STUDENT IDEAS ABOUT THE MOON AND ITS PHASES AND THE IMPACT OF A REAL 3D MODEL OF THE SUN/EARTH/MOON SYSTEM IN AN INTRODUCTORY ASTRONOMY LABORATORY COURSE

by

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Thesis Advisor: Dr. Neil Comins

An Abstract of the Thesis Presented

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Students who take a college level introductory astronomy lab course for non-science majors answer survey questions about the Moon and its phases as part of a regular curriculum. We analyze responses to these questions to determine student ideas about the phases of the Moon and whether or not there is any pattern to these ideas. In addition, we look at the effects of changes to an astronomy lab lesson that incorporate a real three-dimensional (3D) model of the Sun/Earth/Moon system to determine whether or not the use of a real 3D model affects student ideas about the Moon and its phases. Our hypothesis is that there is a relationship between the concept that the phases of the Moon are caused by Earth's shadow and the concept that the

Moon is more apt to be up at night than during the day. We also propose that the 3D model will assist students in obtaining correct conceptions about the Moon. Results from the study show that college-level students possess unscientific ideas about the cause of the phases of the Moon and that a large percentage of these students believe the Moon is only up at night. Students' ideas about the phases did not show any relationship to their ideas about when one is most likely to observe the Moon whether it is night or day. Use of the 3D model did not have an effect on students gaining scientific concepts about the Moon and its phases.

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CHAPTER 1

INTRODUCTION

In much of the research into science education there lies a focus on student misconceptions and conceptual change. Students come into the classroom with ideas about nature that are often unscientific and deeply rooted in the culture of the individual student. Scientists and educators are faced with the challenge of getting students to adopt accepted scientific thought to explain natural phenomena, overturning their existing unscientific ideas in what education researchers refer to as a process of conceptual change.

A model for conceptual change, often referred to as the misconceptions model, proposes dealing with unscientific student ideas as naïve and inaccurate - ideas that must be confronted as wrong. When these ideas are shown to the students as Awrong,@ a dissonance develops in the cognitive processes of the student, and the naïve ideas that have explained the natural phenomena to the student are now challenged. The resolution to this conflict is to present the accepted scientific concept hoping that the students can recognize it as a more acceptable explanation. Hermann and Lewis describe this approach as a three step process involving, Aidentifying the misconception,@ Aoverturning the misconception,@ and Areplacing the misconception@ (Hermann & Lewis, 2003).

The misconceptions model involves conflict in the student cognitive process and researchers have developed models of conceptual change that approach the replacing of unscientific ideas with scientific ones by building on existing student ideas, whether they be naïve, unscientific or incorrect. Ultimately, concepts and knowledge and the way they form or change are as diverse as students themselves. In his paper, “More than misconceptions: Multiple perspectives on student knowledge and reasoning, and an appropriate role for education research,” Hammer addresses this broad spectrum of student cognition by advising researchers and educators to expand their perceptions of the learning process and avoid defining a particular model of student reasoning (Hammer, 1995).

Student ideas about the phases of the Moon come from concepts that developed long before any scientific instruction. How far back do these ideas go in terms of their permanence in memory? Historically and anthropologically, the concepts about the Moon=s phases are old and numerous. In Paul Katzeff=s book, AMoon Madness,@ he mentions several traditional beliefs about the phases of the Moon. One such belief is the way a tribe of Australian aborigines explained the waning Moon as a woman whose endless partying causes her to lose weight (Katzeff, 1988). In our own culture, concepts about the Moon come from family members, books, television, movies, etc.

Until Western/Christian based culture adopted a heliocentric view of our immediate universe, theories about the celestial bodies that are now considered scientifically inaccurate abounded, yet at the time they were devised by the great thinkers of that era and were accepted thought. Today we still teach Newtonian gravitation, though scientifically it is incomplete. NASA relies on General Relativity to calculate orbits, but to teach Einstein’s theory, even at a college level, is essentially unfeasible. In essence this very process of limiting knowledge creates a misconception. The question is how much of a conceptual change do we expect students to make? From the educator's standpoint, the unscientific ideas about the Moon are wrong and need to be replaced with the correct, scientifically accepted ideas. From the student's view, the long-held ideas work well to explain what they see in nature, as did the geocentric model of the universe work for thousands of years. So when is a concept a misconception, or more aptly, if a once accepted scientific conception can become a Amisconception,@ why can=t a currently held scientific conception become a misconception too? In science, we use the method of testing theories with experimentation to validate our ideas and sort out our "misconceptions." Conceptions about nature evolve as our knowledge of the universe grows.

As instructors and researchers, we are faced with the challenge of conceptual change as extremely difficult to achieve. In this research, we approach conceptual change as a scientific process of testing ideas with experimentation. This thesis is divided into two parts. Part One looks at student conceptions about the phases of the Moon. The hypothesis of the research for this part is that certain unscientific ideas about the phases of the Moon are prevalent even within college-level students and that there is a relationship between the concept that the phases of the Moon are caused by Earth's shadow and that the Moon is more apt to be up at night than during the day. In addition, we look at whether or not correct ideas about the cause of the lunar phases are associated with awareness of the day/night cycles of the Moon. This part of the research utilizes three research questions that students answer as part of the regular curriculum in an introductory astronomy lab. We analyze how these research questions are answered by students in the astronomy course during the spring 2004, fall 2004 and spring 2005 semesters and in an online version of the course during the spring of 2005.

Part Two looks into changes in instruction for a lunar phases astronomy lab. We present the students with a model of the Sun/Earth/Moon system and allow them to test their ideas about the phases of the Moon by experimenting with that model. The model, a real (not virtual) 3D model of the Sun/Earth/Moon system, is incorporated into a lesson on the phases of the Moon that the students perform about halfway through the semester lab course. It replaces a portion of the instruction that required students to assemble their own 3D model. In addition to the use of the model, we modified the lesson to incorporate it. We will compare the results of two semesters. The spring 2004 semester represents the control group and fall 2004 semester represents the experimental. Our hypothesis is that a concrete visual and kinesthetic model assists them more in making the observations needed to form scientific conceptions about the Moon and its phases. We test this by analyzing the responses to the survey questions both before and after the lab is performed by the students. We also look at performance in the lab itself to see if there is a significant change in student ideas about the Moon.

CHAPTER 2

A REVIEW OF RELEVANT RESEARCH AND OTHER WORKS

Many of the alternative ideas students bring into the classroom about the phases of the Moon stem from deeply rooted and difficult-to-change concepts they acquired at a young age. For example, children's books often present the Moon as only being present in the nighttime sky and the Sun being present in the daytime sky, when the reality is that the Moon is present in the daytime sky just as often as it is in the nighttime sky in any given month (orbital cycle of the Moon).

Sampling books from a day care center library, we found three titles of interest that support this statement. "what makes day and night," by Franklyn M. Branley, published by Thomas Y. Crowell in 1961, is self-described as a, "…let's-read-and-find-out science book." In this book, which describes the causes of night and day, every picture of the Moon is associated with night time. On page 16, a night picture, the Moon is a waning crescent which means that the Moon is close to the Sun and would therefore be visible during the daytime for a longer period than it would be at night.

In the Sesame Street/Golden Press Book published in 1991 titled "Sleep Tight!" by Constance Allen, all the daytime pictures show the Sun in the background. All the night time pictures show a waxing crescent moon in the background. Again, this phase of the Moon would be more prevalent in the daytime sky. Ethel and Leonard Kessler's "The Day Daddy Stayed

Home," published in 1959 by Xerox Education Publications shows a bed time scene with a waning crescent moon. Having this phase of the Moon present would mean the child in the story was being put to bed some time after midnight and most likely very close to sunrise if such a phase were to be above the horizon enough to appear in a bedroom window. Other books reviewed made similar mistakes about the Moon and understandably, from an artistic position, a crescent moon is more interesting than a full moon. Some of the books reviewed did show a full moon in night scenes which makes their representation of the Moon correct. One of those books was a *Baby's First Book* titled "Baby Looks" published in 1960 by Western Publishing Company.

In looking into student ideas about the Moon that are often fostered at early ages, we have reviewed the works of others who have done research in this area. Because much of this thesis revolves around conceptual change, review of studies into conceptual change are also covered.

2.1 Baxter

John Baxter (1989) investigated the ideas 9 to 16 year olds held about (i) Earth, space and gravity, (ii) day and night, (ii) the phases of the Moon and (iv) seasons (Baxter, 1989). His method of research utilized taped and transcribed interviews with 20 students to develop a survey instrument which was then given to 100 students (48 boys and 52 girls) across the age span (Baxter, p 503).

The survey instrument presented to the students looked into five possible concepts about the cause of the Moon's phases. They were: clouds cover part of the Moon, a planet casts a shadow of the Moon, the Sun casts a shadow on the Moon, Earth casts a shadow on the Moon, and the portion of the illuminated side of the Moon visible from Earth changes. Baxter presented the results from the survey graphically in his article (See Figure 1).

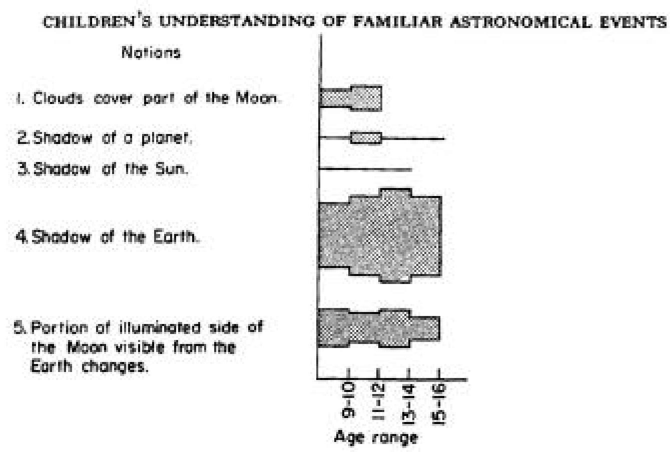


Figure 1 (Baxter, p 510. Copyright 1989, *Int. Journ. Of Sci. Ed.*)

Baxter makes an important point relating to all the areas of the research and not just questions about the Moon. In referring to "pupils' notions" he is referencing their concepts about the four areas of the research cited above.

> The fact that many pupils' notions have historical parallels is forming a useful teaching point. Presentations of ideas held in the past are being used to demonstrate the tentative nature of science. The reference to historical ideas possibly makes pupils feel more comfortable when they realize that their notions, although incorrect in the light of scientific advancement, were once the popular view. They are also giving pupils insights into the kinds of evidence that encouraged scientists over the years to change their theories (Baxter, p 512).

2.2 Stahly, Krockover & Shepardson.

Stahly, Krockover & Shepardson (1999) looked into third graders' ideas about the Moon's phases both before and after instruction. Their methods used interviews from four students from a third grade class of 21. These students varied in abilities and were chosen based on criteria that included their communication skills. The instruction the students received consisted of 6 lessons over a period of 3 weeks, which included the presentation of a 3D model of the Sun/Earth/Moon system. With the researcher acting as a teacher, the material was presented to the students to facilitate their learning while their concepts and conceptual changes were monitored and recorded. Results were obtained from interviews and drawings made by the students.

Stahly et al. found some scientific ideas present after instruction among the four "key informants" they interviewed and observed, but they also found that "The third grade students also seemed to maintain some aspects of their original conceptions representing the resilience of their ideas."

2.3 Trumper

Trumper (2000) surveyed students entering an introductory astronomy course with an instrument of 19 questions covering several topics in basic astronomy. Question 2 on his survey inventoried conceptions about the phases of the Moon (See Figure 2). His results showed 31.6 % of students believed that the phases of the Moon are caused by Earth's shadow. Correct answers were given by 51.3 % of the students (Trumper, p 10). The article was an account of a survey and did not address any efforts toward conceptual change.

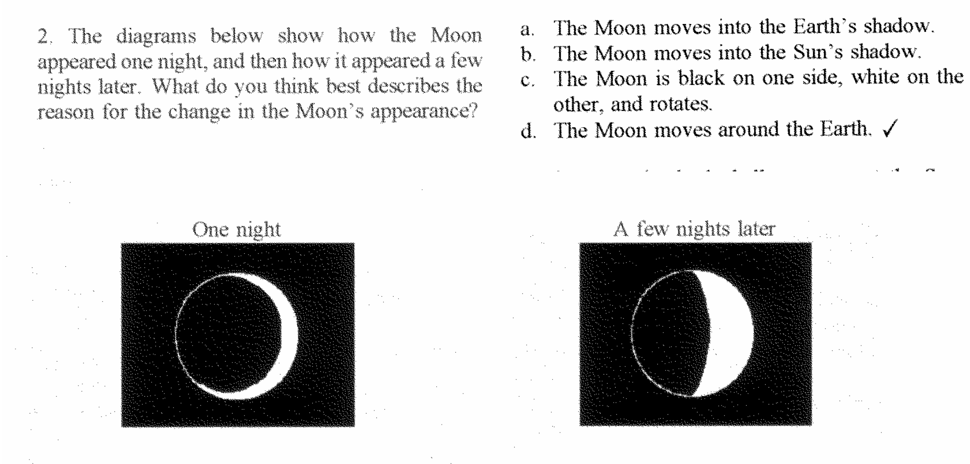


Figure 2 (Trumper, pp 12-13. Copyright 2000, *Phys. Ed.*)

2.4 Barnett and Moran

Barnett and Moran (2002) investigated student conceptions about the Moon and utilized a curriculum to help students develop an understanding of the Sun/Earth/Moon system. The approach used an "eclectic" mix of instructional materials including a 3D computer model. The instructional approach was consistent with current thinking about conceptual change theory (see Posner et. al. 1982), namely respecting student ideas, whether scientific or not, and building on those existing student ideas by providing ways for students to make the proper connections toward a scientific understanding.

Results from the study which included analysis of interviews with the students were mixed. Barnett and Moran sum it up as follows.

> The findings in this study suggest that students at Grade 5 level can develop a sophisticated understanding of the phases of the Moon and eclipses and that instruction does not necessarily need to directly address students' alternative

> frameworks to promote conceptual change. However these findings need to be tempered somewhat. For instance, the post-interviews occurred immediately at the conclusion of the course whereas a delayed interview of perhaps 6 months to a year would yield more conclusive evidence that students' conceptual understanding did indeed change. In addition, the class size was small, and the students were taking the course by their own choice. Therefore our instructional techniques will need to be used with a larger group of students and within a more traditional science classroom if we are to make any generalizeable claims concerning student learning. (Barnett and Moran, p. 875)

2.5 Lindell

In looking into existing research into student understanding of the phases of the Moon, Dr. Rebecca Lindell's name came up. We were able to review her "Moon Concept Inventory" also known as the Lunar Phases Concept Inventory (LPCI) and a lesson titled, "Activity 5: Observing the Moon." This particular activity is designed to get students to observe that the orbit of the Moon around the Earth affects the phases. Question 14 in the activity specifically asks, "What portion of the Moon is always lit?" (Lindell). Some of her research was cited in an *Astronomy Education Review* article by Janelle Bailey and Timothy Slater titled "A Review of Astronomy Education Research" published in 2003. In that article, Bailey and Slater state that Lindell's research using the LCPI and the activity cited above showed an "unusually large average gain" (Bailey & Slater).

2.6 Barab et. al.

We were able to obtain a draft of a document by Barab, et. al. titled, "Virtual Solar System Project" (VSS) that was presented for publication in the *Journal of Science Education and Technology*. This research gave introductory astronomy students at the college level an inquiry-based instruction where students worked in groups. At the core of the instruction was a software package called “CosmoWorlds” that students used for various simulations of astronomical events. The course was divided into two projects the students completed. Project 1 addressed the Sun/Earth/Moon system. Students taking the course raised the issue that learning the 3D software took away time from learning astronomy. In general though, the researchers felt that an inquiry based projects oriented instruction using 3D modeling was beneficial versus a lecture-tutorial based course.

2.7 McDermott

Relevant to this research is existing curriculum. We reviewed Section 5 from McDermott’s *Physics by Inquiry: Astronomy By Sight* which deals with the phases of the Moon, primarily as an informative alternative to the lecture – lab structure of AST 109-110. This particular tutorial requires students to keep a log of Moon observations and utilizes that log to enable students to observe changes in the Moon. It also includes an experiment using a ball in a darkened room with a single light source to simulate the phases, this particular model being very similar to the model used by the spring (control) semester.

2.8 Fanetti

Fanetti (2001), in her thesis for a Master of Science in Astrophysics presented to Iowa State University, examined as the title so aptly says, “The relationships of scale concepts on college age students’ misconceptions about the cause of the lunar phases.” Her hypothesis was that students who had skewed views of the scale of the Earth/Moon system were more apt to assume the Moon’s phases were caused by Earth’s shadow (Fanetti, p65). The results of the research did not show a statistically significant connection between conceptions of the Moon's phases and scale size of the Earth/Moon system.

2.9 Posner et. al.

Posner et. al. (1982) explored the possibilities of developing a conceptual change theory. Their article looks into the conditions that occur when conceptual change occurs in a student's mind and what does not occur when a less than scientific concept persists even after instruction. In summary of their discussion, conceptual change can only occur when a student "…can psychologically construct a coherent meaningful representation of a theory…" (Posner, et al., p 217). That meaningful representation is not necessarily a scientific conception, but a representation that works for the student.

2.10 Comins

In determining how to construct the questions about the Moon and for common ideas about the Moon, we looked at Neil Comins' book, *Heavenly Errors* for concepts people have about the Moon and its phases, and a related website where Comins has listed student misconceptions about astronomical events. By looking at Moon phases misconceptions, we obtained ideas about how to phrase questions used in our study. Comins also describes the true cause of the phases of the Moon in an explicit, easy to understand manner. He spends approximately 2 ½ pages discussing and refuting the idea that the phases are caused by Earth's shadow.

CHAPTER 3

METHODOLOGY

3.1 Lesson Design

This thesis project evolved from the desire by the physics and astronomy department to see if there was some way to assess how well an introductory astronomy course enabled students to fulfill their science requirement for the university general education standards. The University of Maine sets general education requirements that mandate students take the equivalent of two physical or biological science courses with laboratory sections in partial fulfillment of their degree requirements. *AST 109: Introduction to Astronomy* along with *AST110: Introduction to Astronomy Laboratory* account for one of those science courses. These courses are descriptive in nature and require some high school level mathematics. They are primarily taken by non-science majors.

AST 110: Introduction to Astronomy Laboratory, herein after referred to as AST 110, is a one-credit-hour lab the consists of 12 modules or units of instruction performed by students with the aid of teaching tools such as computers, a planetarium, telescopes, discharge tubes of different elements producing light, spectroscopes and models. The lab consists of 10 sections of approximately 24 students each, facilitated by a TA, that meets for approximately 2 hours each week through the semester. In a given week, one unit of instruction is usually covered. In addition to the 12 lab units, there is a viewing portion of the lab that has students do actual observing of celestial objects and constellation identification.

Originally, AST 110 was designed to be done in a lab workbook that was distributed at the start of the semester. At the beginning of the 2000-2001 academic year, Professor Batuski, the course instructor, with the assistance of Adrienne Traxler, then an undergraduate student, redesigned the units so that they could be incorporated into WebCT, an internet-based course tool for using online instruction. A major factor in the redesign of the course is that each astronomy lab lesson is available to every student throughout the semester online for them to read and study at their convenience. When the students come to class, they work in groups of three and take a quiz, specifically "synchronized" with a descriptive explanatory tutorial, as a group. Each individual in the group receives a grade for that lab based on the performance of the group on the quiz.

Batuski and Traxler also developed a series of mini-quizzes that are taken by the students on their own before coming to class, available on the internet to be taken at their convenience. The mini-quizzes contain questions relating to each upcoming lab. Some of these questions are also of pretest and post-test nature. In other words, each mini-quiz contains some questions that have the ability to inventory student conceptions before the upcoming and after an earlier instruction unit. This particular aspect of the course design looked attractive as a way of evaluating the effectiveness of the instruction, along with scores from the group quizzes taken in the lab.

The 12 units of instruction used in the lab are as follows, Lesson 1: An Introduction to using the astronomical telescope

Lesson 2: The Planisphere

Lesson 3: Surface features of the Moon

Lesson 4: The Skygazer=s Almanac

Lesson 5: Motions of the Spheres

Lesson 6: Phases and Eclipses of the Moon

Lesson 7: The Equatorial Coordinate System

Lesson 8: Time and the Celestial Sphere

Lesson 9: Orbit of Mercury and Kepler=s laws

Lesson 10: Stars and Stellar Distances

Lesson 11: Stars and Stellar Spectra

Lesson 12: Galaxies

Of the 12 units, we chose ALesson 6: Phases and Eclipses of the Moon@ to start the process. This particular lesson was picked primarily for a couple of reasons. First, there is a fair amount of research available on student ideas about the phases of the Moon, so we hoped to utilize this information in forming the analysis. Second, in preliminary experimentation with the questions used in the mini-quizzes for a few of the lessons, it was found that a large percentage of students have well-established alternative ideas (misconceptions) about what causes the lunar phases. Since our ultimate goal is to help students incorporate accepted scientific thought into their ideas about nature, we felt that this was an area that needed attention.

We utilized the existing structure of AST 110 as much as possible so as to not conflict with the format of the other lesson units. Before a particular lab meeting, the students take a pretest through the WebCT online course tool as mentioned earlier. This pretest consists of ten multiple choice questions: three questions are referenced directly to the lesson introduction that the students can read at anytime (along with the complete lesson tutorial), four questions are of pretest nature, and three questions are post-test questions relating to the previous week's lesson. These mini-quizzes are set up to be completed before any student attends the actual lab meeting. Students who take the pretests after their lab meeting do not receive any credit for them.

In the astronomy lab are eight computer terminals with Internet access along with four large laboratory work tables/benches. When students attend each lab, they form into groups of a maximum of three students at the start of the lesson and continue to work together throughout the session. A TA provides minimal instruction and primarily is there to make sure the computer terminals and experimental equipment function properly. The tutorial or lesson instruction is available on any of eight computer terminals along with the accompanying quiz. Experimental equipment, such as telescopes or the Sun/Earth/Moon model, are set up for students to use. The quiz questions are only available to the students in the actual lab meeting and are completed by them in groups of a maximum of three individuals. Each group completes one quiz and members of the group share the score they receive for that quiz. Following the lab, and once all lab sections have met and completed the lesson, the mini-quiz for the next lesson in the course sequence becomes available online to the students. As indicated earlier, this mini-quiz contains three questions that were in the last mini-quiz, but now they have become of post-test nature.

For the *Phases and Eclipses of the Moon* lab, each work table has a four-foot-long optical bench set up. Each optical bench has a bright extended light source (a lamp holder with a 50-watt indoor flood lamp) at one end. In the middle of the bench is an Earth/Moon model consisting of a rotating center shaft with an angled end attached to which is a 2 inch rotatable Styrofoam**7** ball. Attached to this Earth representation is a wire arm with a smaller Styrofoam**7** ball at its end, representing the moon. The wire arm assembly can revolve around the Earth model (See Figure 3). In addition, there is provided a metal slide that has a small hole in its center. This slide can be placed in front of the lamp to simulate a point source of light. There is also a screen on a shaft which can be used to observe shadows created by the model when configured according to tutorial instructions.

The entire setup presents the students with several variables: the distance between the Sun model and the Earth/Moon model can be changed, the Earth model's axis of inclination in relation to the Sun model can be changed by rotating the shaft the Earth model is mounted on, the Earth model can rotate, the Moon model can revolve around the Earth model. By following the tutorial, students can generate phases and eclipses and observe the physics involved to produce them in actual three dimensions.

On the following pages (Figs. 3-9) are photographs of the model used in various configurations.

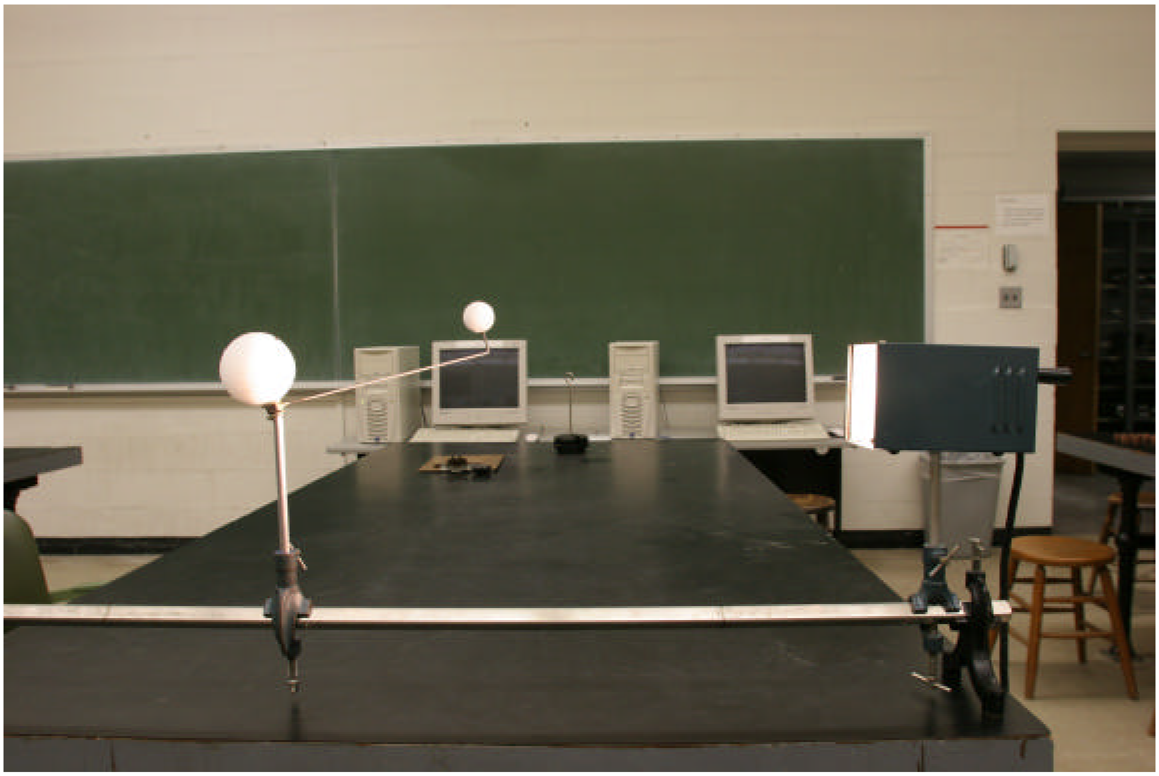


Figure 3 – Three-dimensional physical Earth/Moon model.

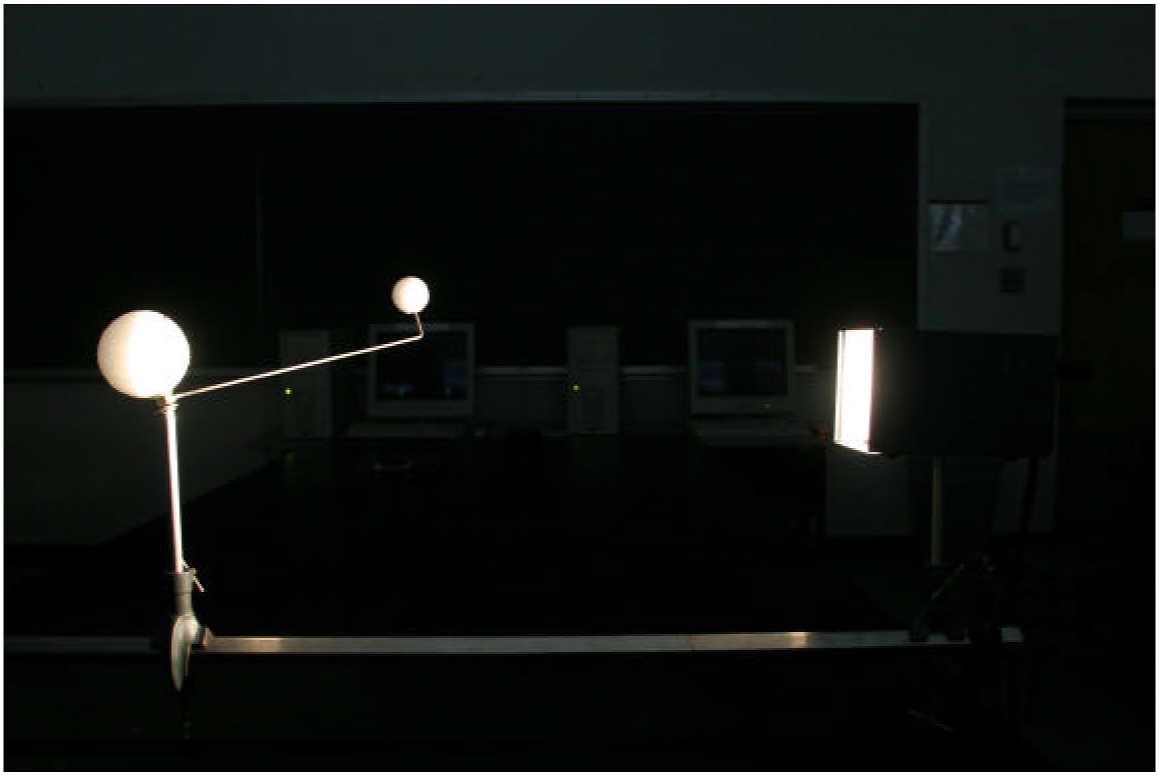


Figure 4 - Standard setup of 3D model with ambient light removed.

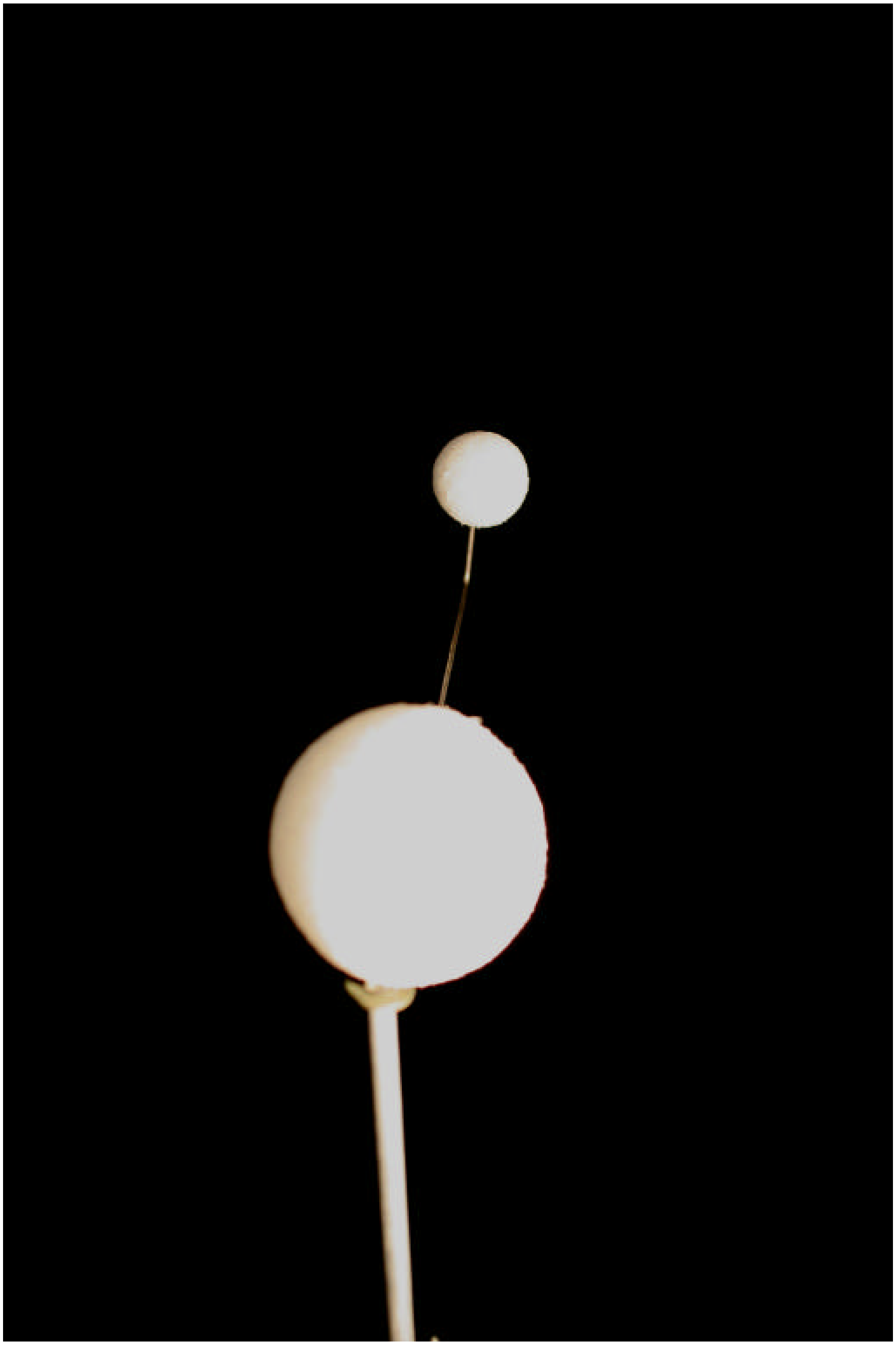


Figure 5 - Model simulating a waxing gibbous Moon.

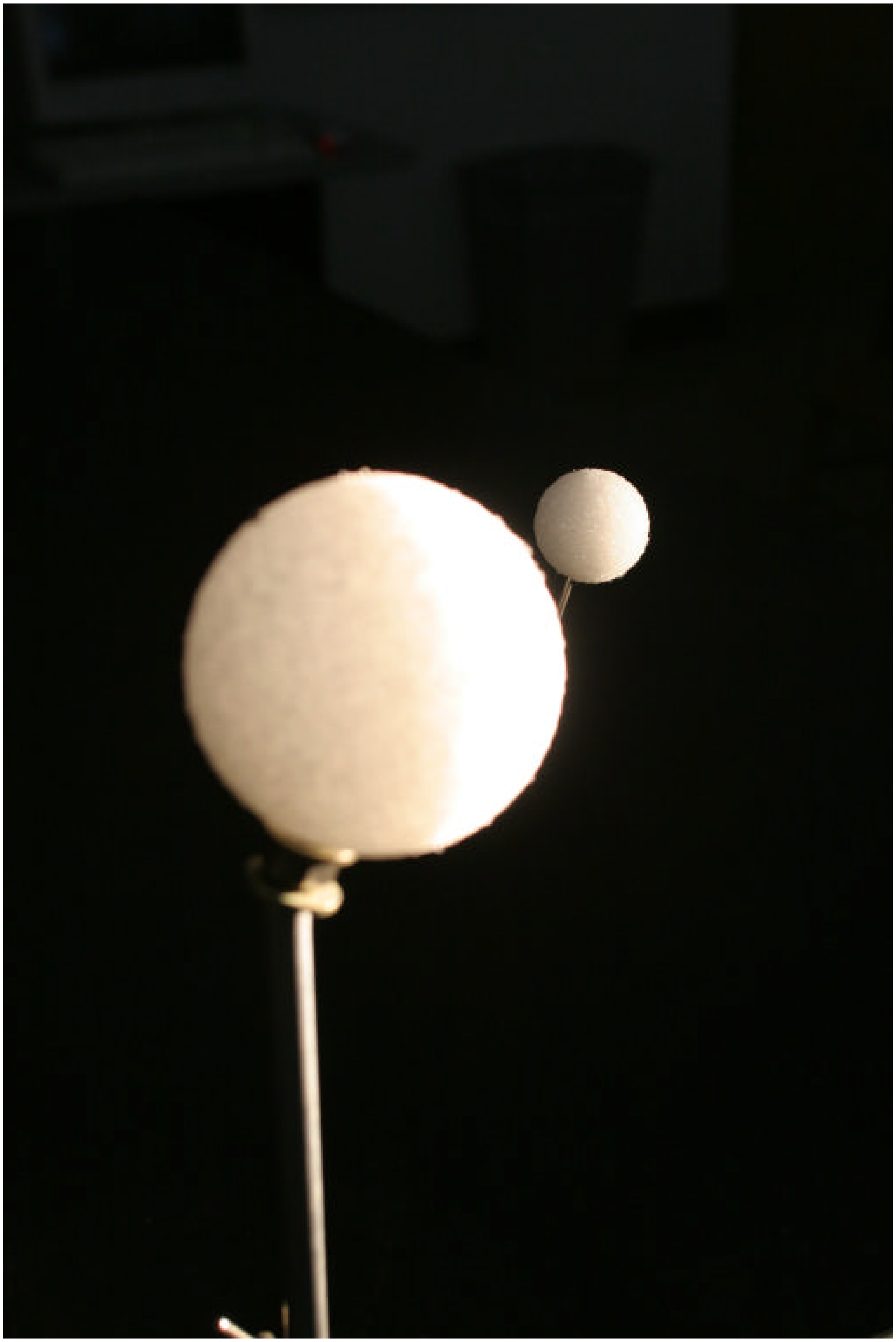


Figure 6 - Model simulating a waxing crescent Moon.

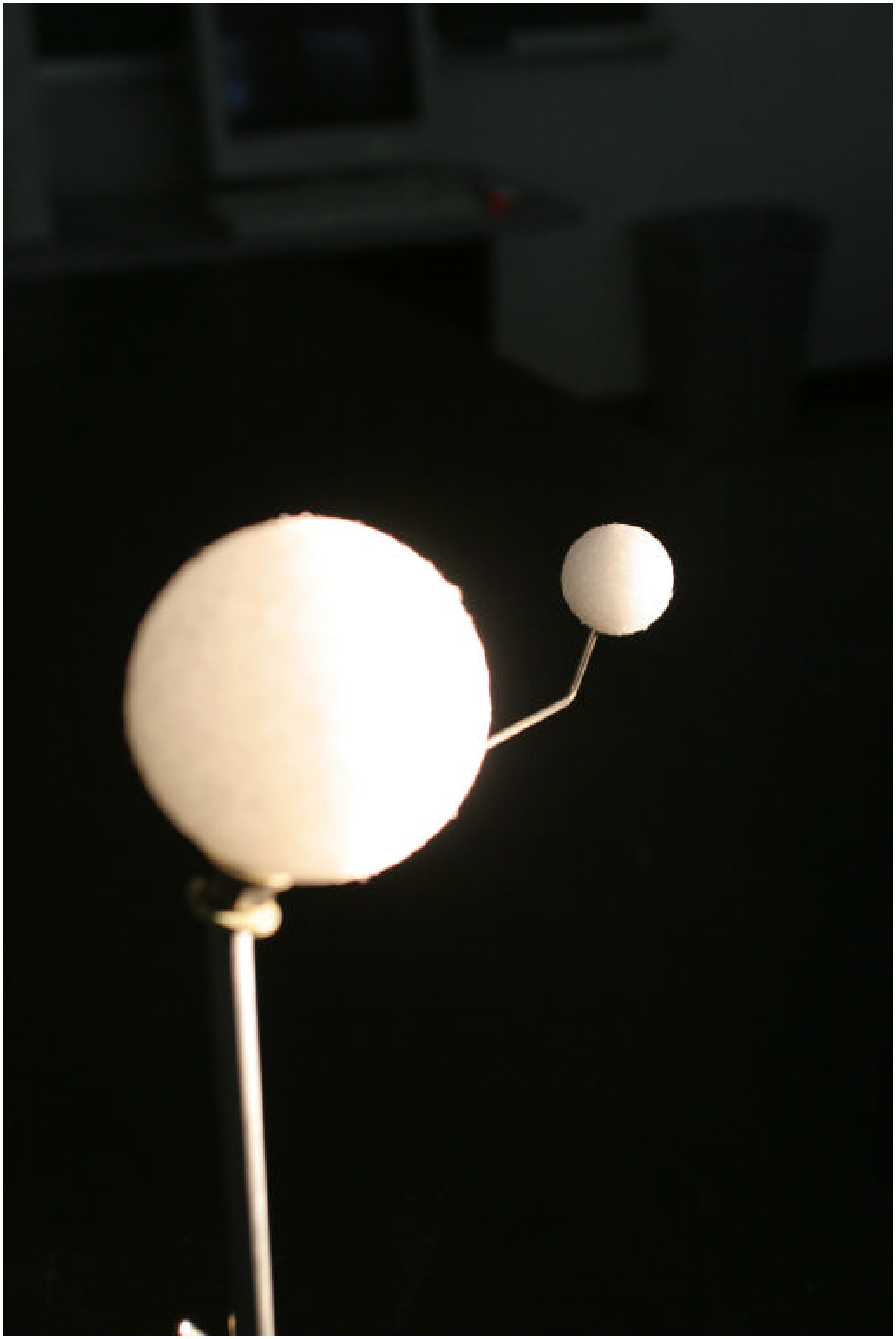


Figure 7 - Model simulating a first quarter Moon.

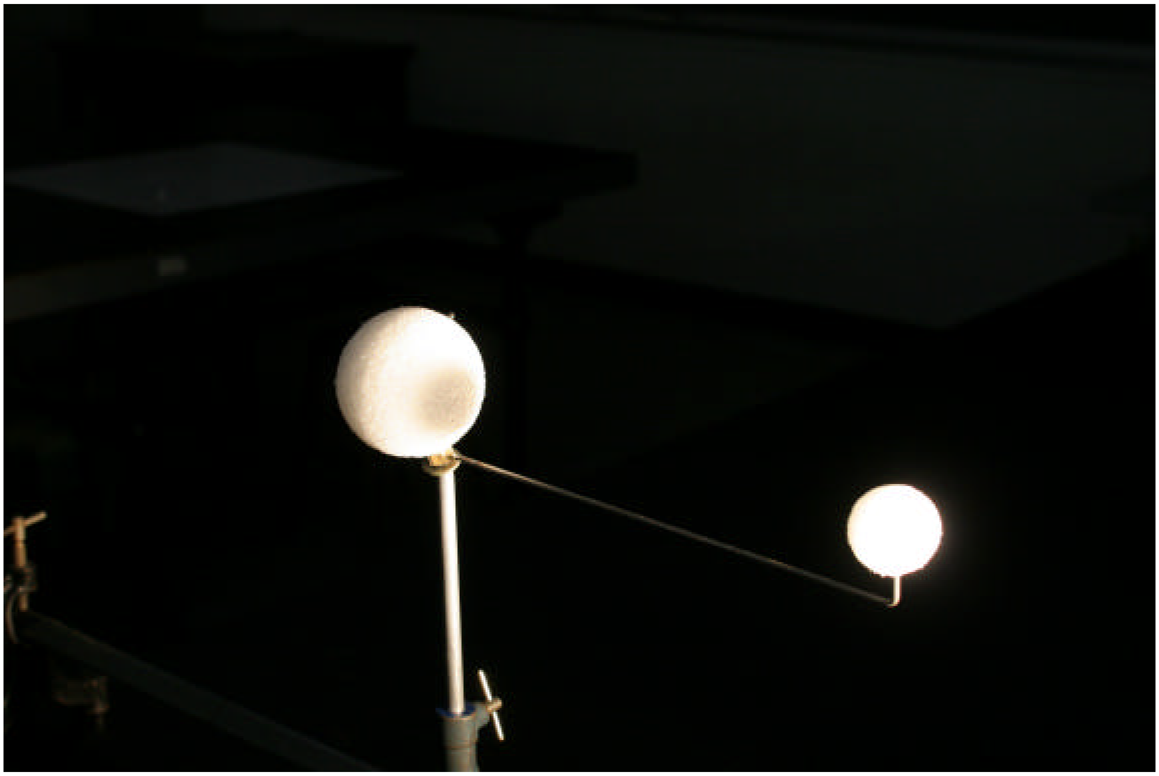


Figure 8 - Model simulating a solar eclipse.

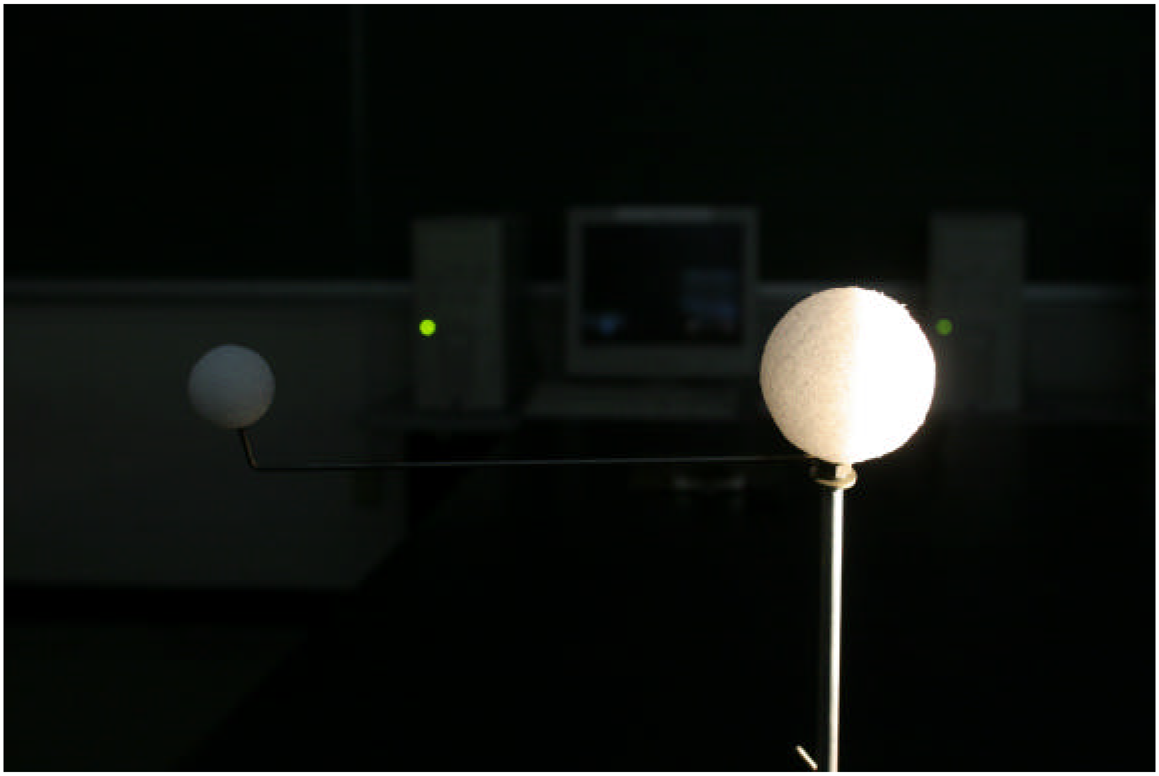


Figure 9 - Model simulating a lunar eclipse.

Prior to the fall of 2004, students did not have access to this particular model. Instead, they had a light source on the optical bench and a wooden dowel with two different sized balls attached to the ends of the stick, looking very much like a small irregular dumbbell. The instruction directed the students to move this prop around in the path of the light source to simulate phases and eclipses. Students in the spring of 2004 effectively had to build their own 3D model (See Appendix 2). The analysis of data looks into any changes in student knowledge that may be attributable to the lesson modifications, particularly the use of the new three dimensional Sun/Earth/Moon model, by looking at the pre/post test results and any changes in percentage of correct answers on the quizzes between semesters.

3.2 Pretest Design

As introduced earlier, the original format of all pretests for AST 110 follow a ten-question test design of multiple-choice or single-answer genre questions. Typically, three questions relate to the introductory tutorial information, four questions are of pretest nature and three questions are post test questions for the previous lesson. Each question counts one point for a total of ten points. All of the pretests count for 10% of a student's final grade in the course. The questions specific to the introductory material have one right answer. The pre/post-test questions have one obviously wrong answer. We inform the students that we grade the pretests this way because we want to know whether or not the introductory material was read before the pretest is taken. We also want to know how the students think about particular aspects of each lesson. For these pre/post test questions, we are looking for an honest answer rather than a correct one. The one wrong answer is usually made blatantly obvious by its absurdity. We believe that students will be more apt to answer honestly and not try to look up answers before they take the quiz with this format. Incidentally, the questions that require one right answer are straightforward and the material that contains the necessary information to answer correctly is easily accessible during the quiz. Statistically, the amount of time students take on the pretests is very low, usually averaging less than 10 minutes. For the Moon phases lesson, we chose to inventory four of the more common ideas about what causes the phases. In addition, we chose to inventory students’ ideas about when one can see the moon and whether or not the phases have anything to do with the times of day or night that the moon is visible.

3.3 Pretest Questions

The first pretest-style question students are asked is as follows,

Question 4 (1 point)
I__________ notice that the Moon appears in different shapes at different times.

a. Often
b. Sometimes
c. Rarely
d. Never
e. I have never seen the moon.

The last answer both sensibly (and grammatically) is incorrect. This is the only answer that the students can choose and not receive a point. The purpose of this inventory question is to see if factors that may limit a student’s observation of the Moon have any effect on the students’ ideas about the phases.

The next question used for the research requires the students to choose when the best time is to see the moon.

Question 5 (1 point)

The Moon is most likely to be high in the sky at_________.

a. 6:00 AM
b. 6:00 PM
c. the North Pole
d. midnight
e. noon
f. anytime day or night

In this question, the wrong answer is Ac.@ Here, we are trying to inventory the conception that the Sun is up during the day and the Moon is up at night.

The specific phase question that we ask of the students is worded as follows.

Question 6 (1 point)
The Moon’s different shapes at different times are caused by

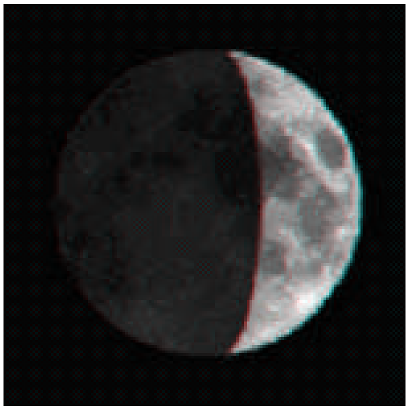
a. clouds blocking our view of the entire Moon.
b. the Moon deflating and then inflating again.
c. Earth’s shadow falling on the Moon.
d. the fraction of the Moon that is lit by the Sun.
e. the position of the Moon in its orbit around Earth.
f. Earth’s gravity pulling the moon into different shapes.

The answer that scores no points is Ab.@ It should be noted that the post test version of this question was worded, AThe phases of the Moon are caused by...@ The choices are identical. (See Appendices). There are several ideas about the Moon=s phases that we inventory here. The most prevalent misconception has to do with earth=s shadow. In general, we follow Baxter with his notions (see Baxter, page 6). Answer Aa@ parallels Baxter=s Notion 1. Answer Ac@ follows Baxter=s Notion 4 and Answer Ad@ follows Baxter=s Notion 5 to some extent. Notion 5 says the Aphases of Moon explained in terms of portion of illuminated side of the moon visible from Earth (Baxter, 509). A similar explanation might be the way one student answered the question in the summer 2004 course when given the questions in printed form. This student rewrote answer "d" before they chose it as "the portion of the Moon that is lit by the Sun *that we see*." As this student noticed, we worded answer "d" so that scientifically it is an incomplete (it is interesting that a student would rewrite an answer so that they can choose it). Answer "e" is the response we considered to be correct for this particular question, but "d" has correct aspects to it, especially if other students understand it to mean what the student mentioned above student wrote. We will be looking at both "d" and "e" as potentially correct responses in the analysis section.

It's worthy to point out that answer "f" might be considered correct also, but these changes are not observable with the naked eye nor has any real shape change been measured to date. Scientists believe that the Earth, because of tidal effects, causes seismological activity on the Moon resulting in Moon quakes. These quakes were detected during the Apollo missions.

The third question used in the concept inventory involved relating a particular phase to rise and set times and was worded as follows.

Question 7 (1 point)
A moon in the phase shown below would_________.



a. set before sunset
b. rise after sunset
c. neither rise nor set
d. set after sunset
e. rise at sunset

With this question, we hoped to determine if students make a connection to Moon phases and times that the Moon is visible. Here, the correct response is “d” and the unscientific conception we are looking for would be the idea that the Moon is only up at night. Students possessing that concept would most likely choose answer “b” or possibly “e”.

CHAPTER 4

RESULTS

We will be looking at the results of this study over the next three chapters. This chapter consists of the actual data obtained over the period of study and is present in tables and graphs. In Chapter 5, we analyze these results with some statistical tools to determine whether or not there are any statistically significant differences between semesters in the way the survey questions were answered and whether or not there was any changes from before instruction to after instruction. In Chapter 6, we will discuss the results and analysis and how they affect the hypotheses of this study. We present the results as tables and, in some cases, graphs. In each table, the correct response to each question, if there is one correct response, is highlighted in italics (for Question 6, where there are arguably three correct answers, "d", "e" and "f", we have italicized the correct answer we were looking for, "e"). In each table, the common misconception we expected to find is underlined.

4.1 Part One - Question results for three semesters

4.1.1 Results for Question 4

Results for Question 4 were obtained for the spring and fall 2004 semesters. Data was not obtained for the spring 2005 semester because it was felt that they would be very similar to data obtained and would not enhance the research. Results show a large majority of the students observe the Moon on a regular basis. Question 4 was presented as follows in the pretest.

Question 4 (1 point)

I__________ notice that the Moon appears in different shapes at different times.

a. Often
b. Sometimes
c. Rarely
d. Never
e. I have never seen the moon.

Table 1 lists the answer distribution for Question 4 during the spring and fall 2004 semesters.

Table 1 - Results for Question 4, spring and fall 2004.

Question 4	**a**	**b**	**c**	**d**	**e**	**Total**
						N =
Frequency						
Spring 04	113	25	5			143
Fall 04	107	30	3	1	1	142
Percent						**%**
Spring 04	79.0	17.5	3.5	0.0	0.0	100
Fall 04	75.4	21.1	2.1	0.7	0.7	100

Results for Question 4 are represented graphically in Figure 10.

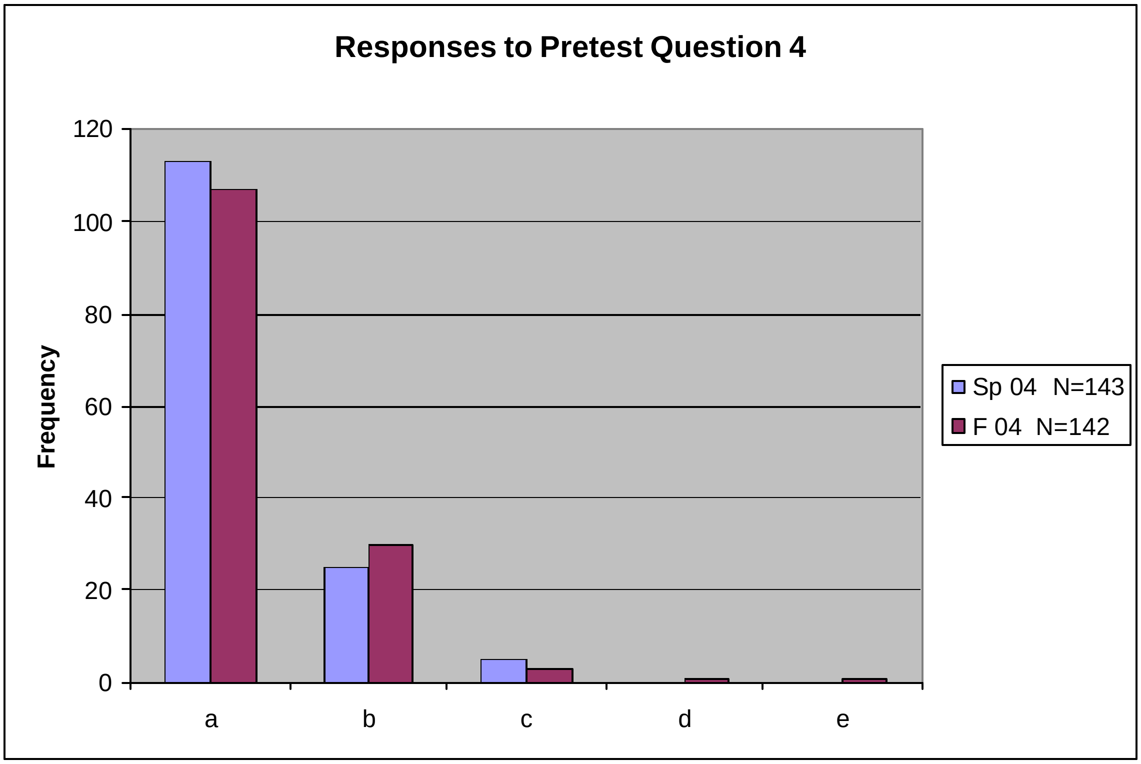


Figure 10 – Question 4 pretest results graph.

4.1.2 Results for Question 5

Question 5 was worded on the pretest as follows.

Question 5 (1 point)

The Moon is most likely to be high in the sky at_________.

a. 6:00 AM
b. 6:00 PM
c. the North Pole
d. Midnight
e. noon
f. anytime day or night

Table 2 shows the frequency of responses for each answer for all of the semesters in the study and the total of all responses.

Table 2 – Results for Question 5.

Question 5	**a**	**b**	**c**	**d**	**e**	***f***	**Unanswered**	**Total**
				_				***N =***
Frequency				_				
Spring 04	1	5	1	59	13	*63*	1	143
Fall 04	2	4	3	72	7	*54*	0	142
Spring 05	3	7	3	59	5	*76*		153
Spr Online 05	1	2	2	16	6	*16*		43
Total	7	18	9	206	31	*209*	1	481
Percent								
Spring 04	0.7	3.5	0.7	41.3	9.1	*44.1*	0.7	100
Fall 04	1.4	2.8	2.1	50.7	4.9	*38.0*	0.0	100
Spring 05	2.0	4.6	2.0	38.6	3.3	*49.7*	0.0	100
Spr Online 05	2.3	4.7	4.7	37.2	14.0	*37.2*	0.0	100
Total	1.5	3.7	1.9	42.8	6.4	*43.5*	0.2	100

Results for Question 5 are represented graphically in Figure 11.

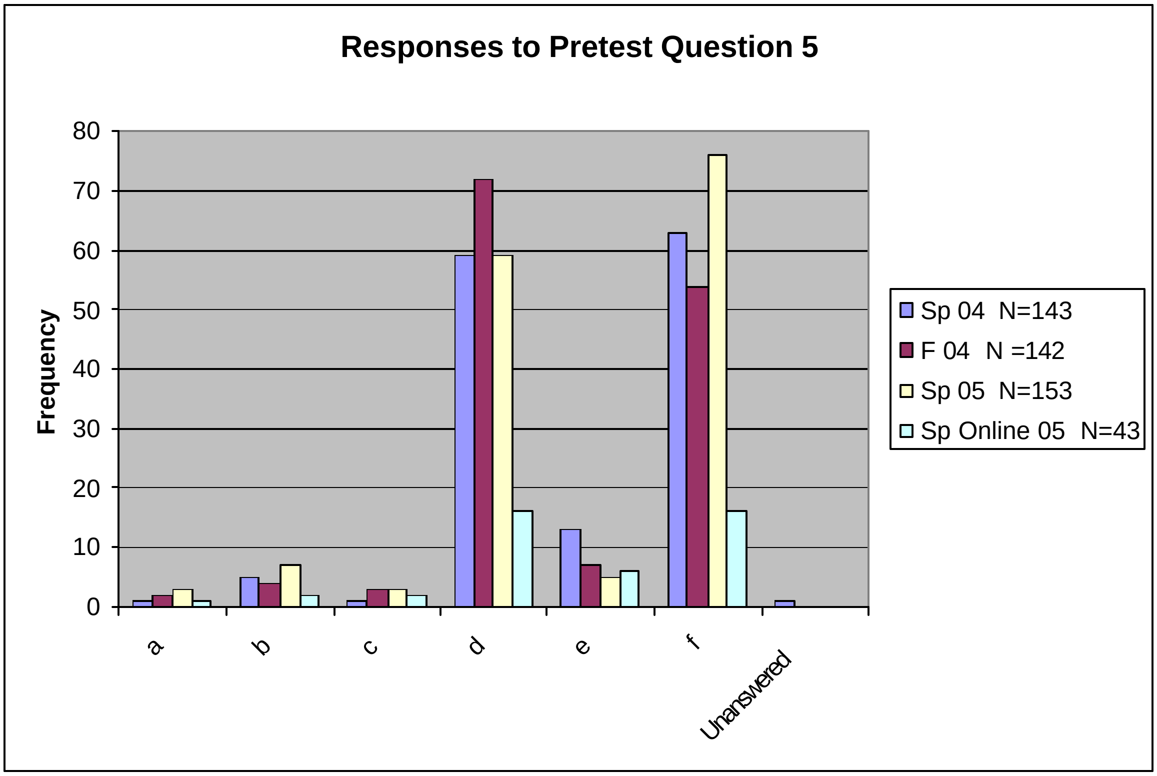


Figure 11 – Question 5 pretest results graph.

4.1.3 Results for Question 6

Question 6 was worded on the pretest as follows.

Question 6 (1 point)
The Moon's different shapes at different times are caused by

a. clouds blocking our view of the entire Moon.
b. the Moon deflating and then inflating again.
c. Earth's shadow falling on the Moon.
d. the fraction of the Moon that is lit by the Sun.
e. the position of the Moon in its orbit around Earth.
f. Earth's gravity pulling the moon into different shapes.

Table 3 lists the answer distribution for Question 6 for all the semesters in the study.

Table 3 - Results for Question 6.

Question 6	**a**	**b**	**c**	**d**	***e***	**f**	**Total**
							N =
Frequency							
Spring 04	0	1	45	56	*41*	0	143
Fall 04	0	0	35	56	*49*	2	142
Spring 05	1	0	31	75	*45*	1	153
Spr Online 05	1	1	11	17	*13*	0	43
Total	2	2	122	204	*148*	3	481
Percent							
Spring 04	0.0	0.7	31.5	39.2	*28.7*	0.0	100
Fall 04	0.0	0.0	24.6	39.4	*34.5*	1.4	100
Spring 05	0.7	0.0	20.3	49.0	*29.4*	0.7	100
Spr Online 05	2.3	2.3	25.6	39.5	*30.2*	0.0	100
Total	0.4	0.4	25.4	42.4	*30.8*	0.6	100

Figure 12 shows the results of Question graphically.

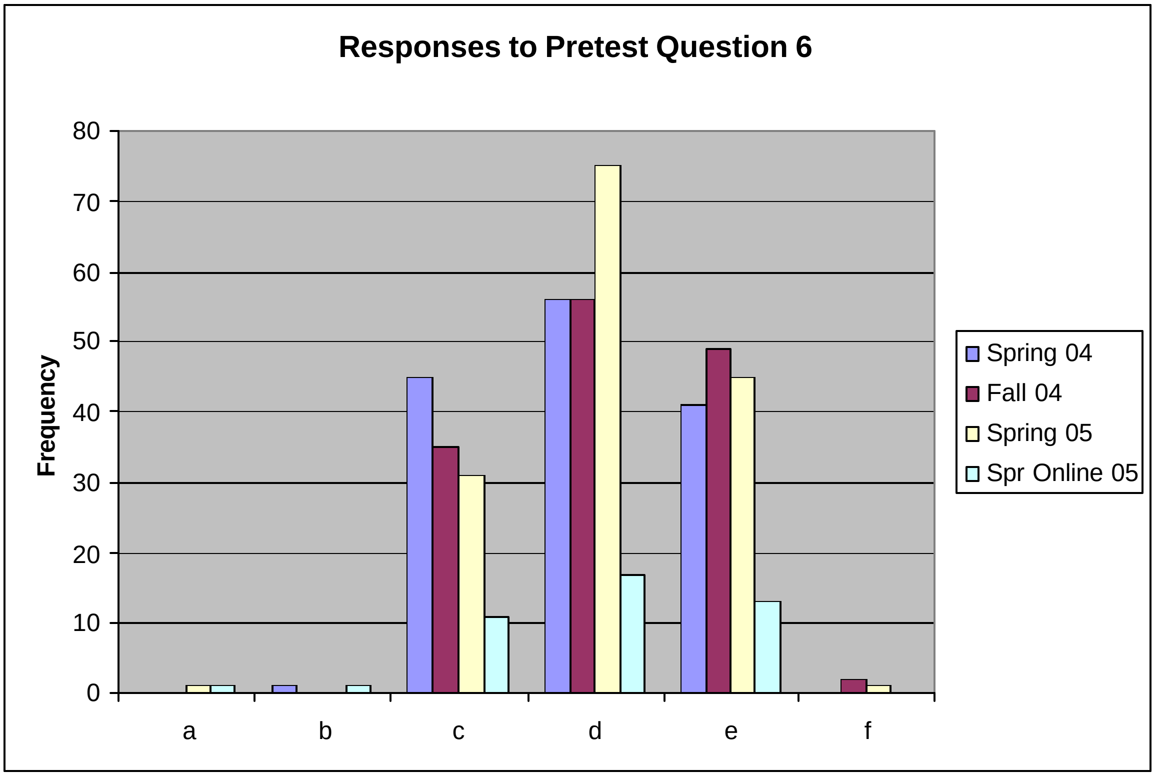
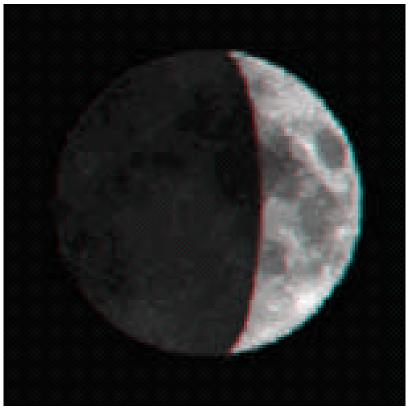


Figure 12 – Question 6 pretest results graph.

4.1.4 Results for Question 7

Question 7 was worded on the pretest as follows.

Question 7 (1 point)
A moon in the phase shown below would_________.



a. set before sunset
b. rise after sunset
c. neither rise nor set
d. set after sunset
e. rise at sunset

Table 4 shows the answer distribution for all semesters in the study.

Table 4 – Results for Question 7

Question 7	**a**	**b**	**c**	***d***	**e**	**Total**
						***N*=**
Frequency						
Spring 04	14	52	12	*50*	15	143
Fall 04	19	42	24	*27*	30	142
Spring 05	30	43	13	*53*	14	153
Spr Online 05	5	12	7	*12*	7	43
Total	68	149	56	*142*	66	481
Percent						
Spring 04	9.8	36.4	8.4	*35.0*	10.5	100
Fall 04	13.4	29.6	16.9	*19.0*	21.1	100
Spring 05	19.6	28.1	8.5	*34.6*	9.2	100
Spr Online 05	11.6	27.9	16.3	*27.9*	16.3	100
Total	14.1	31.0	11.6	*29.5*	13.7	100

Results for Question 7 are illustrated in Figure 13.

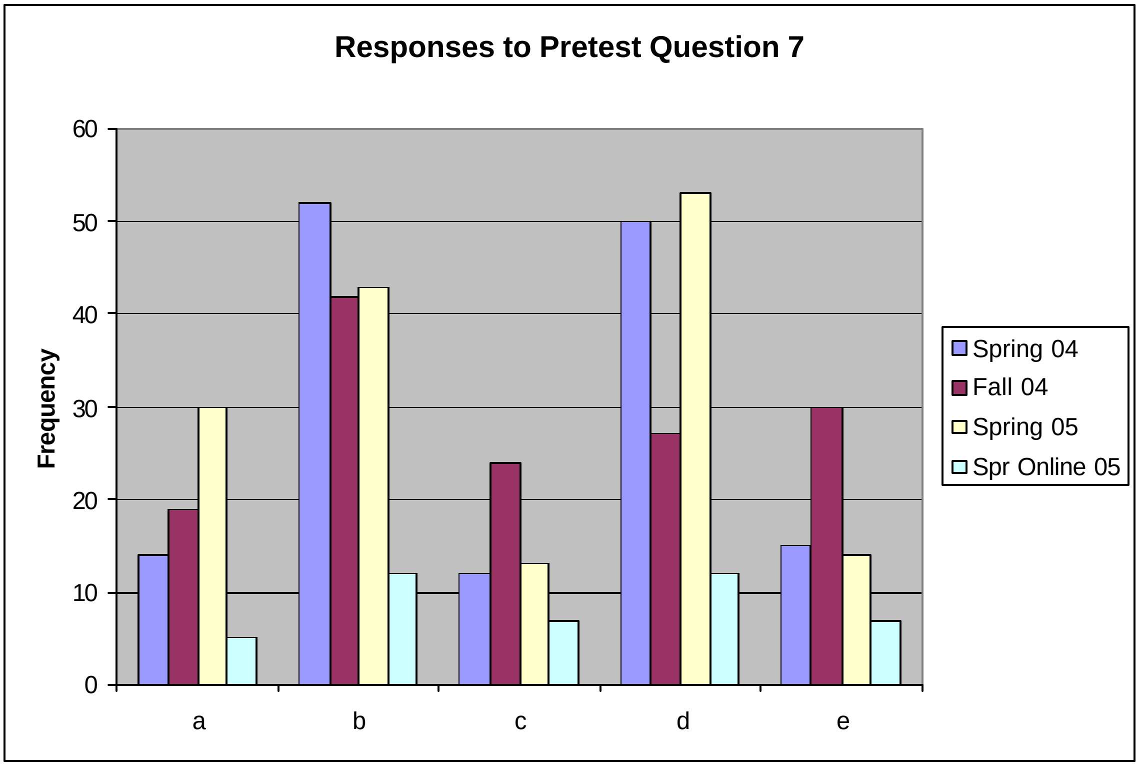


Figure 13 – Question 7 pretest results graph.

4.1.5 Correlation of Questions 5, 6 & 7 answer frequency

In this section we look at how certain answers to Question 6 correlate to responses for Questions 5 and 7. We are looking primarily to see if ideas about the Moon are consistent. Our hypothesis is that students who believe the phases are caused by Earth's shadow are more likely to believe that the Moon is up only at night and that students who have correct ideas about the cause of the Moon's phases are more apt to understand the relationship of phase to rise and set times. Because our hypothesis hinges on phase concepts, we are only looking at the relationship of the other two questions to Question 6. We have sorted students for how they answered Question 6 in to the following groups: students who chose the idea that the Moon's phases are caused by Earth's shadow (Question 6, answer "c"), students who chose that the phases are caused by the fraction lit (Question 6, answer "d") and students who chose that the phases are caused by the orbit of the Moon around the Earth (Question 6, answer "e"). We did not look at the tiny number of students who chose answers other than "c," "d," and "e."

The results for students who chose Question 6, answer "c" (Earth's shadow causes the phases) are listed in Table 5.

Table 5 - Questions 5 and 7 from students who chose Question 6, answer "c."

Question 5	**a**	**b**	**C**	**d**	**e**	***f***	**Total**
							***N* =**
Frequency	0	8	1	63	8	*42*	122
Percent	0.0	6.6	0.8	51.6	6.6	*34.4*	100

Question 7	**a**	**b**	**c**	***d***	**e**	**Total**
						***N* =**
Frequency	14	44	16	*31*	17	122
Percent	11.5	36.1	13.1	*25.4*	13.9	100

The results for students who chose Question 6, answer "d" (phases cause by fraction of the Moon lit) are in Table 6.

Table 6 - 5 and 7 from students who chose Question 6, answer "d."

Question 5	**a**	**b**	**c**	**d**	**e**	***f***	**Unans**	**Total**
								N =
Frequency	5	4	4	73	11	*106*	1	204
Percent	2.5	2.0	2.0	35.8	5.4	*52.0*	0.5	100.0

Question 7	**a**	**b**	**c**	***d***	**e**	**Total**
						N =
Frequency	32	64	22	*62*	24	204
Percent	15.7	31.4	10.8	*30.4*	11.8	100

The results for students who chose Question 6, answer “e” (phases caused by position of the Moon) are shown in Table 7.

Table 7 - Questions 5 and 7 from students who chose Question 6, answer "e."

Question 5	**a**	**b**	**c**	**d**	**e**	***f***	**Total**
							N =
Frequency	2	5	2	67	12	*60*	148
Percent	1.4	3.4	1.4	45.3	8.1	*40.5*	100.0

Question 7	**a**	**b**	**c**	***d***	**e**	**Total**
						N =
Frequency	20	39	16	*48*	25	148
Percent	13.5	26.4	10.8	*32.4*	16.9	100

4.2 Part Two – Lesson modifications and use of 3D model

In this section of the results, we looked at both pre- and post-lesson answers for the same survey questions used in Part One. We also tracked student concepts by looking at answer choice trends for the three survey questions present in both the pretest and the post test. Finally, we compared frequency of correct responses on quiz questions common to both lessons for the spring and fall 2004 semesters. The spring 2004 semester represents the control data and the fall 2004, the semester where the 3D model was implemented, is the experimental data.

4.2.1 Question 5 pre- and post-lesson results

Table 8 lists the results for the responses to Question 5 for the spring 2004 (control) semester. Of the 143 students who took the pretest, only 119 did the quiz and the post test. This is reflected in the change in *N*. The value for *N* is additionally reduced by one to take into account for a single student who answered all questions on pretest, post test and quiz except for Question 5 on the pretest. This person's data, therefore, has been removed for this one question. Figure 14 shows a graphic representation of the data.

Table 8 - Pre and post lesson results for Question 5 – Spring 2004.

	a	b	c	d	e	*f*	Totals
Frequency							***N =***
Pre lesson	1	3	1	51	10	*52*	118
Post lesson	2	4	2	44	7	*59*	118
Percent							
Pre lesson	0.8	2.5	0.8	43.2	8.5	*44.1*	100
Post lesson	1.7	3.4	1.7	37.3	5.9	*50.0*	100

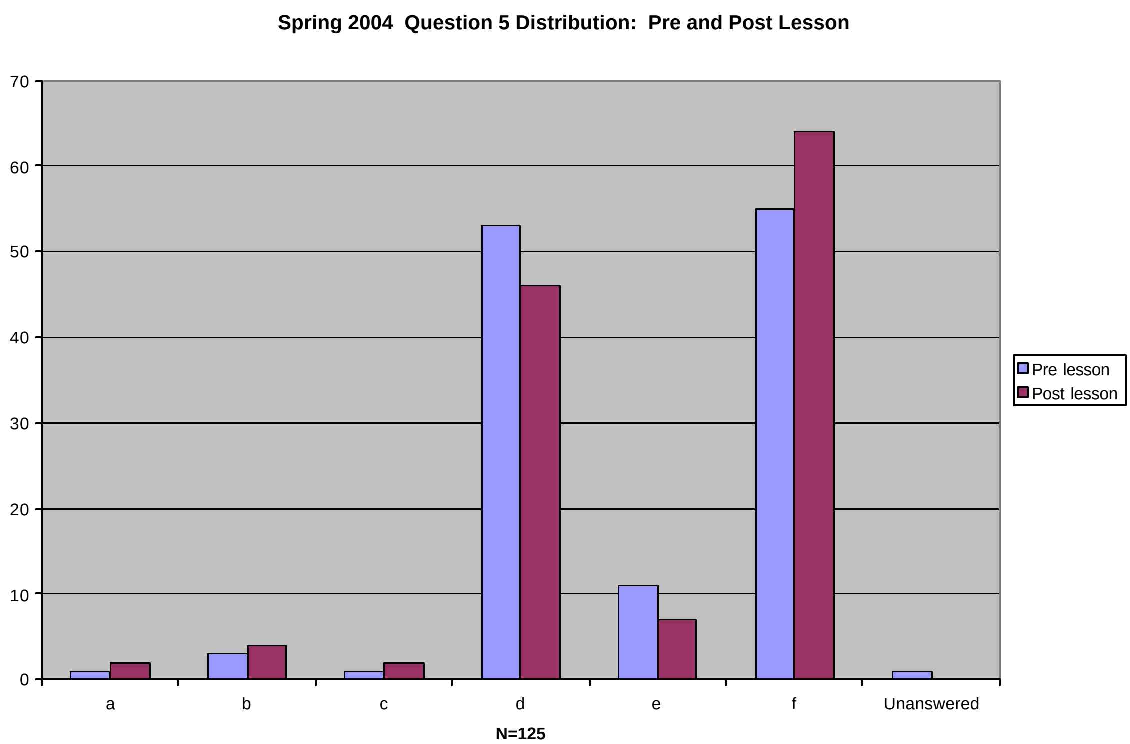


Figure 14 – Question 5, pre and post lesson - Spring 2004.

Table 9 lists the results for Question 5 in the fall 2004 (experimental) semester. Of the 142 students who took the pretest, only 87 took the quiz and the post test. Figure 15 graphs the data for Question 5.

Table 9 - Pre and post lesson results for Question 5 – Fall 2004.

	a	b	c	d	e	*f*	Totals
Frequency							***N =***
Pre lesson	0	4	2	45	3	*33*	87
Post lesson	2	3	0	41	4	*37*	87
Percent							
Pre lesson	0.0	4.6	2.3	51.7	3.4	*37.9*	100
Post lesson	2.3	3.4	0.0	47.1	4.6	*42.5*	100

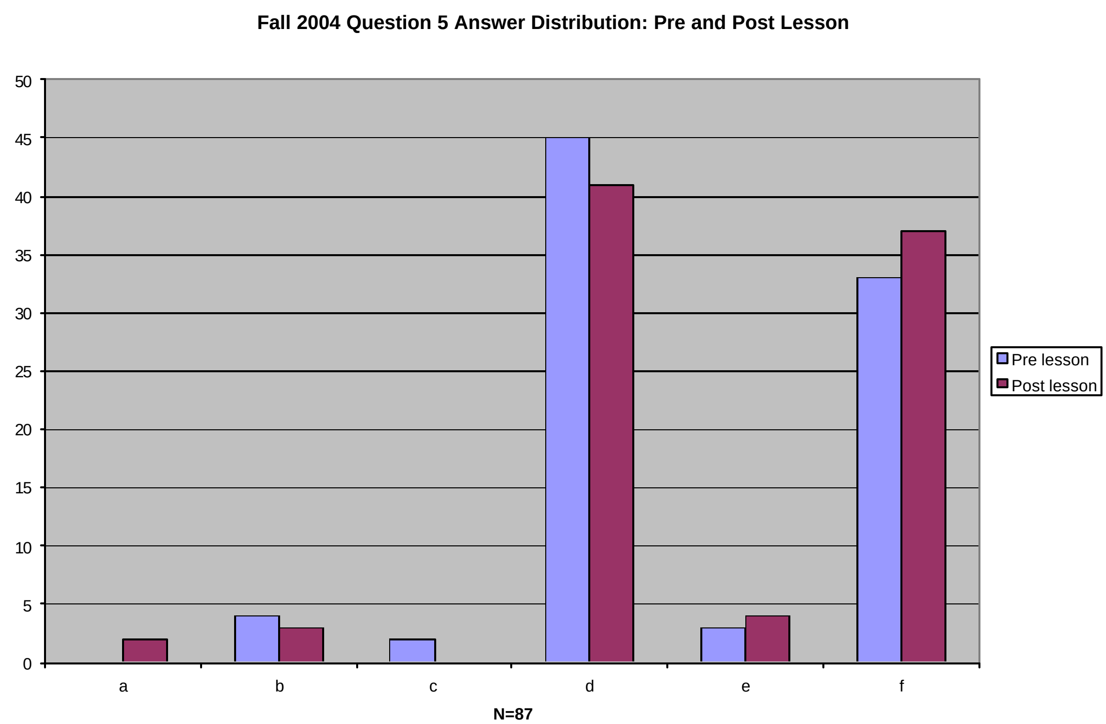


Figure 15 – Question 5, pre and post lesson - Fall 2004.

4.2.2 Question 6 pre and post lesson results

It is important to clarify how Question 6 wording changed from pretest to post test for the fall semester only. In the spring 2004 semester the question was worded identically for both the pre and post test as,

Question 6 (1 point)
The Moon's different shapes at different times are caused by

a. clouds blocking our view of the entire Moon.
b. the Moon deflating and then inflating again.
c. Earth's shadow falling on the Moon.
d. the fraction of the Moon that is lit by the Sun.
e. the position of the Moon in its orbit around Earth.
f. Earth's gravity pulling the moon into different shapes.

For the fall 2004 semester, the pretest wording was as follows.

Question 6 (1 point)
The Moon's different shapes at different times are caused by

a. clouds blocking our view of the entire Moon.
b. the Moon deflating and then inflating again.
c. Earth's shadow falling on the Moon.
d. the fraction of the Moon that is lit by the Sun.
e. the position of the Moon in its orbit around Earth.
f. Earth's gravity pulling the moon into different shapes.

The post test question was worded this way.

Question 6 (1 point)
The phases of the Moon are caused by

a. clouds blocking our view of the entire Moon.
b. the Moon deflating and then inflating again.
c. Earth's shadow falling on the Moon.
d. the fraction of the Moon that is lit by the Sun.
e. the position of the Moon in its orbit around Earth.
f. Earth's gravity pulling the moon into different shapes.

Table 10 shows the results for Question 6 in the spring 2004 semester. Figure 16 represents that data graphically.

Table 10 - Pre and post lesson results for Question 6 – Spring 2004.

	a	b	c	d	*e*	f	Totals
Frequency							***N =***
Pre lesson	0	1	34	49	*35*		119
Post lesson	1	0	37	43	*37*	1	119
Percent							
Pre lesson	0.0	0.8	28.6	41.2	*29.4*	0.0	100
Post lesson	0.8	0.0	31.1	36.1	*31.1*	0.8	100

Figure 16 – Question 6, pre and post lesson - Spring 2004.

Table 11 shows the results for Question 6 in the fall 2004 semester. Figure 17 represents that data graphically.

Table 11 - Pre and post lesson results for Question 6 – Fall 2004.

	a	**b**	**c**	**d**	***e***	**f**	**Totals**
Frequency							***N =***
Pre lesson	0	0	18	33	*35*	1	87
Post lesson	0	0	19	40	*28*	0	87
Percent							
Pre lesson	0.0	0.0	20.7	37.9	*40.2*	1.1	100
Post lesson	0.0	0.0	21.8	46.0	*32.2*	0.0	100

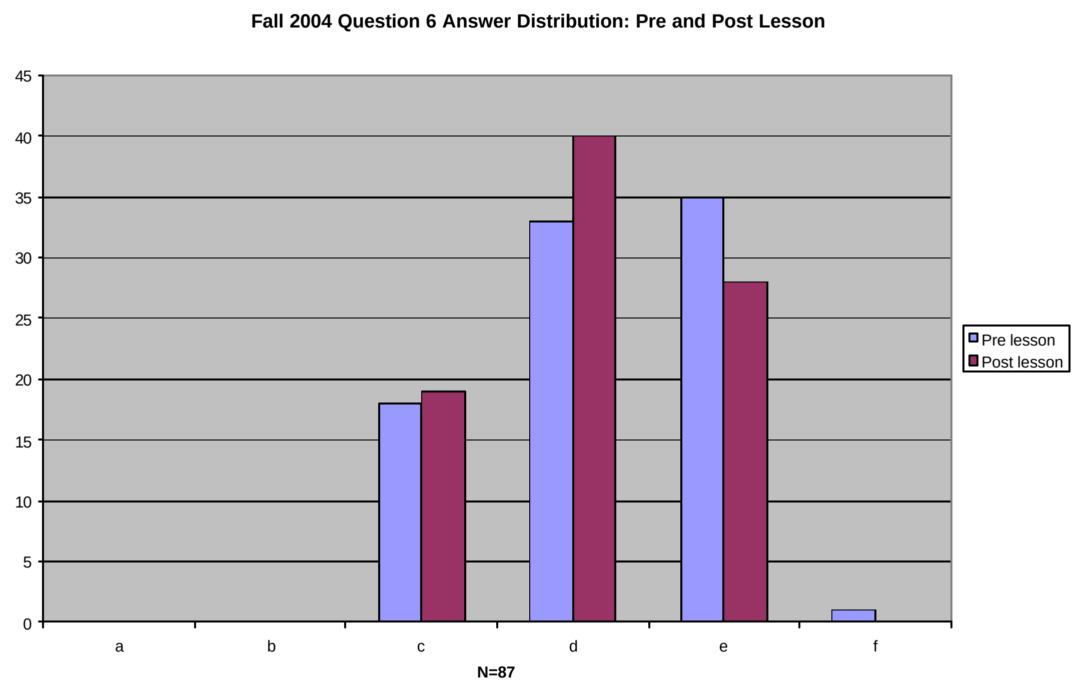


Figure 17 - Question 6, pre and post lesson - Fall 2004.

4.2.3 Question 7 pre and post lesson results

There were no wording changes to Question 7. Table 12 shows the pre and post lesson results for the spring 2004 semester and Figure 18 shows the results graphically.

Table 12 - Pre and post lesson results for Question 7 – Spring 2004.

	a	b	c	*d*	e	Totals
Frequency						***N =***
Pre lesson	12	43	11	*40*	13	119
Post lesson	15	34	6	*47*	17	119
Percent						
Pre lesson	10.1	36.1	9.2	*33.6*	10.9	100
Post lesson	12.6	28.6	5.0	*39.5*	14.3	100

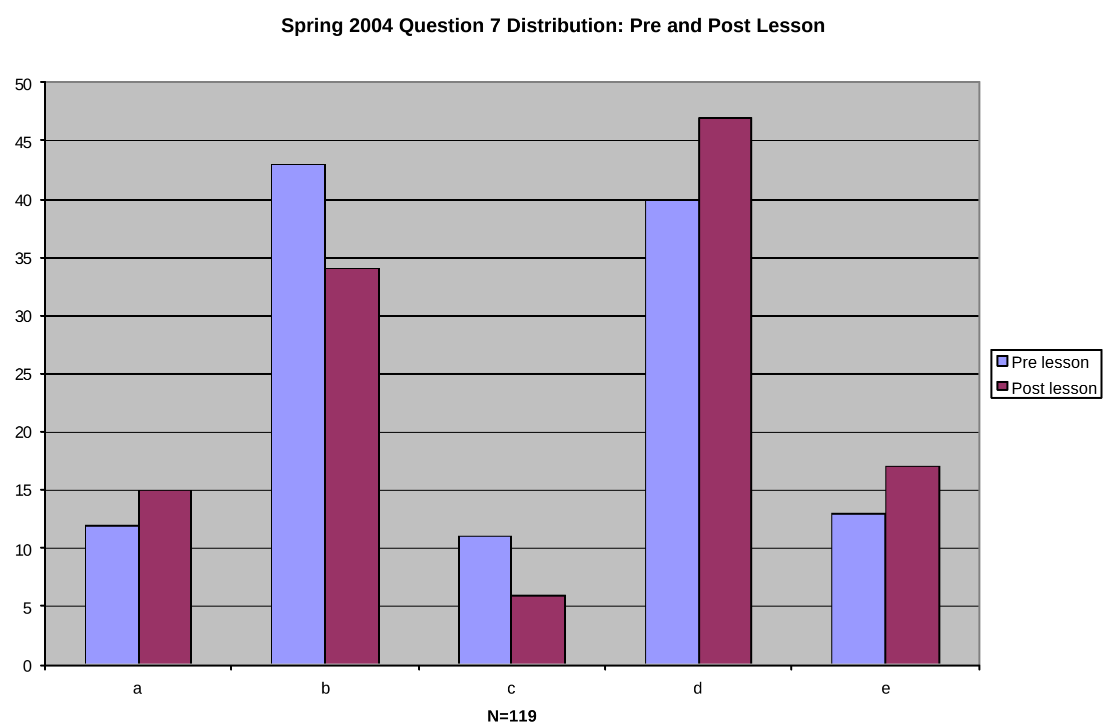


Figure 18 - Question 7, pre and post lesson - Spring 2004.

Table 13 shows the pre and post lesson results for the fall 2004 semester and Figure 19 shows the results graphically.

Table 13 - Pre and post lesson results for Question 7 – Fall 2004

	a	b	c	*d*	e	Totals
Frequency						***N =***
Pre lesson	9	30	17	*17*	14	87
Post lesson	10	33	7	*25*	12	87
Percent						
Pre lesson	10.3	34.5	19.5	*19.5*	16.1	100
Post lesson	11.5	37.9	8.0	*28.7*	13.8	100

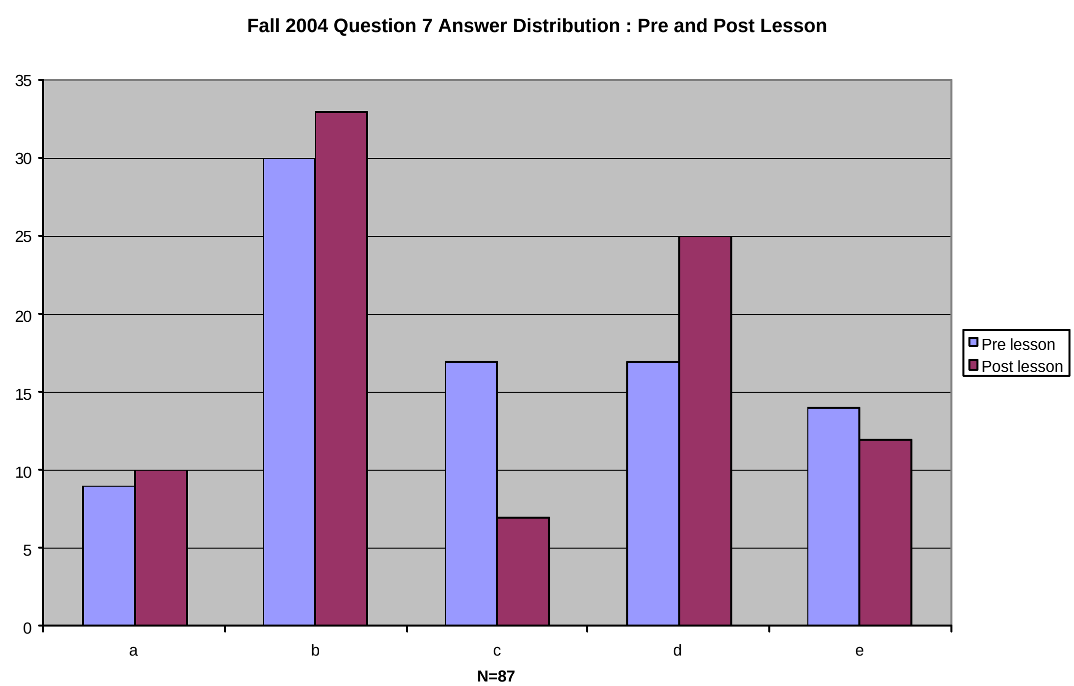


Figure 19 - Question 7, pre and post lesson - Fall 2004.

4.2.4 Question 5 concept inventory

The tables generated for this section, and the following sections for questions 6 and 7, show the frequency of answer choice combinations as a result of doing the quiz. Each answer choice combination that occurred is listed. For example, if a student chose answer “a” on the pretest and then answer “c” on the post test, that result would appear as “a-c”. If a student did not change their answers from pretest to post test, then their results would appear as “a-a”. Table 14 lists concepts for Question 5.

Table 14 - Question 5 concept inventory.

Question 5 concepts							
	Spring 2004				**Fall 2004**		
	Answer choice	**Freq.**	**% of total**		**Answer choice**	**Freq.**	**% of total**
	a-a	1	0.8		a-a		0.0
	b-a		0.0		b-a	1	1.1
	b-d	1	0.8		b-d	1	1.1
	b-e	2	1.7		b-e		0.0
	b-f		0.0		b-f	2	2.3
	c-d	1	0.8		c-d	2	2.3
	d-a		0.0		d-a	1	1.1
	d-b	2	1.7		d-b	3	3.4
Strong Midnight	d-d	30	25.2		d-d	31	35.6
	d-e	1	0.8		d-e	1	1.1
Midnight to anytime	d-f	18	15.1		d-f	9	10.3
	e-a	1	0.8		e-a		0.0
	e-c	1	0.8		e-c		0.0
	e-d	4	3.4		e-d	1	1.1
	e-e	3	2.5		e-e	2	2.3
	e-f	1	0.8		e-f		0.0
	f-b	2	1.7		f-b		0.0
	f-c	1	0.8		f-c		0.0
Anytime to Midnight	f-d	8	6.7		f-d	6	6.9
	f-e	1	0.8		f-e	1	1.1
Strong Anytime	f-f	40	33.6		f-f	26	29.9
	Unans - f	1	0.8		Unans - f		0
	Total	119			**Total**	87	

4.2.5 Question 6 concept inventory

Question 6 answer choices by students who did the quiz are listed in Table 15.

Table 15 - Question 6 concept inventory.

Question 6 Concepts							
	Sp 2004				**F 2004**		
	Answer choice	Freq.	% of total			Freq.	% of total
	b-e	1	0.8				0.0
Strong shadow	c-c	22	18.5			11	12.6
Shadow to portion lit	c-d	7	5.9			6	6.9
Shadow to position	c-e	5	4.2			1	1.1
	d-a	1	0.8				0.0
Portion lit to shadow	d-c	7	5.9			2	2.3
Strong portion lit	d-d	29	24.4			20	23.0
Portion lit to position	d-e	12	10.1			11	12.6
Position to shadow	e-c	8	6.7			6	6.9
Position to portion lit	e-d	7	5.9			14	16.1
Strong position	e-e	19	16.0			15	17.2
	e-f	1	0.8				0.0
	f-e		0.0			1	1.1
	Total	119	100.0		Total	87	100.0

4.2.6 Question 7 concept inventory

Answer choices for Question 7 by students who took both pre and post lesson tests are listed in Table 16.

Table 16 - Question 7 concept inventory

Question 7 Concepts							
	Sp 2004				**F 2004**		
	Answer choice	Freq.	% of total			Freq.	% of total
	a-a	5	4.2			3	3.4
	a-b	3	2.5				0.0
	a-c	2	1.7			1	1.1
	a-d	2	1.7			4	4.6
	a-e		0.0			1	1.1
	b-a	4	3.4			1	1.1
Strong rise after	b-b	16	13.4			18	20.7
	b-c	1	0.8			1	1.1
Rise after to set after	b-d	16	13.4			7	8.0
	b-e	6	5.0			3	3.4
	c-a	1	0.8			3	3.4
	c-b	3	2.5			4	4.6
	c-c	3	2.5			2	2.3
	c-d	2	1.7			5	5.7
	c-e	2	1.7			3	3.4
	d-a	4	3.4			3	3.4
Set after to rise after	d-b	8	6.7			6	6.9
	d-c		0.0			1	1.1
Strong set after	d-d	25	21.0			6	6.9
	d-e	3	2.5			1	1.1
	e-a	1	0.8				0.0
	e-b	4	3.4			5	5.7
	e-c		0.0			2	2.3
	e-d	2	1.7			3	3.4
Strong rise at	e-e	6	5.0			4	4.6
	Total	119	100.0		Total	87	100.0

4.2.7 Lesson quiz question results

Up to this point, the results shown come from the questions on the pre-lesson test and the post-lesson test. In the lab itself, students perform a tutorial and an accompanying quiz that consists of 25 multiple choice and short answer questions. The lab quiz is what makes up the majority of the grade that students receive for each lab. The quizzes are slightly different between the spring and fall 2004 semesters and therefore do have some questions that are not common to both. The percent of correct responses for each question that was common to both the spring and fall semester quizzes are listed. Note that these were questions from the quizzes taken during the lab and are not questions that were in the pre and post lesson tests that have been previously looked at. The performance on these lab quiz questions is observed to see if there is any change in lesson performance between the two semesters under study. Questions that were not common to both quizzes are omitted. See Table 17.

Table 17- Lesson quiz performance - Spring and Fall 2004

Percent of correct responses for questions common to both semester quizzes	**Sp 2004**	**Fall 2004**
Question 3	78	76
Question 4	91	88
Question 5	75	76
Question 6	91	90
Question 7	76	70
Question 8	82	82
Question 10	89	80
Question 12	78	66
Question 13	89	84
Question 14	75	82
Question 15	96	96
Question 16	87	90
Question 18	60	68
Question 19	53	38
Question 20	75	48
Question 21	47	40
Question 22	85	86
Question 23	53	58
Average	76.7	73.2

CHAPTER 5

ANALYSIS

In analyzing the responses to the survey questions in Part One, we combined all of the responses for all semesters and courses into one group of total responses. We considered this total of all respondents to the questions to be our normative group with an *N* value of 481. We then chose to see if there was any variation in the way the questions were answered in each individual semester and course from this standard. We measured any statistical significance by converting the frequency of responses, for each possible answer to each question, to percent of the total for that particular group. We then applied the P^2 statistical test as described by Coladarci, et. al. in their book, *Fundamentals of Statistical Reasoning in Education* (Coladarci, et. al., 2004). Questions 5 and 6 have six possible answers each which give five degrees of freedom. Question 7 has five possible answers and therefore 4 degrees of freedom. The value for P^2 with $a = 5\%$ represents what the sum of the discrepancies must exceed to represent a statistically significant difference.

In Part Two, our normative group is the spring 2004 (control) group. We again converted the frequency of responses to percent of the total for each group and apply the P^2 statistical test to see if the fall 2004 (experimental) group deviates significantly from the expected values.

5.1 Part One – Analysis of pretest questions for three semesters

5.1.1 Analysis of Question 4 results

The results for Question 4, the question addressing how often students observe the Moon, show that a large majority of UMaine students observe the Moon frequently, with 79% choosing answer "a" in the spring semester and 75.4 % in the fall semester (See Table 1, page 31). These results are plausible for a rural college in that a rural environment would have less of a limitation for observing the Moon in the form of light pollution and/or tall buildings. These results, in conjunction with the results from the other questions, show that students may see the Moon often, but they don't see any pattern in when and where they see it in the sky. This type of question associated with similar research would be interesting to ask in an urban educational environment, where light pollution and tall buildings could play a factor in the ability of students to observe the Moon.

5.1.2 Analysis of Question 5 results

Question 5, the question that asked students about when the Moon is most likely to be high in the sky, shows that for all semesters, an almost equal percentage of students believe the Moon is most likely to be high in the sky at Midnight as do students who said anytime day or night (See Table 2, page 33). A statistical analysis of these results comparing each semester to the total for all semesters in terms of percentages shows a statistically significant difference for the spring online semester with a proportionally higher number of students answering "e" for noon (See Table 18, page 58). This is an interesting difference and whether or not the online course environment might influence this difference is a question for further study, but is not a part of this research.

Overall the results show that a high percentage of students believe the Moon to be most likely in the sky at night time, 42.8% versus 43.5% who chose anytime day or night. The unscientific concept that the Sun is up during the day and the Moon is up only at night appears to be as prevalent as the reality that the Moon's presence in the sky can be at anytime depending on its point in the lunar cycle.

Table 18 - Chi-squared statistics for Question 5.

Chi squared	a	b	c	d	e	f	Una nsw ered	Total	df	P^2 at a = .05	Significant
Spring 04	0.4	0.0	0.7	0.1	1.1	0.0	1.2	3.5	5	11.07	No
Fall 04	0.0	0.2	0.0	1.4	0.4	0.7	0.2	3.0	5	11.07	No
Spring 05	0.2	0.2	0.0	0.4	1.6	0.9	0.2	3.5	5	11.07	No
Spr Online 05	0.5	0.2	4.1	0.7	8.7	0.9	0.2	15.5	5	11.07	Yes

By looking at the graph (see Figure 11, page 34), one can see a difference between the spring semesters and the fall semester. Using the spring 2004 semester as the expected values, the chi-squared values show no statistically significant difference between semesters (see Table 19).

Table 19 - Comparing fall 2004 and spring 2005 to the spring 2004 semester.

	a	b	c	d	e	f	Unans wered	Total	df	P^2 at a = .05	Significant
Fall 04	0.7	0.1	2.9	2.2	1.9	0.8	0.3	8.9	5	11.07	No
Spring 05	2.3	0.3	2.3	0.2	3.7	0.7	0.3	9.9	5	11.07	No

5.1.3 Analysis of Question 6 results

This question, because of the way it was worded, provides the most interesting results for analysis. The frequency of responses for answers has more students choosing the fraction lit concept as causing the changing shape of the Moon, 42.4%. The answer that was closest to the scientifically accepted concept, answer “e” for the position of the Moon in its orbit scored 30.8 percent. Response, “f”, scored 0.6 percent and the common idea that the Moon’s phases are caused by Earth’s shadow, tallied 25.4 percent coming close to Trumper’s results (see Table 3, page 35).

By looking at these results, we can see that the majority of the students took the question as it was intended, to inventory concepts about the phases of the Moon. It can be understood that the “Moon’s different shapes at different times” was interpreted to mean the Moon’s phases as was hoped. For the three students who understood the question literally and answered “f,” we only hope that they chose that answer because they understood the causes of seismic activity on the Moon.

It is interesting to see that more students chose answer “d,” the fraction of the Moon that is lit by the Sun, even with the position of the Moon in its orbit available as an option. This answer was worded in such a way that it was literally incorrect. If it had been worded as, “The Moon’s different shape*(s)* at different times *is* caused by the fraction of the Moon that is lit by the Sun *that we see*, then “d” would have been entirely a correct choice. What this says about student ideas and/or their ability to read and comprehend a question is of arguable measure. It is entirely plausible that students completed the question in their mind using a form of psychological closure, in which case this response would have to be considered as an indicator that the student understands the cause of the Moon's phases.

In looking at differences in responses across all the semesters in the study, there is a statistically significant difference between the spring online semester and the total responses (see Table 20). Students in the online semester had a higher percentage of choosing answers "a" and "b." This is interesting that these choices would have a higher occurrence with the online students versus the live course and may be a situation where several students in the online course just guessed without really reading the answers. Overall, the frequency of choosing these two answers is not of sufficient value to consider them as prevalent ideas about the Moon's phases, particularly the Moon deflating and inflating again, though the clouds blocking the Moon is an idea about the Moon's phases explored by Baxter.

Table 20- Chi-squared statistics for Question 6.

Chi squared	a	b	c	d	e	f	Total	df	P^2 at a = .05	Significant
Spring 04	0.4	0.2	1.5	0.2	0.1	0.6	3.1	5	11.07	No
Fall 04	0.4	0.4	0.0	0.2	0.5	1.0	2.5	5	11.07	No
Spring 05	0.1	0.4	1.0	1.0	0.1	0.0	2.7	5	11.07	No
Spr Online 05	8.8	8.8	0.0	0.2	0.0	0.6	18.4	5	11.07	Yes

5.1.4 Analysis of Question 7 results

This question was used to see if students understand the relationship between the Moon's phase and the times of its rising and setting. Overall, this is a difficult question to answer and because it is hard, we see answers occurring in a wider spread, with each possible answer receiving at least 10% of responses. Answer "b," rise after sunset, received 31% and answer "d", the correct response of set after sunset received 29.5%, making these two choices almost even in frequency of occurrence. It is enlightening to see that so many students were able to choose the correct response on a question of this caliber, yet the high percentage of answer "b" indicates that the idea that the Moon always rises after sunset is prevalent.

A comparison of semesters to the total responses shows a statistically significant difference for the fall 2004 semester from the total (see Table 21). In discussion with Professors Batuski and Comins, it is believed this difference may be attributable to the differences in presentation of the lecture course associated with the lab. The lecture course is taught by both professors who alternate each semester. Professor Comins teaches the fall semester lecture course and Professor Batuski teaches the spring semester lecture course.

Table 21 - Chi-squared statistics for Question 7.

Chi squared	a	b	c	d	e	Total	df	P^2 at a = .05	Significant
Spring 04	1.3	0.9	0.9	1.0	0.8	4.9	4	9.49	No
Fall 04	0.0	0.1	2.4	3.7	4.0	10.2	4	9.49	Yes
Spring 05	2.1	0.3	0.8	0.9	1.5	5.6	4	9.49	No
Spr Online 05	0.4	0.3	1.8	0.1	0.5	3.2	4	9.49	No

5.1.5 Analysis of the relationship of Questions 5, 6 & 7 answer frequency

For students who chose answer “c” on question 6, there was no statistically significant difference in the way they answered Questions 5 and 7 from the total population in the study (see Table 22). This also holds true for students who chose answer “d” on Question 6 (see Table 23) and for students who chose answer “e” (see Table 24).

Table 22 - Chi-squared statistics for students who chose Question 6, answer "c."

Chi squared	a	b	c	d	e	f	Total	df	P^2 at a = .05	Significant
Question 5	1.5	2.1	0.6	1.8	0.0	1.9	7.9	5	11.07	No
Question 7	0.5	0.8	0.2	0.6	0.0		2.1	4	9.49	No

Table 23 - Chi-squared statistics for students who chose Question 6, answer "d.”

Chi squared	a	b	c	d	e	f	Total	df	P^2 at a = .05	Significant
Question 5	0.7	0.8	0.0	1.2	0.2	1.7	4.5	5	11.07	No
Question 7	0.2	0.0	0.1	0.0	0.3		0.5	4	9.49	No

Table 24 - Chi-squared statistics for students who chose Question 6, answer "e.”

Chi squared	a	b	c	d	e	f	Total	df	P^2 at a = .05	Significant
Question 5	0.0	0.0	0.1	0.1	0.4	0.2	1.0	5	11.07	No
Question 7	0.0	0.7	0.1	0.3	0.7		1.8	4	9.49	No

This shows no significant relationship between how students answered Question 6 and how they answered Questions 5 and 7.

One should point out that students who hold the idea that the Moon is only up at night might have a tendency to choose Question 5 answer "d" and Question 7 answer "b". Of the 206 students in all semesters who chose 5d and the 149 who chose 7b, 72 chose both 7b and 5d. Looking at these students and the way they answered Question 6, we see no statistically significant difference compared to the total group. (See Table 25).

Table 25 - Statistics for students who answered 5d and 7b.

Question 6	**a**	**b**	**c**	**d**	**e**	**f**	**Total**			
Freq.	1	0	24	25	22	0	72			
Percent	1.4	0.0	33.3	34.7	30.6	0.0	100.0			
Chi squared	**a**	**b**	**c**	**d**	**e**	**f**	**Total**	**df**	**P^2 at a = .05**	**Significant**
Question 6	2.3	0.4	2.5	1.4	0	0.6	7.2	5	11.49	No

5.2 Analysis of Lesson modifications and use of 3D model

In this section, we look at the data relevant to usage of the 3D model and lesson modifications. First we do an analysis of the three question results both before and after the lab lesson and we look at performance on the lab lesson itself

5.2.1 Question 5, 6 and 7 pre and post lesson analysis

The factors important to investigate here are whether or not there is a statistically significant difference in how students answered the survey questions on the post test from the pretest and whether or not there is a statistically significant difference between semesters. We first look at each semester individually and then compare the fall (experimental) semester post test results to the spring (control).

The spring 2004 semester showed no statistically significant difference in the way the survey questions were answered before and after the lesson (see **Table 26**).

Table 26 – Chi-squared statistics for pre and post lesson results, spring 2004.

Chi squared	a	b	c	d	e	f	Total	df	P^2 at a = .05	Significant
Question 5	0.8	0.3	0.8	0.8	0.8	0.8	4.4	5	11.07	No
Question 6	0.8	0.8	0.2	0.6	0.1	0.8	3.5	5	11.07	No
Question 7	0.6	1.6	1.9	1.0	1.0		6.2	4	9.49	No

The fall semester shows a difference before and after the lesson on Question 7 (see Table 27). Looking at Figure 19 on page 49, one can see a change in the frequency of answers “c” and “d.”

The changes are tracked in the concept inventory for question 7 in Table 16, page 53.

Table 27 – Chi-squared statistics for pre and post lesson results, fall 2004.

Chi squared	a	b	c	d	e	f	Total	df	P^2 at a = .05	Significant
Question 5	2.3	0.3	2.3	0.4	0.4	0.6	6.2	5	11.07	No
Question 6	0.0	0.0	0.1	1.7	1.6	1.1	4.5	5	11.07	No
Question 7	0.1	0.3	6.8	4.3	0.3		11.9	4	9.49	Yes

Of the 87 students in this semester, 17.2% changed from answering “c” to some other answer. 21.8% changed to “d” from some other answer. The percent of students who changed from “c” to “d” was 5.7%. It should be pointed out that answering “c” on Question 7 implies that the Moon would always be in the sky or never be in the sky, and once the student realizes this, they would most likely realize that it is the wrong choice. This idea might explain why there is such a high percentage of students who switched from “c” but not to the correct answer “d.” Answer “c” is also the answer that scores no points on the mini-quiz.

In comparing post lesson results between semesters, we use the spring (control) semester as the expected values. The fall semester shows no statistically significant difference in the way students answered the post lesson survey questions from the spring semester (see Table 28).

Table 28 – Chi-squared statistics post lesson results spring and fall semesters

Chi squared	a	b	c	d	e	f	Total	df	P^2 at a = .05	Significant
Question 5	0.2	0.0	1.7	2.6	0.3	1.1	5.9	5	11.07	No
Question 6	0.8	0.0	2.8	2.7	0.0	0.8	7.2	5	11.07	No
Question 7	0.1	3.1	1.8	2.9	0.0		7.9	4	9.49	No

5.2.2 Analysis of Question Concept Inventories

The correct response for Question 5 was answer “f.” For the spring 2004 semester, the percent of students changing to this answer after the lesson was 15.9% and the percent of students changing from this answer after instruction was 10%, leaving a gain of 5.9%. In the fall semester, 12.6% switched to answer “f” after the lesson, with 8% switching away leaving a gain of 4.6%. This shows little difference in performance on this question between semesters (See Table 14, page 48). Spring and fall showed no statistical difference among students going from the correct answer to the “midnight” answer.

For Question 6, taking into consideration the aspects of the fraction lit response and considering that students who chose it hold the correct concepts of the Moon's phases, then there was a net increase of 10.9% in the spring and 8% in the fall semester of students holding scientifically accepted concepts.

For Question 7, the spring semester had an 8.9% net gain of students shifting to the correct response. The fall semester had a net gain of 9.2% showing a negligible difference between the semesters (See Table 16, page 53).

5.2.3 Lesson Quiz performance

Most of the questions on the quizzes are multiple-choice. In analyzing the quiz performance between semesters, we use a P^2 as with the previous analyses but because there is a single category for frequency of occurrence, the degrees of freedom are reduced to one (each question had several possible answers and therefore higher degrees of freedom, but we are only comparing a single frequency before and after instruction and that is the frequency of the correct response (see Table 29). Again, we look at the discrepancy between expected and observed values to exceed the value for P^2 at a = 5%. The only two questions, ironically, that are significantly different are questions 19 and 20. Both questions are math questions that would lend themselves nicely to normal distributions and a more thorough analysis but the data would be irrelevant to this study. Why students do poorly on the few simple math questions is a topic for another study.

Table 29 – Chi-squared statistics from quiz results comparison between semesters.

Percent of correct responses for questions common to both semester quizzes	Sp 2004	Fall 2004	P^2	df	a = .05	Significant
Question 3	78	76	0.05	1	3.84	No
Question 4	91	88	0.10	1	3.84	No
Question 5	75	76	0.01	1	3.84	No
Question 6	91	90	0.01	1	3.84	No
Question 7	76	70	0.47	1	3.84	No
Question 8	82	82	0.00	1	3.84	No
Question 10	89	80	0.91	1	3.84	No
Question 12	78	66	1.85	1	3.84	No
Question 13	89	84	0.28	1	3.84	No
Question 14	75	82	0.65	1	3.84	No
Question 15	96	96	0.00	1	3.84	No
Question 16	87	90	0.10	1	3.84	No
Question 18	60	68	1.07	1	3.84	No
Question 19	53	38	4.25	1	3.84	Yes
Question 20	75	48	9.72	1	3.84	Yes
Question 21	47	40	1.04	1	3.84	No
Question 22	85	86	0.01	1	3.84	No
Question 23	53	58	0.47	1	3.84	No
Average	76.7	73.2	0.15	1	3.84	No

CHAPTER 6

DISCUSSION

How effective were the three survey questions in the ability to illicit student ideas? Were they worded in such a way that they could cause students to answer in a certain way? Question 5 results indicate that of the possible choices present to the student, there are two prevalent ideas about when the Moon is up (high in the sky). These two ideas are the scientifically accepted idea and the idea about the Moon that is ingrained into our minds at an early age. Because the answer choices cover a spread of 24 hours, students were able to choose a best answer to suit their ideas. The wording is to the point but not steering students to a particular response.

Question 6 shows three prevalent ideas about the Moon's phases. The Earth's shadow idea occurs in this study with a frequency consistent with other research. With the answer choices worded the way they were, one might argue that answer "d" (the fraction lit) drew students away from answer "e" (the position of the Moon in its orbit). If this was the case, the data might have shown a higher percentage of concept change from "d" to "e" in the pre-lesson post-lesson analysis as a result of the lesson instruction clarifying the concept for students who might have been swayed. The results indicate that fraction lit idea drew the highest percentage of responses. These results are consistent across semesters and remain prevalent even after instruction both with and without the 3D model, and with the 3D model actually showed an increase of students believing the fraction lit idea (see Table 15, page 52). In addition, one of the quiz questions presented to the fall 2004 students only addresses the idea of how much of the moon is lit by the Sun. This was the first question on the lab quiz about the Moon that students answered in groups. That question was worded as follows.

Question 2 (4 points)
For this question, assume that the Sun, Earth and Moon are not aligned in a way as to produce an eclipse. Look down on the Earth/Moon model from the orientation of being above the North Pole of the Earth. At any point in its orbit around the Earth, how much of the Moon is illuminated by the Sun?

a. 0%
b. 16%
c. 33 1/3%
d. 45%
e. 50%
f. 78%
g. 100%

Out of 50 groups that did the quiz, 86% answered this question correctly by choosing answer "e" (the 14% that chose other answers did not have a preference as to which one was correct). Yet, there was still an increase in students choosing the fraction lit response to Question 6.

Question 7 results reinforce the idea that the Moon is in the sky at night regardless of the phase with 31% of all students choosing that a waxing crescent moon would rise after sunset even though this is physically impossible.

We originally thought that student ideas about the Moon would be consistent. Results from analysis of the survey questions indicate that ***there is no pattern as to what students believe about when the Moon is present in the sky and the cause of the Moon's phases.*** In other words, there is no statistically significant difference in the way the students answered the questions regardless of their ideas about the cause of the Moon's phases. This indicates that

there is a lack of a conceptual connection between actual phase and times the Moon is visible.

How effective was the 3D model in impacting student ideas? Based on the data obtained from post lesson questions, there was little if any change between semesters in student ideas. Question 7 showed a statistically significant difference, yet the changes were not related to the 3D model. Performance on the lesson quiz and concept changes tracked showed little difference between semesters. Based on these results and analysis, ***changes to the lesson and use of the 3D model showed no difference in student performance.***

Does this mean that the 3D model is useless as a teaching tool or that the changes to the lesson did not improve instruction? A recent study of mostly engineering students in an introductory physics course showed similar results. Ortiz, et. al., published in the June 2005 issue of *American Journal of Physics*, found student difficulties with certain concepts persisted even when presented with hands-on models (Ortiz et al. 2005).

CHAPTER 7

7. CONCLUSION

Initially it was hoped that the use of the 3D model and the changes to the lesson would cause more students to adopt the position of the Moon as the cause of its phases. Even though there was a shift away from the Earth's shadow response and other responses (though not statistically significant), there still lies the question of why the fraction of the Moon lit by the Sun remained more popular. Ultimately, the position of the Moon in its orbit around Earth as the cause of the Moon's phases is a more complex concept. This may be a factor in why there was less of a transition toward the position view. How to get students to adopt the more scientific explanation requires some further study.

Even though the research in this work and in other recent studies shows the ineffectiveness of using real 3D models, we believe that students who can use a hands-on visual model of the Sun/Earth/Moon system in studying the phases of the Moon has merit in instruction and changes to the lesson to incorporate that model are of equal value. Why? We are seeing a trend in educational psychology that shows and supports the importance of presenting instruction so that students can discover relationships for themselves by being active learners. The 3D model allows students to do this with the Moon, its phases and eclipses. The true effectiveness of the model may come into light as more semesters use the set up and as refinements to the way the lab is taught are made. Needless to say, this is an area that needs more research.

This study comes with its own set of limitations and some suggestions. The use of just 3 questions to survey student ideas about the Moon limits greatly the accuracy of the survey and because of this limitation the results should be looked upon as indicators. For future semesters, it would be helpful to increase the size of the mini-quizzes students take before the labs to 15 or 20 questions versus the current 10. Since the average time students spend on these quizzes is less than 10 minutes per week, it would not increase the workload of the course greatly. An increase in questions may enable a more accurate survey by quizzing the same topic with different wording. As seen in this study, a single phase question was most probably interpreted in different ways. Having more that one phase question phrased differently may allow for more accurate interpretation of student conceptions about the Moon's phases.

Something to consider in comparing the spring and the fall semesters and in looking at the facts of the AST 110 astronomy lab itself are that the spring had 112 students in the pre-lesson post-lesson portion of the study whereas the fall semester had only 87. This is quite significant change considering both semesters had full registration for the astronomy lab with rarely any room left at the start of the semester. That spells out to 240 students who started both semesters. Both semesters had around 140 students who took Lesson 6 pretest (spring N = 143, fall N = 142). Why then did the fall semester only have 87 students who completed the pretest, lesson and post test versus 112 in the spring? One possible explanation, which was documented with emails from students, was a language barrier. Six of the ten sections of the astronomy lab in the fall semester were taught by TA's where English was a second language to them. This language barrier may have had an impact on attendance. As coordinator of the lab course, I received numerous complaints from students that they could not understand the TA who taught the lab. This dilemma is not unique to the University of Maine and was recently documented in a *New York Times* article by Alan Finder about foreign teachers on college campuses (Finder, 6/24/2005). Determining the extent of how this language barrier affects student learning is an area that should be researched further.

As far as the lab design itself is concerned, as a TA myself for 4 semesters, I was able to observe a consistent pattern in the way a large portion of students did the lab. Their method of choice was to open up the quiz on the desktop and start on it. If they came to a question that they could not answer, they would ask for help. I would tell them to read the lesson at that point and some would. Some would guess and get out of the lab as soon as possible.

This is a problem the department is aware of and the lab is at this point being redesigned so that the quiz questions are integrated into the lesson rather than opening up in a separate window on the desktop of the lab computers. shows what students see when working on the lab. Notice that it is easy to open the quiz without opening the lesson in its own desktop window.

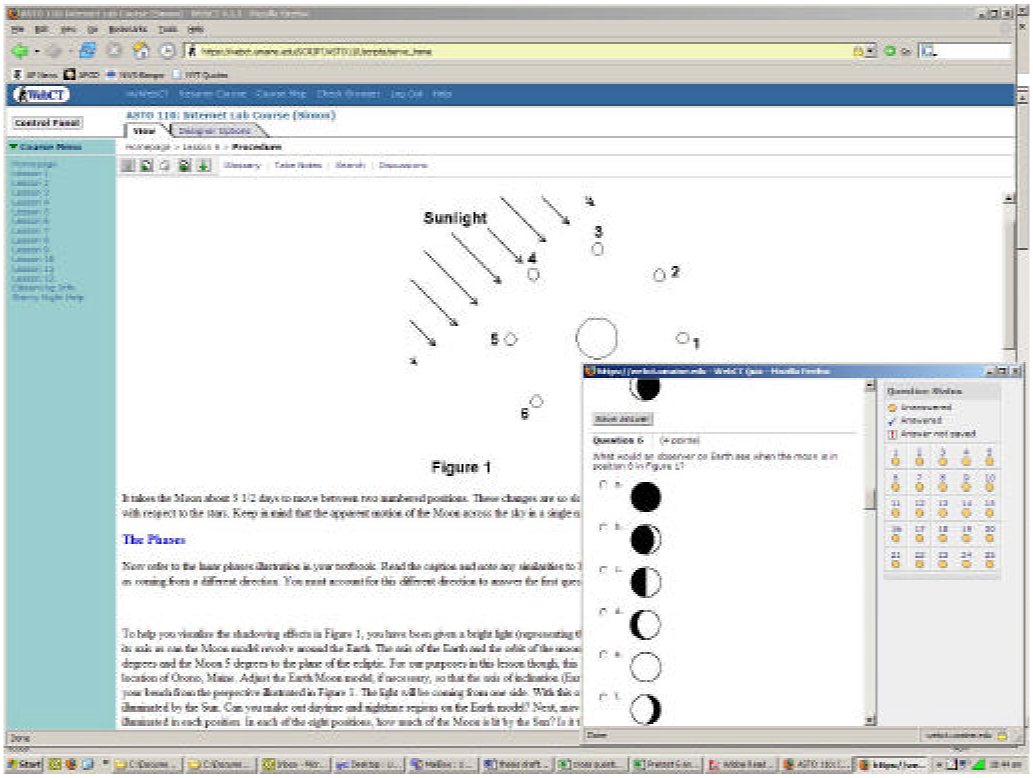


Figure 20 - Typical desktop view for AST 110 lab lesson.

Perhaps the process of conceptual change and the gaining of scientific concepts about the Moon and its phases can be made more successful by integrating the quiz into the lesson tutorial, by making the relevant questions to be answered for credit made available only after portions of the tutorial are read and completed. This can be done by limiting the availability of the questions until a particular question is answered that has the answer imbedded in the instruction. What comes to mind in how to structure the lesson on the computer is to model after computer adventure games that won't allow you to continue to the next part of the game until a certain task is completed or a particular item is found. The lessons could be reprogrammed to do this and the result would be that students have to follow a certain path. In other words, the lesson needs to provide more guidance so that students can't just attempt to answer all the quiz questions and be done. By guiding them through the lesson, they will be directed to inquire about the cause of the phases of the Moon and the relationships that affect rise and set times. The lesson should require the students to explain their reasoning. This can be done with the addition of a short essay question similar to questions 24 and 25 (see appendices).

Ideally, the TA should act as a facilitator of the students' learning. The TA's should be more active in the student learning process by asking the students to explain their reasoning and promote discussion within the groups. We believe that this is a necessary ingredient in inquiry based learning. TA's attend a seminar at the beginning of the year to give then some instructional skills and if not already being done, this seminar should cover some of the methods of guided inquiry in the classroom.

It is not always feasible to have TA's that are familiar with teaching methods, but it would greatly assist the students in this particular astronomy lab if the TA's could challenge students to think about their answers to the quiz questions before they complete them. This is entirely possible as each TA has a maximum of 8 groups to deal with in the lab. Circulating around the groups and monitoring their answer choices should be standard operating procedure. The TA's should also ask each student or group as they leave the lab, "What causes the phases of the Moon?" This in itself would be valuable survey information.

As a last word, student ideas about natural events such as the phases of the Moon are reinforced by unscientific reasons that come from deeply ingrained concepts often fostered in childhood such as through children's stories and parental influence. It remains a tremendous challenge for educators to present material in such a way that the scientific reasons for natural events become the ideas that students possess. Science and education need to devise ways to become a part of our culture so that the scientific concepts are the ones that are presented at home.

REFERENCES

Allen, C. *Sleep Tight!* Western Publishing Co., 1991

Bailey, J. & Slater, T. "A Review of Astronomy Education Research," *Astronomy Education Review,* **2**(2), 2003-2004

Barab, S., Hay, K., Squire, K., Barnett, M., Schmidt, R., Karrigan, K. Yamagata-Lynch, L. & Johnson, C. "Virtual Solar System Project: Learning through a Technology-Rich, Inquiry-Based, Participatory Learning Environment," accepted for publication, *Journal of Science Education and Technology,* 1999, http://it.usu.edu/~bshelton/courses/immersive/readings/keating99virtual.pdf, 9/16/2004

Barnett, M. & Moran, J. "Addressing children's alternative frameworks of the Moon's phases and eclipses," *International Journal of Science Education,* **24**(8), 2002, 859-879

Baxter, J. "Children's understanding of familiar astronomical events," *International Journal of Science Education,* **22**, 1989, 502-513

Branley, F. M. *what makes day and night*, New York: Thomas Y. Crowell Co., 1961

Coladarci, T., Cobb, C. D., Minium, E. W., & Clarke, R. C., *Fundamentals of Statistical Reasoning in Education,* Hoboken: John Wiley & Sons, Inc., 2004

Comins, N. *Heavenly Errors,* New York: Columbia University Press, 2001

Comins, N. http://www.physics.umaine.edu/ncomins/moons.htm#phases,

Fanetti, T. M. *The relationships of scale concepts on college age students' misconceptions about the cause of the lunar phases,* Thesis submitted, Ames: Iowa State University, 2001

Finder, A. "Unclear on American Campus: What the Foreign Teacher Said." *The New York Times*, 6/24/2005, www.nytimes.com, 6/24/2005

Golden Books, *Baby Looks,* Racine: Western Publishing Co., Inc., 1960

Hammer, D. "More than misconceptions: Multiple perspectives on student knowledge and reasoning, and an appropriate role for education research," *American Journal of Physics,* **64**(10), 1995, 1316-1325

Hermann, R & Lewis, B. "Moon Misconceptions," *The Science Teacher*, Nov 2003, 51-55

Katzeff, P. *Moon Madness*, Secaucus: Citadel Press, 1988

Kessler, E. & L. *The Day Daddy Stayed Home*, Xerox Education Publications, 1959

Lindell, R. "Activity 5: Observing the Moon," www.phys.ksu.edu/perg/www/pdf/obs**moon**.pdf, 2/9/2004

Lindell, R. "Moon Concept Inventory," www.phys.ksu.edu/perg/www/pdf/**moon**.pdf, 2/4/2004

McDermott, L. "Astronomy by Sight: the sun, moon and stars," *Physics By Inquiry*, John Wiley & Sons, Inc.

Ortiz, L., Heron, P. & Shaffer, P. "Student understanding of static equilibrium: Predicting and accounting for balancing" *American Journal of Physics* **73**(6), 2005 545-553.

Posner, G., Strike, K., Hewson, P., & Gertzog, W. "Accommodation of a Scientific Conception: Toward a Theory of Conceptual Change," *Science Education*, **66**(2), 1982, 211-227

Stahly, L., Krockover, G., Shepardson, D., "Third Grade Students' Ideas about the Lunar Phases," *Journal of Research in Science Teaching*, **36**(2), 1999, 159-177

Trumper, R. "University students' conceptions of basic astronomy concepts," *Physics Education*, **35**(1), 2000, 9-14

APPENDICES

Appendix A – Lesson 6 Pretest

Lesson 6 Pretest

Name: (Preview)

Start time:

Number of questions: 10

Question 1 (1 point)

Introduction: What is the angular size of the Moon? (enter the number only, no degrees sign)

Answer:

Question 2 (1 point)

Introduction: Why does the Moon appear to move east to west across the sky during a few hours of observing?

a. the rotation of the Earth
b. the Moon's orbit around the Earth
c. the revolution of the Earth around the Sun
d. the Earth is still and both Moon and stars are spinning around it

Question 3 (1 point)

Introduction: Looking down on the Moon's north pole from above, which direction does the Moon rotate on its axis? (one-word answer)

Answer:

Question 4 (1 point)

I__________ notice that the Moon appears in different shapes at different times.

a. Often
b. Sometimes
c. Rarely
d. Never
e. I have never seen the moon.

Question 5 (1 point)

The Moon is most likely to be high in the sky at_________.

l

a. 6:00 AM
b. 6:00 PM
c. the North Pole
d. midnight
e. noon
f. anytime day or night

Question 6 (1 point)

The Moon's different shapes at different times are caused by

l

a. clouds blocking our view of the entire Moon.
b. the Moon deflating and then inflating again.
c. Earth's shadow falling on the Moon.
d. the fraction of the Moon that is lit by the Sun.
e. the position of the Moon in its orbit around Earth.
f. Earth's gravity pulling the moon into different shapes.

Question 7 (1 point)

A moon in the phase shown below would_________.

a. set before sunset.
b. rise after sunset.
c. neither rise nor set.
d. set after sunset.
e. rise at sunset.

Question 8 (1 point)

What constellation is the Sun in on the Vernal Equinox?

a. Aquila
b. Bootes
c. Canis Major
d. Pisces
e. Virgo
f. Three Musketeers

Question 9 (1 point)

When a planet moves from east to west, its motion is ________.

l

a. prograde
b. retrograde
c. circumpolar
d. tidal
e. an optical illusion (the planet is really stationary)

Question 10 (1 point)

Relative to the Earth, how fast do the inferior planets (those closer to the Sun) move through their orbits?

l

a. faster
b. slower
c. the same speed
d. they do not actually move

Appendix B - Spring 2004 Lesson

Review from Introduction

Figure 1 shows the Earth-Moon system as viewed looking down on the Earth's north rotational pole. The eight numbered Moon positions are in sequence, showing that the Moon orbits around the Earth counterclockwise, starting at position 1, and moving in order to position 8.

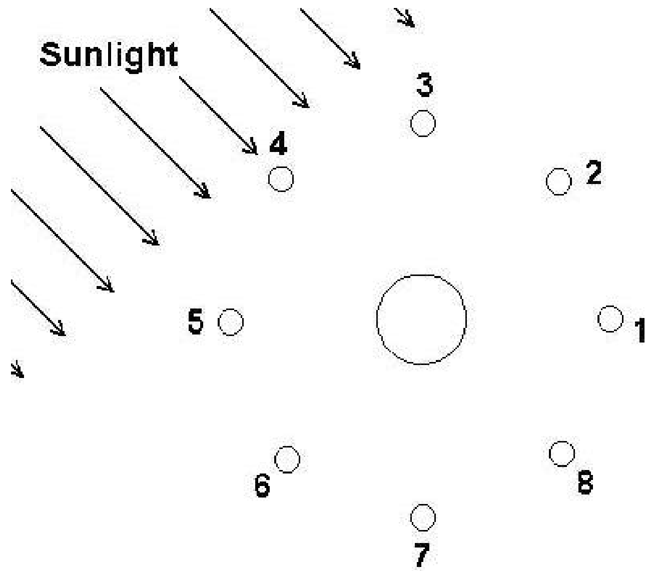


Figure 1

It takes the Moon about 3 1/2 days to move between two numbered positions. These changes are so slow that, during any given night, the Moon stays in essentially the same place in its orbit. From this perspective, the Earth also rotates counterclockwise on its axis. Keep in mind that the apparent motion of the Moon across the sky in a single night is due to the rotation of the Earth.

The Phases

Now look at the figure in your textbook that shows the phases of the Moon in these same positions. **Please note** that in the text figure, the Moon has different shadowing effects in each of the two images at each point in the orbit, because you are looking at the Moon from two different perspectives at each point! The inner image is looking at the Moon from space, above the Earth. The outer image (photograph) is looking at the Moon from the surface of the Earth.

Note also that Figure 1 differs slightly from the text image in that sunlight is drawn as coming from a different direction. You must first account for this different direction to answer the questions below.

To help you visualize the shadowing effects in Figure 1, you have been given a bright light (representing the Sun), a model of the Earth (not to scale), and a ball on a stick for the Moon (also not to scale). First, look at the Earth and Moon from the perspective in the upper panel in Figure 1. Stand with the light coming from your right. Place the Earth in the light beam, so you are looking down on the North Pole, and note how it is shadowed by the Sun. Next, hold the Moon in each of the eight positions shown in the figure, noting how the Moon is shadowed in each position.

Next, to visualize each of the phases in the lower panel of Figure 1, remove the Earth from the light beam. Sit on a stool so that your head is in the light beam. You are now the Earth (or more precisely, an observer on the Earth)! Hold the Moon in orbit around your head, noting how the Moon is lit in each of the eight positions.

You should now be able to answer questions 1-7.

Moon Phases and Time of Day

For the next few questions, assume each day has 12 hours of daylight, and that the Moon is up the same amount of time each 24 hour day. Recall the Moon may be up in the sky in daylight and/or night.

Once you have finished this section, you will be able to tell what time of day and/or night to look for a particular phase of the Moon. This is also helpful if you want to know what time to look at the sky **without** a Moon.

You should now be able to answer questions 8-14.

Lunar Eclipses

Recall that the Earth always casts a shadow in space, since it is always lit by the Sun. The same is true for the Moon.

When the Moon passes directly between the Earth and the Sun, the Moon's shadow falls on the Earth. Observers in this shadow would not be able to see the Sun, because the Moon would be in the way. We call this a **solar eclipse**.

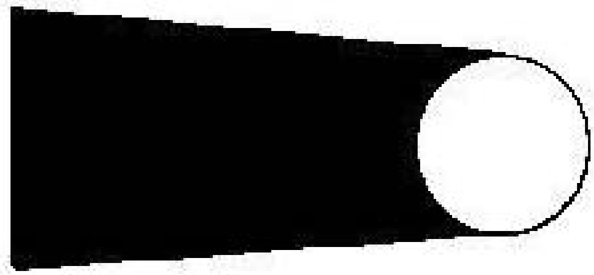


Figure 2

If the light source is a point source, an object will cast a dark, well-defined shadow called an **umbra**. Viewing the light source from within the umbra, you would see the object casting the shadow completely "covers" or eclipses the light source.

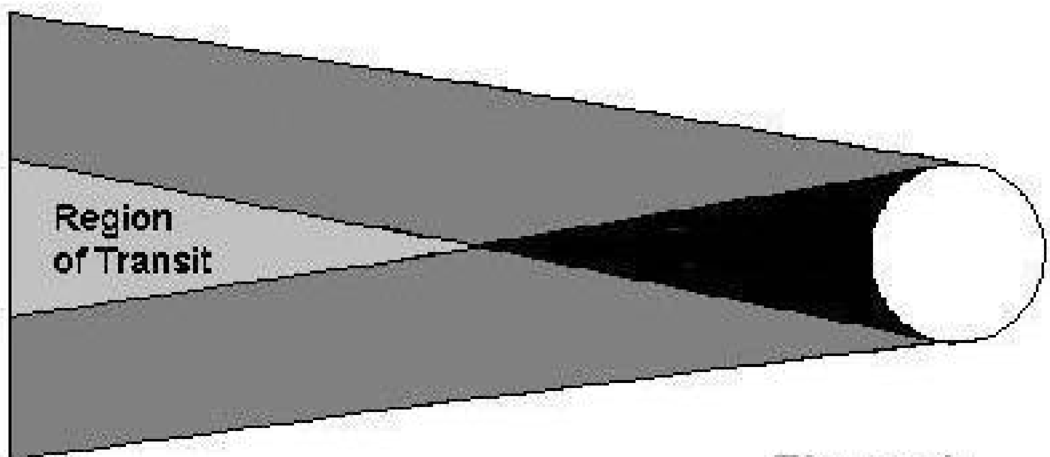


Figure 3

The Sun is not a point, but an extended light source. It will cast a shadow consisting of three distinct regions. First is a dark cone, called the **umbra**, from which the source is completely eclipsed. Around the umbra is a semi-dark region, called the **penumbra**, within which only some of the light is blocked. Finally, in an extension of the umbra cone, called the **region of transit**, the body casting the shadow would appear insufficient to "cover" the source and the light source would look like a doughnut.

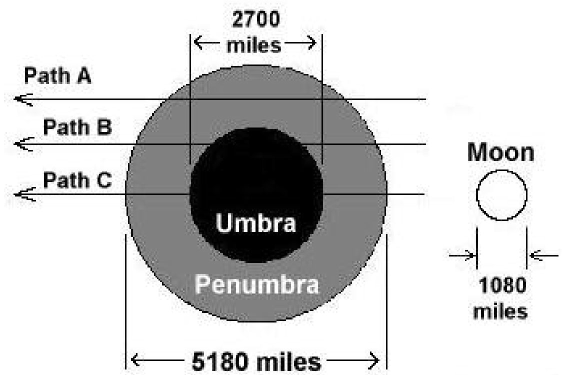


Figure 4

There are three types of lunar eclipses, each illustrated in the cross section of the Earth's shadow pictured above. Paths A and B are both paths where the Moon is partially eclipsed. Path C takes the Moon through roughly the middle of the umbra and results in a total lunar eclipse.

The shadows of Figure 4 have the dimensions of the Earth's umbra and penumbra at the average distance of the Moon. The diameter of the moon is included here, so that you can calculate the timing of a total eclipse with the moon passing through the center of the Earth's umbra.

You should now be able to complete the quiz.

Appendix C - Spring 2004 Quiz

Lesson 6

Name:
Start time:
Number of questions: 25

Question 1 (points)

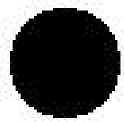
Enter the names of everyone in your group.

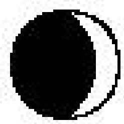
Answer:

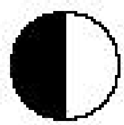
1.
2.
3.
4.

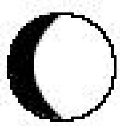
Question 2 (4 points)

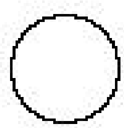
What would an observer on Earth see when the moon is in position 1 in Figure 1?

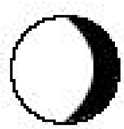
a. 

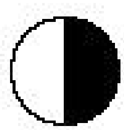
b. 

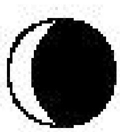
c. 

d. 

e. 

f. 

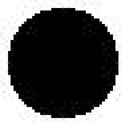
g. 

h. 

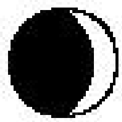
Question 3 (4 points)

What would an observer on Earth see when the moon is in position 3 in Figure 1?

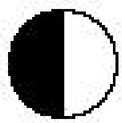
a.



b.



c.



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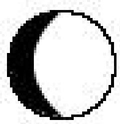

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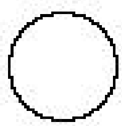

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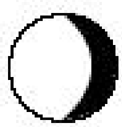

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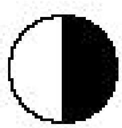

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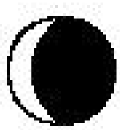
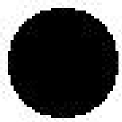


Question 4 (4 points)

What would an observer on Earth see when the moon is in position 4 in Figure 1?

a.


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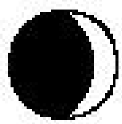

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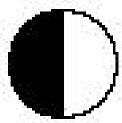

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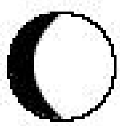

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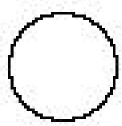

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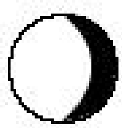

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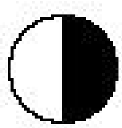

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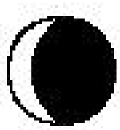
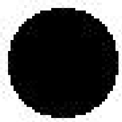
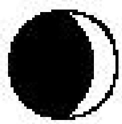
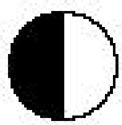


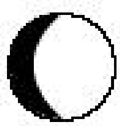
Question 5 (4 points)

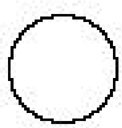
What would an observer on Earth see when the moon is in position 6 in Figure 1?

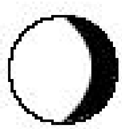
a. 

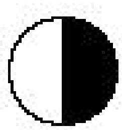
b. 

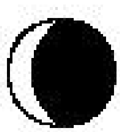
c. 

d. 

e. 

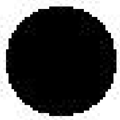
f. 

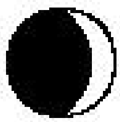
g. 

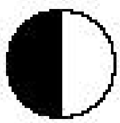
h. 

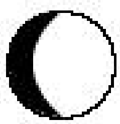
Question 6 (4 points)

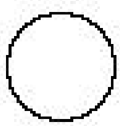
What would an observer on Earth see when the moon is in position 8 in Figure 1?

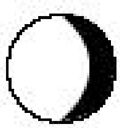
a. 

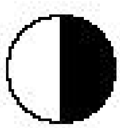
b. 

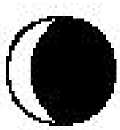
c. 

d. 

e. 

f. 

g. 

h. 

Question 7 (4 points)

It is possible to see the Moon during the daylight hours! Which position in Figure 1 represents a Moon which is only "up" during the day? (Hint: Which phase of the Moon is always up with the Sun?)

I

a. 1
b. 2
c. 3
d. 4
e. 5
f. 6
g. 7
h. 8

I

Question 8 (4 points)

Which position in Figure 1 represents a Moon which is up all night? (Hint: Which Moon position will not be in the sky while the Sun is above the horizon?)

I

a. 1
b. 2
c. 3
d. 4
e. 5
f. 6
g. 7
h. 8

I

Question 9 (4 points)

If the new Moon is up all day, and the full Moon is up all night, will the times of moonrise and moonset between these phases always be the same, or will they shift a little each day? Explain.

Equation: Equation editor

Question 10 (4 points)

Which phase is after the full Moon and halfway to the new Moon?

a. waning gibbous
b. waning crescent
c. waxing gibbous
d. third quarter
e. first quarter

Question 11 (4 points)

If the full Moon is up all night, during what part of the day/night cycle is the first quarter Moon in the sky? (Hint: Recall the first quarter Moon is halfway between the new and full phases.)

a. Sunset to midnight
b. Midnight to noon
c. Dawn to sunset
d. Noon to midnight
e. Sunset to dawn
f. About 9 AM to 9 PM

Question 12 (4 points)

During what part of the day/night cycle is the third quarter Moon in the sky?

a. Sunset to midnight
b. Midnight to noon
c. Dawn to sunset
d. Noon to midnight
e. Sunset to dawn
f. About 9 AM to 9 PM

Question 13 (4 points)

If you wanted to see a waning crescent Moon, which of the following times would you be able to see it?

a. just after sunset
b. at midnight
c. just before sunrise

Question 14 (4 points)

If you wanted to spend an entire night observing faint objects (like galaxies), you would want a "moonless sky". Which three phases of the eight would be the best?

a. full moon, waxing crescent, first quarter
b. new moon, waxing crescent, first quarter
c. waning gibbous, waning crescent, new moon
d. waning crescent, new moon, waxing crescent
e. waning crescent, full moon, waxing crescent
f. new moon, waning crescent, third quarter

Question 15 (4 points)

Keep in mind that the same side of the Moon faces the Earth as the Moon revolves in orbit. How does the Moon rotate on its axis as viewed in Figure 1?

a. clockwise
b. counterclockwise
c. top of moon is headed into the page
d. top of moon is headed out of the page

Question 16 (4 points)

Choose which phase (position in Figure 1) the moon can be in at the time of a lunar eclipse.

a. 1
b. 2
c. 3
d. 4
e. 5
f. 6
g. 7
h. 8

Question 17 (4 points)

A point source of light and an extended source of light have been set up on your laboratory table with an object to cast a shadow. Using a note card or piece of paper, hold the card close to the object and observe its shadow. Move the card away from the object to see the changes in the shadow as the card is drawn further away. Do this for each type of light source and describe what you see.

POINT SOURCE:

EXTENDED SOURCE:

Equation: Equation editor

Question 18 (5 points)

For the next four questions, look at Figure 4 on the Procedure page. Assume that the Moon is moving on Path C, directly through the center of the umbra.

What is the distance that the moon travels while any part of it is within the earth's umbra? (Hint: Be careful to think of a specific point on the moon, like the center perhaps, and how far it will travel while any part of the moon is being touched by the umbra.)

________ miles (give whole number only - no words or punctuation)

Answer:

Question 19 (5 points)

The Moon's average orbital speed is 2120 miles per hour. Estimate the maximum duration of the entire umbral part of the total lunar eclipse. (The umbral part of an eclipse is when any part of the Moon is in the umbra.) Use Path C in Figure 4. Express your answer as a whole number of minutes - give number only.

___________ minutes

Answer:

Question 20 (5 points)

What is the distance that the moon travels while it is entirely within the earth's umbra? (Hint: be careful to think of a specific point on the moon and how far it will travel while no part of the moon is outside the umbra.)

________ miles (Give whole number only, no words or punctuation)

Answer:

Question 21 (5 points)

Estimate the maximum time of totality. (Totality is when the Moon is completely within the umbra.) This will again require you to use Path C in Figure 4. Express your answer as a whole number of minutes.

___________ minutes

Answer:

Question 22 (4 points)

What phase (position in Figure 1) must the Moon be in during a solar eclipse, when the Moon's shadow falls over a portion of the Earth?

a. 1

b. 2

c. 3

d. 4

e. 5

f. 6

g. 7

h. 8

Question 23 (4 points)

Let us say you were watching a solar eclipse, standing right on the center of the spot where the umbra shadow of the Moon is directed toward the Earth. Let us also say that the umbra's cone did not quite reach the Earth, so you are standing in the Region of Transit. What type of eclipse are you seeing?

a. Total solar eclipse

b. Annular solar eclipse

c. Partial solar eclipse

d. Penumbral solar eclipse

Question 24 (4 points)

Go back to the exercise above with the bright light and the fruit (or ball) on a stick. Describe briefly how you can avoid having a 'lunar eclipse' when your head is the earth and the moon gets into opposition with the sun (your lamp).

Equation: Equation editor

Question 25 (4 points)

How does your previous answer (24.) relate to the inclination of the orbit described above?

Equation: Equation editor

Appendix D - Fall 2004 Lesson

Review from Introduction

Figure 1 shows the Earth-Moon system as viewed looking down on the Earth's north rotational pole. The eight numbered Moon positions are in sequence, showing that the Moon orbits around the Earth counterclockwise, starting at position 1, and moving in order to position 8. From this perspective, the Earth also rotates counterclockwise on its axis.

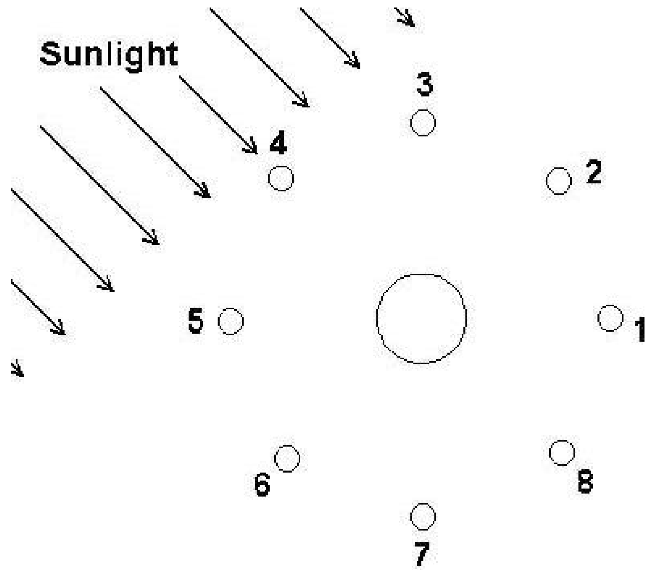


Figure 1

It takes the Moon about 3 1/2 days to move between two numbered positions. These changes are so slow that during any given night, the Moon appears to stay in essentially the same relative location with respect to the stars. Keep in mind that the apparent motion of the Moon across the sky in a single night is due to the rotation of the Earth.

The Phases

Now refer to the lunar phases illustration in your textbook. Read the caption and note any similarities to Figure 1 above. Note that Figure 1 differs slightly from the text image in that sunlight is drawn as coming from a different direction. You must account for this different direction to answer the first questions in the quiz.

To help you visualize the shadowing effects in Figure 1, you have been given a bright light (representing the Sun), and a model of the Earth/Moon system (not to scale). The Earth model can rotate on its axis as can the Moon model revolve around the Earth. The axis of the Earth and the orbit of the moon are tilted (In actuality, these tilts are independent of each other, the Earth being tilted 23 degrees and the Moon 5 degrees to the plane of the ecliptic. For our purposes in this lesson though, this model will suffice). Placed on the Earth sphere is a push pin to symbolize approximately the location of Orono, Maine. Adjust the Earth/Moon model, if necessary, so that the axis of inclination (Earth's tilt) is tilting away from the light source (Sun model). Look at the Earth-Moon model on your bench from the perpective illustrated in Figure 1. The light will be coming from one side. With this orientation, you are looking down on the Northern Hemisphere. Note how the Earth is illuminated by the Sun. Can you make out daytime and nighttime regions on the Earth model? Next, move the Moon in each of the eight positions shown in the figure, noting how the Moon is illuminated in each position. In each of the eight positions, how much of the Moon is lit by the Sun? Is it the same amount in all positions? Now view the moon from the perspective of being at the spot where the push pin marks Orono. If necessary rotate the Earth model so that the moon is visible from that orientation. How much of the part of the moon that is lit by the Sun can you see? How does this change as the Moon moves through the different positions in its orbit around the Earth? Discuss these questions with your group.

You should now be able to answer questions 1-6.

Moon Phases and Time of Day

For the next few questions, assume each day has 12 hours of daylight, and that the Moon is up the same amount of time each 24 hour day. Recall the Moon may be up in the sky in daylight and/or night. Why is this? Rotate the Earth on its axis and imagine you are standing on it. Notice the relationship on the Moon and the Sun with the moon in the eight different positions as the Earth rotates. Which heavenly body comes into view first (rises) as the Earth rotates? Which sets first? Does it change with the Moon in different positions? Experiment with the model and discuss this with your group.

Once you have finished this section, you will be able to tell what time of day and/or night to look for a particular phase of the Moon. This is also helpful if you want to know what time to look at the sky **without** a Moon.

You should now be able to answer questions 7-14.

Lunar Eclipses

Recall that the Earth always casts a shadow in space, since it is always lit by the Sun. The same is true for the Moon.

When the Moon passes directly between the Earth and the Sun, the Moon's shadow falls on the Earth. Observers in this shadow would not be able to see the Sun, because the Moon would be in the way. We call this a **solar eclipse**. You can simulate this by turning the Earth's axis so the tilt is perpendicular to the light source. Ask your instructor for assistance if needed.

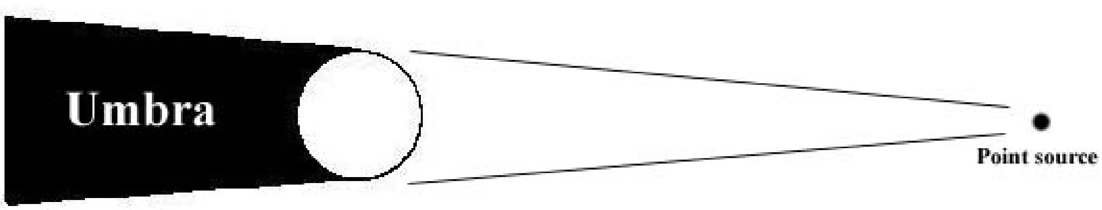


Figure 2

If the light source is a point source, an object will cast a dark, well-defined shadow called an **umbra** (See **Figure 2**). Viewing the light source from within the umbra, you would see the object casting the shadow completely "covers" or eclipses the light source.

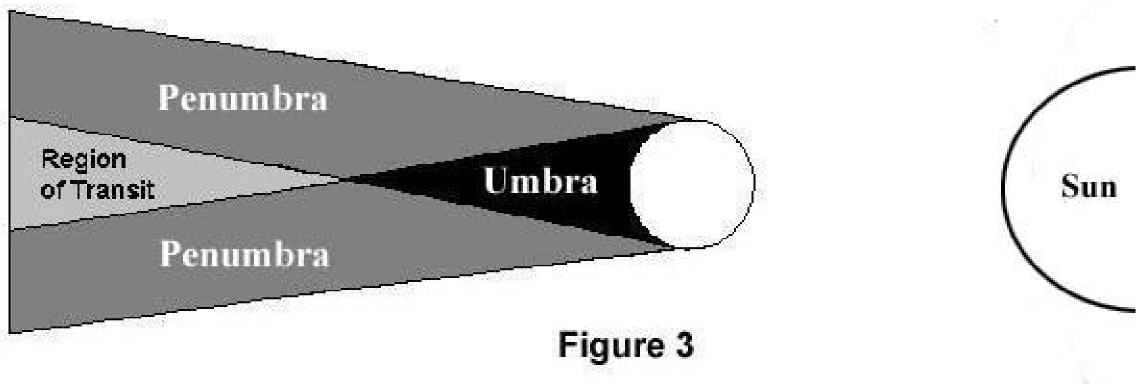


Figure 3

The Sun is not a point, but an extended light source. It will cast a shadow consisting of three distinct regions (See **Figure 3**). First is a dark cone, also called the **umbra**, from which the source is completely eclipsed. Around the umbra is a semi-dark region, called the **penumbra**, within which only some of the light is blocked. Finally, in an extension of the umbra cone, called the **region of transit**, the body casting the shadow would appear insufficient to "cover" the source and the light source would look like a ring or doughnut.

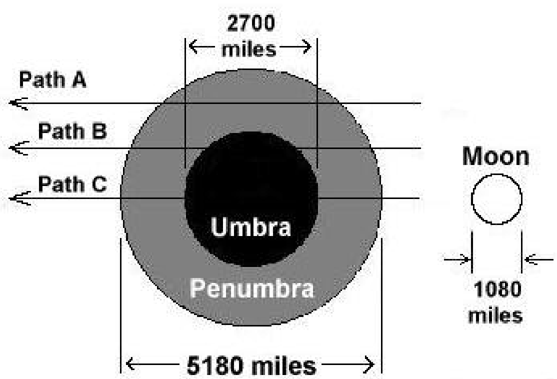


Figure 4

There are three types of lunar eclipses, each illustrated in the cross section of the Earth's shadow pictured above. Paths A and B are both paths where the Moon is partially eclipsed. Path C takes the Moon through roughly the middle of the umbra and results in a total lunar eclipse.

The shadows of Figure 4 have the dimensions of the Earth's umbra and penumbra at the average distance of the Moon. The diameter of the moon is included here, so that you can calculate the duration of a total eclipse with the moon passing through the center of the Earth's umbra.

You should now be able to complete the quiz.

Appendix E - Fall 2004 Quiz

Lesson 6

Name:

Start time:

Number of questions: 25

Question 1 (0 points)

Enter the names of everyone in your group.

Answer:

1.
2.
3.
4.

Question 2 (4 points)

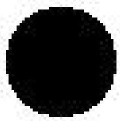
For this question, assume that the Sun, Earth and Moon are not aligned in a way as to produce an eclipse. Look down on the Earth/Moon model from the orientation of being above the North Pole of the Earth. At any point in its orbit around the Earth, how much of the Moon is illuminated by the Sun?

a. 0%
b. 16%
c. 33 1/3%
d. 45%
e. 50%
f. 78%
g. 100%

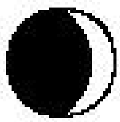
Question 3 (4 points)

What would an observer on Earth see when the moon is in position 3 in Figure 1?

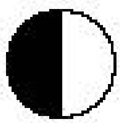
a.



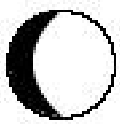
b.



c.



d.



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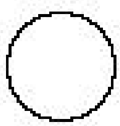

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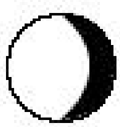

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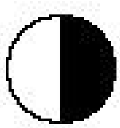
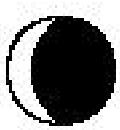
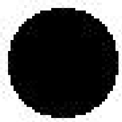


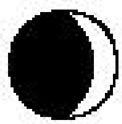
h.

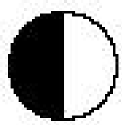


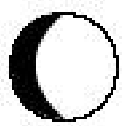
Question 4 (4 points)

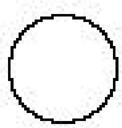
What would an observer on Earth see when the moon is in position 4 in Figure 1?

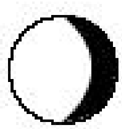
a. 

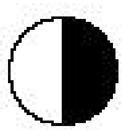
b. 

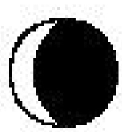
c. 

d. 

e. 

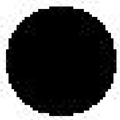
f. 

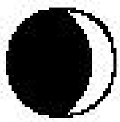
g. 

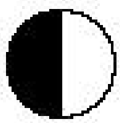
h. 

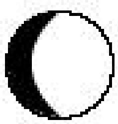
Question 5 (4 points)

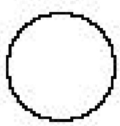
What would an observer on Earth see when the moon is in position 6 in Figure 1?

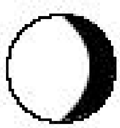
a. 

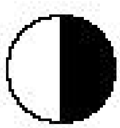
b. 

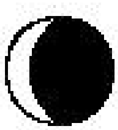
c. 

d. 

e. 

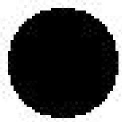
f. 

g. 

h. 

Question 6 (4 points)

What would an observer on Earth see when the moon is in position 8 in Figure 1?

a.


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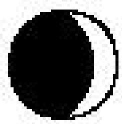

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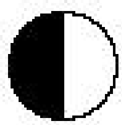

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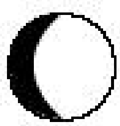

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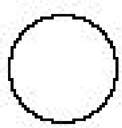

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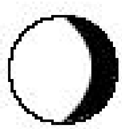
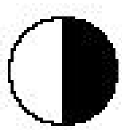
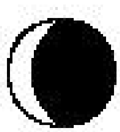


g.


h.


Question 7 (4 points)

It is possible to see the Moon during the daylight hours! Which position in Figure 1 represents a Moon which is only "up" during the day? (Hint: Which phase of the Moon is always up with the Sun?)

l

a. 1

b. 2

c. 3

d. 4

e. 5

f. 6

g. 7

h. 8

Question 8 (4 points)

Which position in Figure 1 represents a Moon which is up all night? (Hint: Which Moon position will not be in the sky while the Sun is above the horizon?)

l

a. 1

b. 2

c. 3

d. 4

e. 5

f. 6

g. 7

h. 8

Question 9 (4 points)

Will the times of moonrise and moonset between these phases always be the same, or will they shift a little each day? Explain.

Equation: Equation editor

Question 10 (4 points)

Which phase is after the full Moon and halfway to the new Moon?

a. waning gibbous
b. waning crescent
c. waxing gibbous
d. third quarter
e. first quarter

Question 11 (4 points)

During what part of the day/night cycle is the first quarter Moon in the sky? (Hint: Recall the first quarter Moon is halfway between the new and full phases.)

a. Sunset to midnight
b. Midnight to noon
c. Dawn to sunset
d. Noon to midnight
e. Sunset to dawn
f. About 9 AM to 9 PM

Question 12 (4 points)

During what part of the day/night cycle is the third quarter Moon in the sky?

a. Sunset to midnight
b. Midnight to noon
c. Dawn to sunset
d. Noon to midnight
e. Sunset to dawn
f. About 9 AM to 9 PM

Question 13 (4 points)

If you wanted to see a waning crescent Moon, which of the following times would you be able to see it?

a. just after sunset
b. at midnight
c. just before sunrise

Question 14 (4 points)

If you wanted to spend an entire night observing faint objects (like galaxies), you would want a "moonless sky". Which three phases of the eight would be the best?

a. full moon, waxing crescent, first quarter
b. new moon, waxing crescent, first quarter
c. waning gibbous, waning crescent, new moon
d. waning crescent, new moon, waxing crescent
e. waning crescent, full moon, waxing crescent
f. new moon, waning crescent, third quarter

Question 15 (4 points)

Keep in mind that the same side of the Moon faces the Earth as the Moon revolves in orbit. How does the Moon rotate on its axis as viewed in Figure 1?

a. clockwise

b. counterclockwise

c. top of moon rotates into the page

d. the moon does not rotate

Question 16 (4 points)

Choose which phase (position in Figure 1) the moon must be in at the time of a lunar eclipse.

a. 1

b. 2

c. 3

d. 4

e. 5

f. 6

g. 7

h. 8

Question 17 (4 points)

The lamp you have been using as a Sun model represents an extended source of light. Observe the shadow generated with this light source by placing the Moon model near it and holding the screen provided behind the Moon model. Move the screen back and forth as necessary. Now simulate a point source of light by sliding the card with the pinhole down into the lamp holder in front of the light bulb. Again, observe the shadow the Moon model generates with this different light source. Record your observations below.

POINT SOURCE:

EXTENDED SOURCE:

Equation: Equation editor

Question 18 (5 points)

For the next four questions, look at Figure 4 on the Procedure page. Assume that the Moon is moving on Path C, directly through the center of the umbra.

What is the distance that the moon travels while *any* part of it is within the earth's umbra? (Hint: Be careful to think of a specific point on the moon. Pick one point, like its leading edge and measue how far it will travel while any part of the moon is being touched by the umbra.)

________ miles (give whole number only - no words or punctuation)

Answer:

Question 19 (5 points)

The Moon's average orbital speed is 2120 miles per hour. Estimate the maximum duration of the entire umbral part of the total lunar eclipse. (The umbral part of an eclipse is when *any* part of the Moon is in the umbra.) Use Path C in Figure 4. Express your answer as a whole number of minutes - give number only.

___________ minutes

Answer:

Question 20 (5 points)

What is the distance that the moon travels while it is entirely within the earth's umbra? (Hint: be careful to think of a specific point on the moon as in Question 18..)

________ miles (Give whole number only, no words or punctuation)

Answer:

Question 21 (5 points)

Estimate the maximum time of totality. (Totality is when the Moon is completely within the umbra.) This will again require you to use Path C in Figure 4. Express your answer as a whole number of minutes.

___________ minutes

Answer:

Question 22 (4 points)

What phase (position in Figure 1) must the Moon be in during a solar eclipse, when the Moon's shadow falls over a portion of the Earth?

a. 1

b. 2

c. 3

d. 4

e. 5

f. 6

g. 7

h. 8

Question 23 (4 points)

Let us say you were watching a solar eclipse, standing right on the center of the spot where the umbra shadow of the Moon is directed toward the Earth. Let us also say that the umbra's cone did not quite reach the Earth, so you are standing in the Region of Transit. What type of eclipse are you seeing?

a. Total solar eclipse

b. Annular solar eclipse

c. Partial solar eclipse

d. Penumbral solar eclipse

Question 24 (4 points)

From working with the Sun and Earth/Moon models, what can you say about what is needed in order for an eclipse not to occur?

Equation: Equation editor

Question 25 (4 points)

How does your previous answer (24.) relate to the tilt of the Moon's orbit?

Equation: Equation editor

Appendix F - Lesson 7 Pretest

Lesson 7 Pretest

Name:

Start time:

Number of questions: 10

Question 1 (1 point)

Introduction: What causes the movement of the stars across the night sky?

a. The stars' orbits around the center of the Milky Way Galaxy

b. The motion of the Earth

c. The stars' orbits around the Earth

d. The tidal force of the Moon

Question 2 (1 point)

Which of the following statements are true about Polaris(the North Star)? **Select all possible answers.**

a. **IN ORDER TO GET CREDIT FOR THIS QUESTION, YOU MUST SELECT THIS ANSWER ALONG WITH YOUR OTHERS.**

b. Polaris will always be the "North Star."

c. Polaris is directly overhead.

d. Polaris is located exactly at the North Celestial Pole.

e. Polaris is in the constellation Ursa Minor.

f. Polaris is the star Santa Claus uses to navigate on Christmas eve.

g. Polaris is the brightest star in the sky.

Question 3 (1 point)

Introduction: What are the horizontal and vertical lines drawn on the celestial sphere?

a. Right ascension and declination

b. Latitude and longitude

c. X-coordinates and Y-coordinates

Question 4 (1 point)

What are the units of right ascension (how we measure east and west on the sky)?

a. Years, days, hours
b. Hours, minutes, seconds
c. Degrees, arcminutes, arcseconds
d. Yards, feet, inches
e. Pounds, fortnights, bushels

Question 5 (1 point)

Introduction: What is the relationship of night and day during an equinox?

a. Night is at its longest
b. Day is at its longest
c. Night and day are equal
d. Impossible to tell
e. Night and day length have no relation to the equinox

Question 6 (1 point)

What are the units of declination (how we measure north and south on the sky)?

a. Years, days, hours
b. Hours, minutes, seconds
c. Degrees, arcminutes, arcseconds
d. Yards, feet, inches
e. Pounds, fortnights, bushels

Question 7 (1 point)

The Earth's rotation axis is tilted with respect to the plane of Earth's orbit. In degrees, approximately what is the angle between the equator and the orbital plane?

a. 10
b. 23
c. 34
d. 47
e. 360

Question 8 (1 point)

The Moon is most likely to be high in the sky at_________.

I

a. 6:00 AM
b. 6:00 PM
c. the North Pole
d. midnight
e. noon
f. anytime day or night

Question 9 (1 point)

The phases of the moon are caused by

I

a. clouds blocking our view of the entire Moon.
b. the Moon deflating and then inflating again.
c. Earth's shadow falling on the Moon.
d. the fraction of the Moon that is lit by the Sun.
e. the position of the Moon in its orbit around Earth.
f. Earth's gravity pulling the moon into different shapes.

Question 10 (1 point)

A moon in the phase shown below would_________.

a. set before sunset.

b. rise after sunset.

c. neither rise nor set.

d. set after sunset.

e. rise at sunset.

BIOGRAPHY OF AUTHOR

James (Jace) Cohen was born in New York City on February 17, 1954. He was raised in Pound Ridge, New York and Stamford, Connecticut and graduated from the Taft School in Watertown, Connecticut in 1972. He attended Syracuse University and the University of Maine and graduated from the University of Maine in 2003 with a Bachelor of Arts in Physics and a Minor in Astronomy. Since then he has been pursuing a Master of Science in Teaching through the Center for Mathematics and Science Education Research at the University of Maine.

Upon completion of the Masters program, he plans to teach physics and math at a school in Maine.