71	67	-4
S12	76	66	-10
S13	69	67	-2
S14	77	46	-31
S15	56	50	-6
S16	60	67	7
S17	67	80	13
S18	70	46	-24
S19	56	37	-19
S20	60	57	-3
S21	65	40	-25
S22	68	45	-23
S23	45	35	-10
S24	45	39	-6
S25	46	39	-7
S26	51	60	9
S27	37	40	3
S28	40	80	40
S29	35	25	-10
S30	46	75	29
S31	51	60	9
COUNT	31	31	31
AVERAGE	57.4516129	56.48387097	-0.967741935
ST-DEV	12.68815382	16.59492084	16.43671474
T-TEST	-0.327812409		
PVALUE	0.38		