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Researching Effective Methods for
Teaching the Phases of the Moon

Heather Patti Jones

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of
Master of Science

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ABSTRACT

Researching Effective Methods For Teaching the Phases of the Moon

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This study investigated the effectiveness of commonly used instructional methods for teaching the phases of the Moon to fifth and sixth grade students. The instructional methods investigated were the use of diagrams, animations, and models. The effectiveness of each method was tested by measuring students' understanding of Moon phases with a pre and post-assessment after receiving instruction with a specific method or combination of methods. These methods were then evaluated for their ability to help students learn essential concepts, reinforce relevant vocabulary and discourage misconceptions. Results showed that students had better scores with less prevalence of misconception when they were taught using two methods instead of one. Students taught with only computer animations had significantly lower scores and a higher prevalence of misconceptions when compared to the other methods. This may be due to some design errors in the animation used in this study. Even though students taught with only computer animations had significantly lower scores, students taught with computer animations followed by instruction with diagrams had significantly higher scores. Why this combination of instruction was more effective for student learning is a question that requires further research.

Keywords: moon phases, misconceptions, diagrams, models, computer animations

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Chapter 1

Introduction and Background

In 1996, the National Science Education Standards (NSES) were published as part of the National Standards Based Education movement that began in 1989 with the formation of the National Education Goals Panel by President George H. W. Bush. After Math Science Education Standards were released, the National Science Teachers Association (NSTA) in 1991 wrote to the president of the National Research Council asking for the development of the NSES. These were published five years later. The purpose of the NSES as described by the National Research Council ([1996](#)) is to “spell out a vision of science education that will make scientific literacy for all a reality in the 21st century.” What is scientific literacy? According to the same report, it means, “A person can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means that a person has the ability to describe, explain, and predict natural phenomena.” ([National Research Council \(1996\)](#)). This includes natural phenomena seen in the sky such as the phases of the Moon.

Making national goals for scientific literacy was difficult because each state has its own set of policies and standards for education. In an effort to make curriculum more assessable and congruent between states, the NSES was designed to, “provide states with a roadmap to use when creating their own standards.” ([Hollweg & Hill \(2003\)](#)). This roadmap includes an outline of standards for science teaching and professional development, as well as content.

The NSES recommendations for space science education content standards are broad and loosely defined for a range of grade levels as seen in [Table 1.1](#). As you can see, Earth and solar

system astronomy topics are concentrated in the K-4 and 5-8 grade levels while cosmology is emphasized in grades 9-12.

Table 1.1 NSES Earth and space science education content standards

Levels K-4	Levels 5-8	Levels 9-12
<ul style="list-style-type: none"> • Properties of Earth materials • Objects in the sky • Changes in Earth and sky 	<ul style="list-style-type: none"> • Structure of the Earth system • Earth’s history • Earth in the solar system 	<ul style="list-style-type: none"> • Energy in the Earth system • Geochemical cycles • Origin and evolution of the Earth system • Origin and evolution of the Universe

The National Research Council (1996) in the NSES states, “A major goal of science in the middle grades is for students to develop an understanding of Earth and the solar system as a set of closely coupled systems...Most objects in the solar system are in regular and predictable motion. Those motions explain such phenomena as the day, the year, phases of the Moon, and eclipses.” It is important that students understand these concepts because astronomy is an everyday part of life. We all live on the Earth, feel the Sun, and see the stars every day.

Understanding as much as we can about the world around us is what the pursuit of science is all about! Tony Darnell (2011) stated in his article, “Why Astronomy is Important,” when he said, “Knowing and understanding the stage on which your life is being played is crucial for any existence to have real meaning.”

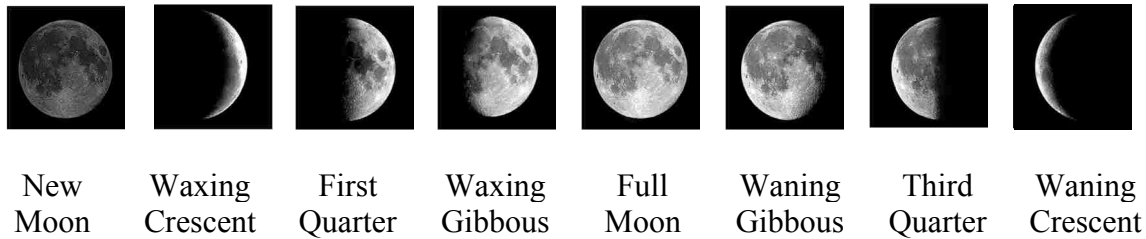
1.1 How Do Phases of the Moon Occur

If we must have “the ability to describe, explain, and predict natural phenomena,” (National Research Council (1996)) to be scientifically literate, then learning astronomy is essential.

Astronomy is the study of many natural phenomena that can be seen daily with our own eyes. No microscope or special detector is needed to see the Sun, stars, visible planets, and the Moon. The

Moon can be seen nearly every day, and with each passing day its appearance changes, slowly changing from new Moon to a full Moon and then back to a new Moon as seen in [Figure 1.1](#).

This naturally occurring phenomenon is called the phases of the Moon. But why does the appearance of the Moon change?



Photographs: Copyright Antonio Cidadao. Used by permission

Figure 1.1: Lunar Cycle

First we must understand that the Moon emits no light of its own but only is visible because it reflects light from the Sun. The Sun is always illuminating half of the Moon. The Moon orbits around the Earth once in approximately 27 days. As it orbits, the orientation of the Earth, Moon and Sun changes, and the amount of the Moon's illuminated surface that can be seen from Earth also changes. This causes the changing appearance of the Moon, called the phases the Moon. The Moon goes through one cycle of Moon phases every 29.5 days. When the Moon's fully illuminated side can be seen from Earth it is called a Full Moon. When the Sun is shining on the far side of the Moon we can't see any of the illuminated surface and the Moon cannot be seen. This phase is called a New Moon. A day or two after a New Moon, the Moon will have moved enough on its orbit to be able to see a small sliver of the Moon illuminated by the Sun. This is called a Waxing Crescent. It is waxing because over the next few days the Moon's visible surface will wax, or become greater and greater, and we will see more of it. When the Moon is waxing, the light from the Sun comes from the right side of the Moon. So its right side is lit

while its left side is dark. Approximately seven days after the New Moon, one quarter of the Moon's spherical surface will be reflects sunlight. This phase is called First Quarter, because one quarter of the Moon's surface is visible and it is one quarter of the way through the Moon's cycle. As more of the Moon's surface reflects the light of the Sun, we can see most of the Moon's surface but not all of it yet. This is called a Waxing Gibbous. Approximately fourteen days after the New Moon, the Moon is now Full. The Sun and Moon are on now on opposite sides of the Earth. Over the next few days, the Moon will begin to wane or waste away and we will be able to see less and less of the Moon's illuminated surface. During a waning Moon, the light from the Sun will come from the left side. So now the left side of the Moon will be lit while the right side is dark. When most of the Moon is lit but some of the visible right side is not, the phase of the Moon is called a Waning Gibbous. A few days later, again a quarter of the Moon's spherical surface will be visible but this time on the left side. This is the Third Quarter Moon and we are three quarters of the way through the Moon's cycle. The last Moon phase is the Waning Crescent, when there is a crescent shaped lit portion of the Moon on the left side. Soon the Moon will be a New Moon again and the cycle will start over again like it does every month. Because of the changing location of the moon with respect to the earth, certain moon phases can only be seen at certain times of night. . A New Moon and a Waxing or Waning Crescent are generally seen during the day. A full Moon is only seen at night. It rises when the Sun is setting and descends below the horizon in the morning when the Sun is rising. A quarter Moon phase is always 90 degrees from the Sun, so it can be seen during parts of both day and night. Although we are able to see more and more of the Moon as it approaches it full phase, we always see the same side of the Moon. This is because the Moon is in a synchronous rotational orbit with the

Earth. It always faces its same side towards the Earth. This is because the Moon is tidally locked by the gravitational pull of the Earth.

1.2 The Problem

After any instruction, students should have an improved understanding of concepts previously not understood. However, in a summary of results of Moon phases education studies assembled by Trundle et al. (2002), as seen in [Table 1.2](#), shows only a low average of 27.8% improvement in correct scientific conceptions of Moon phases after instruction. The participants of these studies vary in age and circumstances ranging from 1st grade students to college astronomy students. It seems that often, regardless of instruction, students maintain incorrect concepts of how Moon phases occur. Additionally there are several common misconceptions that hinder students. Most prevalent is the eclipse misconception, the belief that the Moon's phases are caused by the Earth casting its shadow on the Moon. An average of 50.3% of students was found with the eclipse misconception in [Table 1.2](#). Even the NSES states, "By grades 5-8, students have a clear notion about...the relative positions of the Earth, Sun, and Moon. Nevertheless, more than half of the students will not be able to use these models to explain the phases of the Moon." ([National Research Council \(1996\)](#)). This admission by the NSES seems to set a low standard for astronomy education. Unfortunately, there are no further recommendations to help clarify this concept in grades 9-12. This is not in keeping with the goals of the NSES to have "...all student achieve scientific literacy." ([National Research Council \(1996\)](#)).

There is strong evidence that lack of student understanding may be due to lack of teacher understanding. Trundle et al. in 2002 assessed 42 pre-service elementary teachers and found that only 9.5% of the group had correct scientific conceptions of the phases of the Moon. These

numbers are consistent with other studies as seen on Figure 1.2, such as Callison & Wright (1993), which found that out of 76 elementary pre-service teachers, only 6.6% had correct concepts of Moon phases. A few years later in 1995, Schoon reported only 18% with correct scientific understanding of Moon phases out of 122 pre-service teachers!

Table 1.2 Summary of Previous Moon Phase Education Studies

Author	Participants	N	Most Common Alternative Conception	% of Participants with Scientific Conception	Data-Gathering Method
Baxter (1989)	9–16-year-old students	120	Eclipse	Not indicated	Interviews (<i>n</i> =20) Multiple choice items (<i>n</i> =100)
Bisard et al. (1994)	Middle school through college	708	Eclipse (37.6%)	39.2%	Multiple choice items
Callison & Wright (1993)	Elem. preservice teachers	76	Eclipse	Pre=6.6% Post=22.4%	Interviews and Targan test
Dai & Capie (1990)	Elem. preservice teachers	174	Eclipse	Not indicated	Multiple choice items
Haupt (1950)	1st-grade students	21	Clouds	0%	Interviews
Kueth (1963)	Males entering college	100	Eclipse (70%)	Not indicated	Multiple choice items
Sadler (1987)	9–12th-grade students	213	Eclipse (37%)	Pre=37% Post=60%	Multiple choice items
Schoon (1992)	College students	226	Eclipse (69.5%)	26.1%	Multiple choice items
Schoon (1992)	5th, 8th, and 11th-grade and college students	1213	Eclipse (48.1%)	34.3%	Multiple choice items
Schoon (1995)	Elem. preservice teachers	122	Eclipse (62.3%)	18%	Multiple choice items
Stahly et al. (1999)	3rd-grade students	4	Nonscientific	0%	Interviews and observations
Targan (1988)	College nonscience majors	61	Eclipse Pre=14.8% Post=8.2%	Pre=1.6% Post=18%	Open-ended questions with written responses
Zeilik et al. (1999)	College astronomy students	498	Eclipse (28%)	Pre=31% Post=60%	Multiple choice items

1.3 Why Is It So Hard?

Students' difficulty with learning Moon phases has fascinated researchers. There are several theories why this is such a challenging topic. As discussed in the last section, lack of teacher understanding may easily account for much of the apparent confusion. Teachers may be transmitting incorrect Moon phase concepts and may even teach the eclipse misconception. This may have occurred for generations, compounding the problem by parents now perpetuating misconceptions as well as teachers.

Alternatively, students may be coming to school with their own preconceptions about the Moon. According to Vosniadou & Brewer ([1994](#)), "Children are not blank slates when they are first exposed to the culturally accepted, scientific views, but bring to the acquisition task some initial knowledge about the physical world which appears to be based on interpretations of everyday experience." Students do have everyday experiences with the Moon. It can be seen on most days or night and changes its appearance daily. It is reasonable to assume that students have already come up with their own ideas on how the Moon changes its appearance. However, even after instruction, students sometimes resist changes to their preconceptions as found by Hermann & Lewis ([2003](#)).

The most prevalent misconception is the eclipse misconception, which may come from a misunderstanding of the geometry and motion of the Earth, Moon, and Sun. It may be possible that students do not yet have the spatial reasoning skill to deal with these difficult concepts. Stahly et al. ([1999](#)) stated, "Elementary children are not developmentally and academically prepared for the complex conception of the lunar phase phenomena." Likewise, Hobson ([2008](#)) recommends in reference to the Moon phases, "More research is needed to determine if the expectation, outlined by the national standards, are appropriate."

Even when students do seem to understand the geometry of the bodies that cause the Moon phases, they often defer back to the incorrect eclipse method. Subramaniam & Padalkar (2009) suggests that this may be because, “Typical diagrams of the Earth, Sun, Moon system exaggerate the size of the Earth and the Moon and under-represent distances. If such large bodies move in close proximity and a source of light is aligned with them, it appears inevitable that the shadow of the Earth would fall frequently on the Moon.” This problem with scale is apparent in textbooks and computer animations where the Earth and Moon are drawn larger and the Sun smaller and all much closer together so they will all fit on the page. Even models used in the classroom are often not to scale because they must be big enough for the entire class to see and fit inside the classroom. For example, if a basketball were used to model the Earth, the Moon would be about the size of a tennis ball and they would be approximately 7.3 meters apart (~24 feet, around the size of a typical classroom). Then the Sun would need to be 26 meters in diameter and approximately 2.8 km away! This is far too large to be practical in a classroom setting.

With the increased pressure on teachers to cover more and more content each year in their classrooms they have less and less time to dedicate class time towards astronomical concepts. This squeeze on class time may not be allowing students enough time to obtain correct scientific conceptions of Moon phases. “Research suggests that conceptual change is a gradual, slow reorganization of existing knowledge structures.” (Hobson (2008)). Trundle et al. (2002) were able to achieve an 80% improvement with pre-service elementary school teachers, but that was after three weeks of instruction!

1.4 The Start of a Solution

The low standard of learning set in the NSES and the disappointing statistics in pre-service teacher training paints a gloomy picture for the future of astronomy education. Scientific literacy means, “A person has the ability to describe, explain, and predict natural phenomena.” ([National Research Council \(1996\)](#)). This includes the Moon phases, which can be seen nearly every day. Although it is a concept that can be a difficult to teach, there is no reason to set such low standards for astronomy literacy. It is very apparent that efforts need to be made to improve teacher training. Additionally research should be done to find the most effective methods for teaching these difficult concepts. Effective techniques can help supplement current teacher training so instruction can best be disseminated to the students and help them internalize and retain it. Some approaches may be better at discouraging the prevalent eclipse misconception than others. The beginning of this journey is assessing the effectiveness of currently used teaching methods for the phases of the Moon as done in this research.

1.5 Common Teaching Methods Used

All teachers have their own bag of tricks they use to help students understand concepts. Although every teacher’s style and pedagogy is different, there are some common methods often used by teachers. Such is the case with teaching the phases of the Moon. Some of the traditional methods used to teaching this concept are:

- Diagrams: Drawings and charts to show the position and motion of the Earth, Moon, and Sun for each phase.
- Animations: Computer animations to show the motion and position of the Earth, Moon, and Sun for each phase.
- Models: Three-dimensional models that can be manipulated in a hands-on setting to represent the motion and position of the Earth, Moon, and Sun system for each phase.

Each of these methods emphasizes the positions of the Earth, Moon, and Sun for each of the Moon phases. Visualization of the Earth, Moon, and Sun system is essential for understanding and explaining how the phases occur. Researching the effectiveness of each of these teaching methods used singly and in combination is the purpose of this study.

Chapter 2

Procedures

2.1 Research Questions

The previously mentioned teaching methods each give a different perspective on how the phases of the Moon occur. Each method has pros and cons associated with it. The diagram teaching method (DTM) is good for showing the Earth, Moon, and Sun system as a whole, but not so good at demonstrating how these objects move. The models teaching method (MTM) is good for showing how the Moon reflects the light of the Sun and how its changing position effects it's appearance from Earth. The computer animation teaching model (CATM) is good for showing how the Earth and Moon move around the Sun and each other. These teaching methods

are often used in combination or independently. If they are used independently, which one is the best to use? If two are used in combination, which two would be best? Does the order in which the methods are used make a difference? Is one method or combination of methods more effective than another? If teachers, as they often do, have a limited amount of time with which to teach a concept, which method or combination of methods is best? The purpose of this study is to assess these different methods independently and in combination to answer the following questions:

1. What single method is most effective for teaching Moon phases?
2. What combination of two methods is most effective for teaching the phases of the Moon?
3. Does the order in which two methods are taught make a difference in student comprehension?
4. Which methods are best for discouraging misconceptions?

2.2 Procedures

To answer these questions, each method needed to be tested in an authentic school setting. Aspects of the instructional methods, as a potential confounding variable, would need to be held relatively constant; the only difference being the visual and demonstrational aids used. Although college students at BYU are abundant, it was decided that elementary school children would be used because that is the age when students are first introduced to the phases of the Moon. The target age of students taught was chosen to be 5th-6th grade based on the Utah Science Core Curriculum ([Utah State Board of Education \(2002\)](#)), which recommend the phases of the Moon to be taught during the sixth grade:

Standard 1: Students will understand that the appearance of the Moon changes in a predictable cycle as it orbits Earth and as Earth rotates on its axis

Objective 1: Explain patterns of changes in the appearance of the Moon as it orbits

Objective 2: Demonstrate how the relative positions of Earth the Moon and the Sun create the appearance of the Moon's phases.

After receiving IRB approval from Brigham Young University, we approached Alpine School District and they granted permission for this study, see [Appendix A](#). Alpine School District covers 9 cities and includes over 51 Elementary schools. Principals and teachers from each school were personally contacted and asked if they would be willing to participate in this study.

Before students were taught, participating teachers were met with and told what to expect. Teachers were provided with the pre-test instrument to administer to students before instruction; they were also given the IRB informed consent document and asked to send it to parents explaining the project and their children's participation. Signed parental consent was not required for this study as the instruction is a required part of the educational curriculum and as such considered low risk. Teachers were asked not to teach the Moon phases or astronomy related material until after the post-test was administered. Unfortunately not all teachers followed this instruction as seen in [Chapter 5.2](#).

Instruction was provided by the research team to control for any confounding teacher effects, students were kept in their original classroom groups and taught using different methods as shown in Table 2.1. Originally the study was designed to randomly mix the students into three different groups before instruction began. This way the student's original schoolteacher and classroom dynamics would not be a factor in their final test scores. For instance an elementary

teacher may emphasize listening skills while another teacher emphasizes teamwork. These differences could affect to the final results. Randomly reorganizing the students would effectively eliminate this variable. Although sound in theory, it was not practical in execution. Moving the students around was discovered to be stressful and confusing on the teachers and students during the first school visit and was discontinued. Twenty-four to thirty-six hours after the pre-test was administered, specially trained BYU students

Table 2.1. Study Groups

School	Group	Instruction	School	Group	Instruction
#1	A	DTM	#3	A	D/CATM*
	B	CATM		B	CA/MTM *
	C	MTM		C	M/DTM *
#2	A	DTM	#4	A	CA/DTM *
	B	CATM		B	M/CATM *
	C	MTM		C	D/MTM *

DTM= Diagrams Teaching Method,
 CATM= Computer Animation Teaching Method,
 MTM= Models Teaching Method
 * First day instruction/second day instruction teaching method

taught the elementary students about Moon phases. These BYU students were astronomy or science education majors, trained to present the material in the same order and manner regardless of the method used. First the BYU student instructors were trained to first introduce the names of the phase of the Moon using the same images and labels then explained why the phases of the Moon occur using DTM, CATM or MTM. They were also trained to avoid inadvertently introducing misconceptions when teaching concepts or vocabulary skills by avoiding words like “shadow” which may encourage the eclipse misconception, or “half Moon,” an incorrect term frequently used to describe a quarter Moon phase.

Instruction was typically 40 minutes, with some variations depending on the method used. For example, teaching with CATM often required on average 10-15 minutes extra time to cover the same material. This was due to extra time needed for transporting students to the computer lab and teaching them how to use the program. This time difference was considered unimportant because the extra time was not spent specifically on teaching about Moon phases.

After 15 minutes of instruction on the vocabulary of Moon phases, students were quizzed on the terms they learned. Then the main part of the instruction began as the instructor explained why Moon phases occur using DTM, CATM or MTM to illustrate the concept (for more detail please refer to [Chapter 3](#)). Students were then given diagrams, a computer animation program or model to help them complete a worksheet as seen in [Appendix F](#). The worksheet required students to complete a diagram (a different diagram than used in DTM to instruct). For some questions, they were asked to draw and label the Moon phases when the Earth, Sun and Moon were in certain positions for a Moon phase. Other questions asked them to draw the correct position for a given Moon phase. All students, regardless of teaching method, were required to complete the same worksheet. This may, however have introduced a bias towards diagrams as discussed in [Chapter 5.4](#). Students were then post-tested 24-36 hour after instruction.

Chapter 3

Instructional Methods Lesson Plans

Each lesson plan for the instructional method tested was designed to maintain the integrity of this study. The DTM only used diagrams to teach, the MTM used only models, and CATM only used a computer. Each lesson was separately provided as an unique instructional method in order for the methods to be compared.

3.1 Diagrams

Teaching the phases of the Moon with diagrams is fairly straightforward. The instructor uses a chalkboard or PowerPoint to draw/display the diagram seen in [Figure 3.1](#), and uses it to demonstrate how the changing position of the Earth, Moon and Sun cause the phases of the Moon to occur. This is a very traditional approach. The diagram used to instruct was the same with every class, with the Sun always on the right side of the diagram.

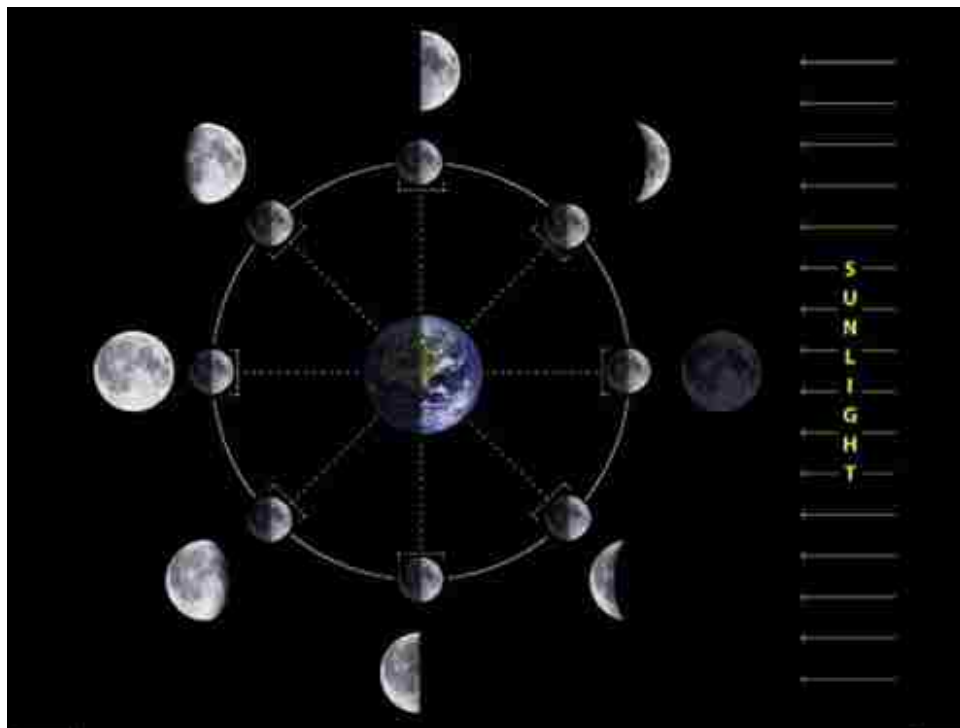


Figure 3.1: Moon Phases Diagram

3.2 Models

The models used were made from large plastic white dimpled balls that were then attached to wooden dowels as seen in [Figure 3.2](#). Before handing out these models to students, the instructor would demonstrate why and how Moon phases occur. In this instructional method

the model of the Moon is orbiting around the Earth (the instructors head); a bright lamp in a darkened classroom is used to simulate the Sun. As the simulation models the effect students see the various phases.



Figure 3.2: Moon Model

3.3 Computer Animations

A BYU Student under the direction of Mike Jones, a professor in the Computer Science Department, created the animation program used in this study. This program was specifically designed to be minimalistic. There is no extra text explaining how the Moon phases occur, and there is no text for labeling the phases of the Moon. The main purpose of this animation was to

provide a visual representation of the Moon phases that could be easily manipulated by students. Built into the animation was a easy to navigate menu that allowed students to toggle between a view of the Earth, Moon and Sun system as seen in [Figure 3.3](#), a view of the Earth and Moon system as seen [Figure 3.4](#), or a view of the Moon as seen from Earth as seen in [Figure 3.5](#). Students were also able to pause the animation, advance the date one day at a time, or increase/decrease the rate at which the animation played with the menu options.

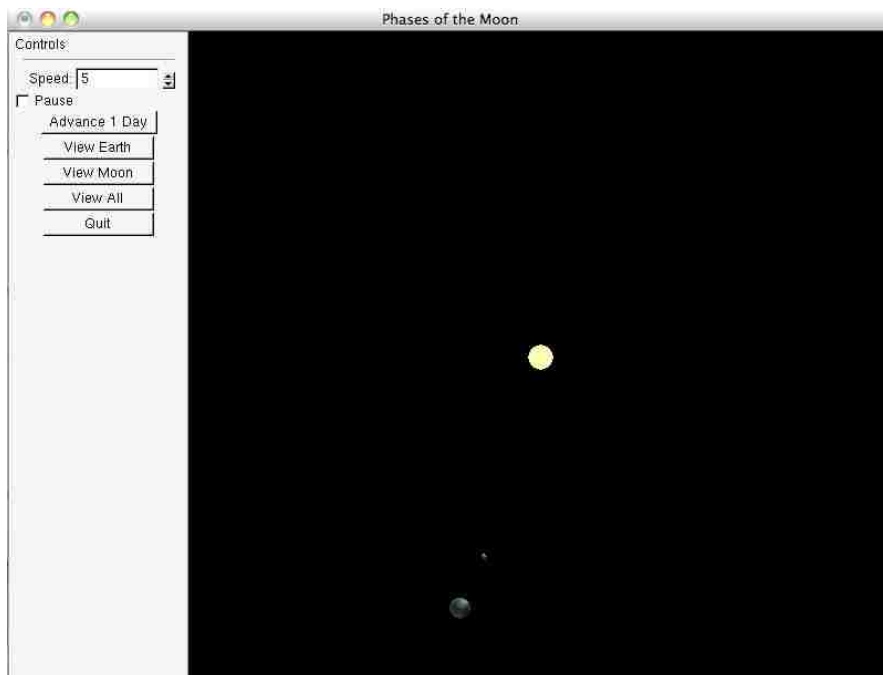


Figure 3.3: Computer Animation Earth, Moon and Sun View

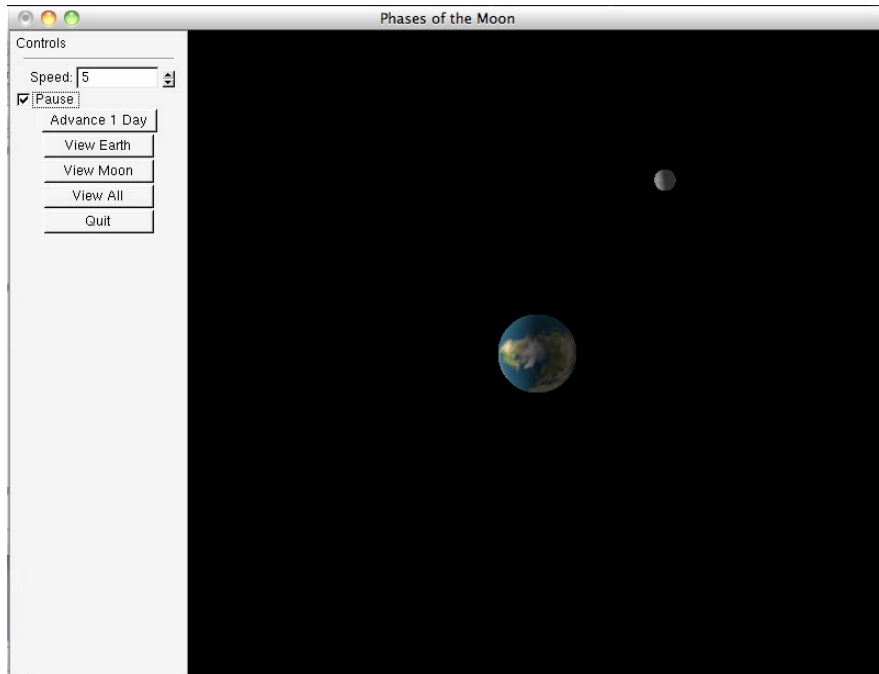


Figure 3.4: Computer Animation View of the Earth and Moon System

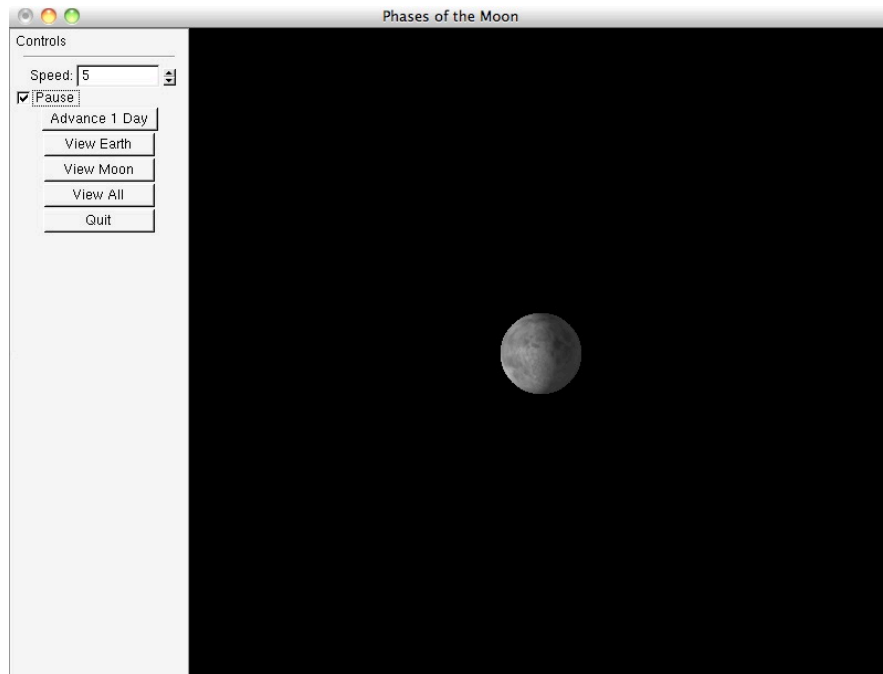


Figure 3.5: Computer Animation View of the Moon as Seen From Earth

The reason for this uncluttered approach was to maintain the integrity of the study. All other teaching methods studied do not include written descriptions and the animation program was designed to be similar. Like the other teaching methods, the instructor used this instructional medium to explain why the Moon phases occur and then allowed the students to manipulate it for themselves while they completed the worksheet.

Chapter 4

Data Collection and Assessment

4.1 Assessment

In order to compare methods, an assessment instrument was developed to determine a student's level of understanding regardless of the teaching method used. The Moon Phases Pre/Post Test was developed using the revision/validation process described below. This test contains a variety of questions including two demographics questions, three short answers, four multiple-choice questions, and one essay question. Each question is geared towards assessing the student's mastery of the relative positions of the Earth, Moon, and Sun for each phase, as well as their ability to correctly identify Moon phases, and the reason why Moon phases occur. To see a copy of this test please refer to [Appendix B](#).

This test was first pilot tested in several beginning astronomy classes at Brigham Young University, then with three elementary age students who were thoroughly interviewed afterward to improve the questions clarity and thus the validity of the results. The most significant change made to the test in its early stages was the wording of the essay question, which originally read:

“Using complete sentences, write a paragraph explaining **WHY** the Moon has phases. Be sure to be clear and specific in your explanation.”

Regardless of the emphasis on the word “why”, the majority of students answered this question by explaining that the Moon is visible at night because it reflects the light of the Sun. This was not the question asked, but repeatedly was the way in which it was answered. They described why the Moon shines but not why it has phases. After some experimentation the wording of the question was changed to read as follows:

“Explain why *changes in the Moon’s appearance* occur every month with a written paragraph in the space below. Be sure to write clearly and that your explanation is complete.”

With this new wording, students started answering the intended question, often providing a drawn picture in addition to a written paragraph as can be seen in the example essay responses in [Appendix D](#). Why the exclusion of the word “phases” had such a significant impact on the student responses requires further study.

4.2 Misconception Indicators

One of the purposes of the pre/post-test is to measure the prevalence of students’ misconceptions. Embedded within the test are several key questions designed to detect the presence of any misconceptions. These indicators were tracked and scored to measure the level of a student’s misconceptions. See [Appendix D](#) for the misconception indicators rubric. These misconceptions were tracked by following responses typical of someone having misconceptions, especially the common eclipse misconception. For instance, question # 7, which asks the students to correctly position a new moon relative to the Earth and Sun allows us to clearly determine the presence of the eclipse misconception. A student with this misconception believes a new Moon will occur “when the Moon is in the Earth’s shadow.” Question # 9 is the inverse

of question #7. Students with misconceptions sometimes remember or conclude that the Moon's full Moon position is opposite of the new Moon position and incorrectly place the Moon between the Sun and the Earth for a full Moon phase. But this answer is not as strong an indicator as question #7 and is weighted less in the final misconception score. Less frequently, a student will realize a full Moon is impossible when the Moon is between the Earth and the Sun. In an effort to compromise between preserving their misconceptions and their scientific reasoning, a student with this partial misconception will choose response C, a gibbous position of the Moon for a full Moon position. Rationalizing that the Moon is "peeking out" from behind the Earth enough to be fully illuminated for a full Moon. Again, this is a less common response and is not as heavily weighted.

Misconception response D is the essay section of the test and considered the strongest indicator of misconceptions. The essay section of the test was carefully read and coded with the level of the student's understanding: full understanding (F.U.), No Understanding (N.U.) or inconclusive (I.C.) for when it was unclear if there were any misconceptions or not. See the essay rubric in [Appendix D](#) for more detail. All these responses together are applied to [Formula 4.1](#), which is weighted to the severity of each indicator then totaled to give an overall, measurable score for the prevalence of a student's misconceptions.

$$A(2)+B(1)+ C(0.5)+D(3) = \text{Misconception Score} \quad (4.1)$$

A=1 if misconception response A is selected

B=1 if misconception response B is selected

C=1 if misconception response C is selected

D=1 if misconceptions are detected in the student's essay response.

Chapter 5

Data and Analysis

5.1 Data

The following data were recorded from pre/post tests and quizzes, then compiled into a single database:

- a. Student ID# (assigned)
- b. School
- c. Grade level
- d. Elementary school teacher
- e. Moon phases instructor(s)
- f. Age
- g. Gender
- h. Vocabulary quiz score
- i. Method(s) used during instruction
- j. Pre-test answers and overall score
- k. Post-test answers and overall score
- l. Misconception score

After this data was compiled, a quality check was run on it to insure the information was transferred correctly. Every fifth entry in the final database was compared against its original documents, out of hundreds of tests; only one data entry error was found and corrected.

5.2 Excluded Data

The intended population for this study was fifth and sixth grade students with little to no prior knowledge of Moon phases and how they occur. Amongst the data collected there were several outliers that did not fit this population and were accordingly excluded. The outliers were excluded from this data set and the reason for their exclusion is summarized in [Table 5.1](#).

Table 5.1. Outliers

Data Set	Reason for Exclusion
School # 2	This was the first school to participate in this study. During instruction there were multiple technical and instructional problems that corrupted the integrity of this data set. These problems were resolved before visiting other schools.
School # 8 School # 9	These schools were taught as an intended extension of this study to researching the effectiveness of using the planetarium as a teaching method. However, because these data sets are incomplete, this aspect of the study was not included in this report.
School # 10 Class # 26 Class # 27	There was significant evidence that the students in these groups had been taught Moon phases before this study, despite the teachers having been asked to postpone teaching the subject. The student's prior knowledge compromised the analysis and it was not included in the final analysis.
Class # 6	This class was extremely undisciplined. Their schoolteacher made no effort to help maintain order in the classroom, possibly because he was due to retire in a few short weeks. This class was unusually distracted and cannot be considered a typical fifth/sixth grade class. They were not included in the final analysis
Class # 24	This was the school district's class for gifted students. These were not typical students. They were knowledgeable about moon phases before instruction and consequently were not included in the final data set for analysis.
Class # 19 Class # 29	This was a combined fifth/sixth grade class where the phases of the Moon had already been taught because of the mixed curriculum. They were not included in the final data set.
Student # 62816	This student was the only 13 year old in the entire data set. It was assumed that this was not a typical 6 th grader compared to the rest of their class and therefore not included in the final data set.
Others	Approximately 800 elementary school students were assessed during the duration of this study. Unfortunately 39% of the data was incomplete. This may be due to students' absence during instruction or testing. Consequently these data sets were not used in the final analysis.

5.3 Analysis

There were many variables in this study that could not be controlled, such as:

- Elementary school teachers
- Student's economic circumstances
- Variations between Moon phases instructors
- Timing (students were not all taught at the same time of day)
- Class size
- Foreknowledge of Moon phases

To determine if these uncontrollable variables are negligible, two separate univariate analysis of variance (ANOVA) tests were performed to determine the comparability of the treatment groups. These tests were used to determine if groups of students were significantly different from each other in terms of prior knowledge and their ability to learn new material. To determine comparability between these groups based on prior knowledge, an ANOVA was applied to students pre-test scores to determine whether significant differences existed between groups of students assigned to the various treatments. With a p -value of $F(8, 366) = 1.60, p = 0.123$ we can assume that the students on average had comparable foreknowledge of Moon phases. A second ANOVA test was used to see if students from the various groups could assimilate and apply new knowledge similarly, by comparing results of the vocabulary quiz scores. Since all students involved were provided identical training on this part of the content and then assessed immediately afterwards, differences in vocabulary quiz scores by treatment group might indicate the presence of a confounding variable. With a p -value of $F(8, 366) = 1.79, p = 0.076$, we can assume that students in these groups were comparable in terms of their ability to incorporate new knowledge. Additionally we might reasonably assume that some of the other potentially confounding factors, like the variations in Moon phase instructors as well as elementary school teachers, were not significant. Since all groups seemed to be similar in terms of prior knowledge

and ability to learn they are comparable. We can now determine with a univariate analysis of variance using a Tukey HSD post hoc test:

1. What single method is most effective for teaching Moon phases?
2. What combination of two methods is most effective for teaching the phase of the Moon?
3. Does the order in which two methods are taught make a difference in student comprehension?
4. Which method(s) is best for discouraging misconceptions?

5.4 Limitations

Unfortunately there is some uncertainty in misconception and post-test data. The assessment itself may favor diagrams instruction. Fifty percent of the questions on the pre/post test require students to complete a diagram. This same style of diagram is used in the pre-test as well as the worksheet used with all methods. Between the diagram on the worksheet and the pre/post tests, students may have been biased towards diagrams, possibly skewing the study results.

The animations may have also skewed some of the results as well. When the animations were designed on campus it contained an unexpected error. One of the viewing options for the program, a Moon-centered view, was not made with the correct Sun/Moon scale. The Sun instead, is abnormally large causing a solar eclipse or near eclipse to occur during every new Moon as seen in [Figure 5.1](#).

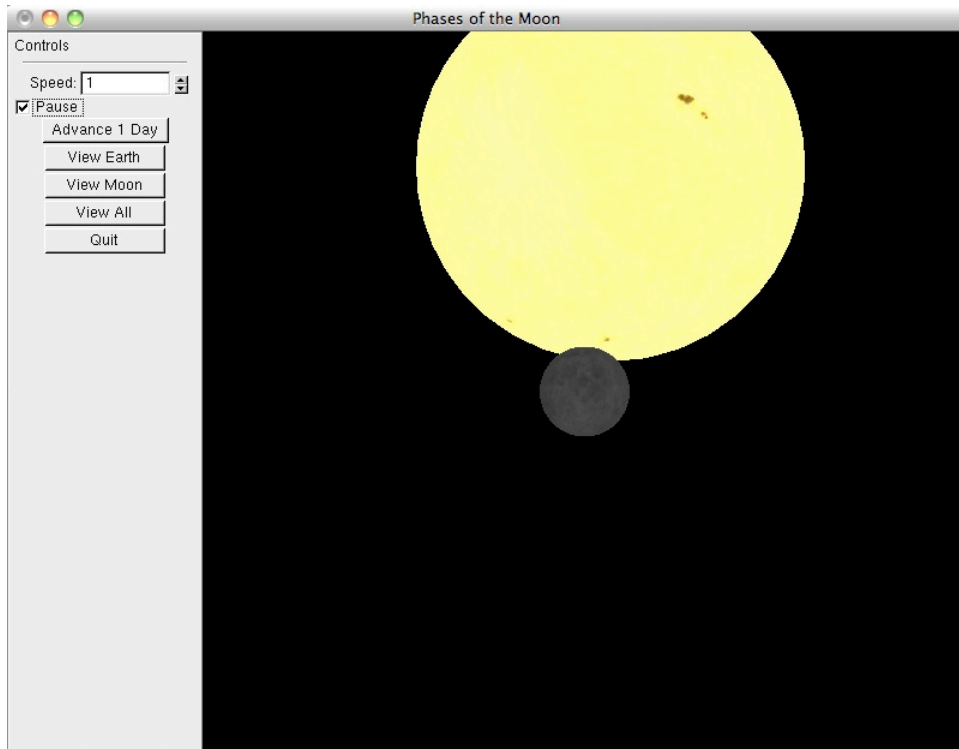


Figure 5.1: Computer Animation Error

Unfortunately, the original animator who designed the program was unable to correct this issue before the study began. Despite this problem, CATM was part one of the instructional methods used in the top scoring method CA/DTM.

Chapter 6

Conclusions and Discussion

6.1 Results

An analysis of variance of the post-test scores for the different methods tested resulted in a gradient of mean scores as seen in [Figure 6.1](#). Out of a possible 14 points, the highest scoring method was CA/DTM with a mean score of 11.30 ($SD=3.36$), and the lowest scoring method

was CATM with a mean score of 5.62 ($SD=3.85$) see [Table 6.1](#). The Tukey HSD post hoc for the post-test results, as summarized in Table 6.2, showed the CA/DTM method had statistically higher scores than CATM, DTM, MTM and M/CATM with a p-value of 0.018 or less. This test also showed the CATM teaching method scored significantly lower than all the other methods with a p-value of 0.014 or less. The Tukey HSD post hoc results also show other significantly different groups in the middle of the distribution. MTM, DTM and M/CATM, are each significantly different from other teaching methods on opposite ends of the distribution as summarized in [Table 6.2](#). This data can be organized into groups of homogeneous subsets by mean scores as seen in [Table 6.3](#), for easier analysis.

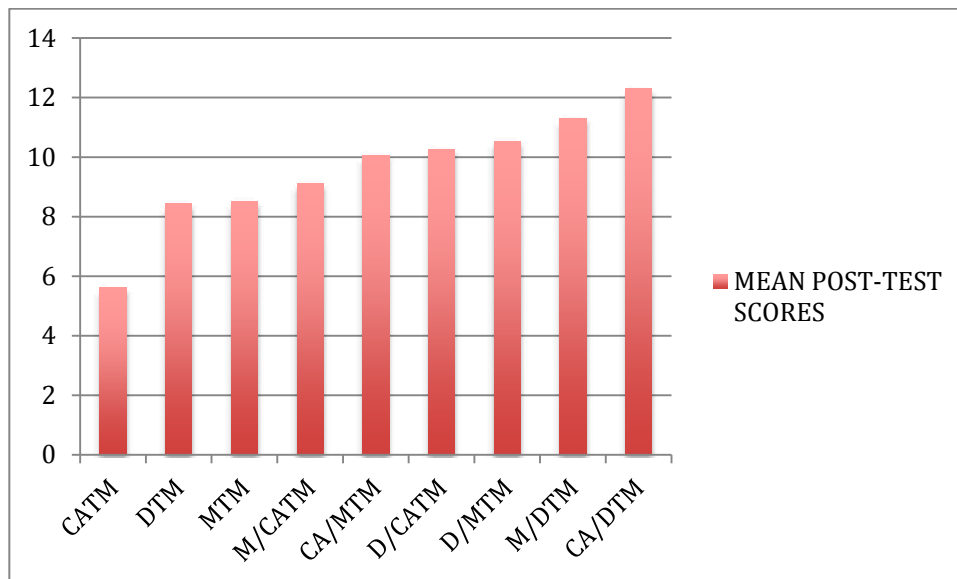


Figure 6.1: Mean Post-Test Scores

Table 6.1. Post-Test Scores

Method	Mean	Std. Deviation	N
CATM	5.62	3.85	37
MTM	8.44	3.71	54
DTM	8.52	4.71	44
M/CATM	9.11	3.60	47
CA/MTM	10.07	3.23	27
D/CATM	10.27	3.36	45
D/MTM	10.53	3.87	49
M/DTM	11.30	3.36	40
CA/DTM	12.29	2.16	24
Total	9.44	4.02	367

Table 6.2. Summary of Tukey HSD Post Hoc for Post-test Results

(I) Method	(J) Method	Sig.
CATM	DTM	.014
	MTM	.011
	CA/DTM	.000
	CA/MTM	.000
	D/CATM	.000
	D/MTM	.000
	M/CATM	.001
	M/DTM	.000
DTM	CATM	.014
	CA/DTM	.002
	M/DTM	.018
MTM	CATM	0.11
	CA/DTM	.001
	M/DTM	.007
M/CATM	CATM	.001
	CA/DTM	.018
CA/DTM	CATM	.000
	DTM	.002
	MTM	.001
	M/CATM	.018

Table 6.3. Homogeneous Subsets Based on Observed Post-test Means

Method	N	Subset			
		1	2	3	4
CATM	37	5.62			
MTM	54		8.44		
DTM	44		8.52		
M/CATM	47		9.11	9.11	
CA/MTM	27		10.07	10.07	10.07
D/CATM	45		10.27	10.27	10.27
D/MTM	49		10.53	10.53	10.53
M/DTM	40			11.30	11.30
CA/DTM	24				12.29
Sig.		1.000	.247	.188	.177

The misconception scores, analyzed similarly, showed an opposite gradient of scores (compare [Figure 6.1](#) and [Figure 6.2](#)).

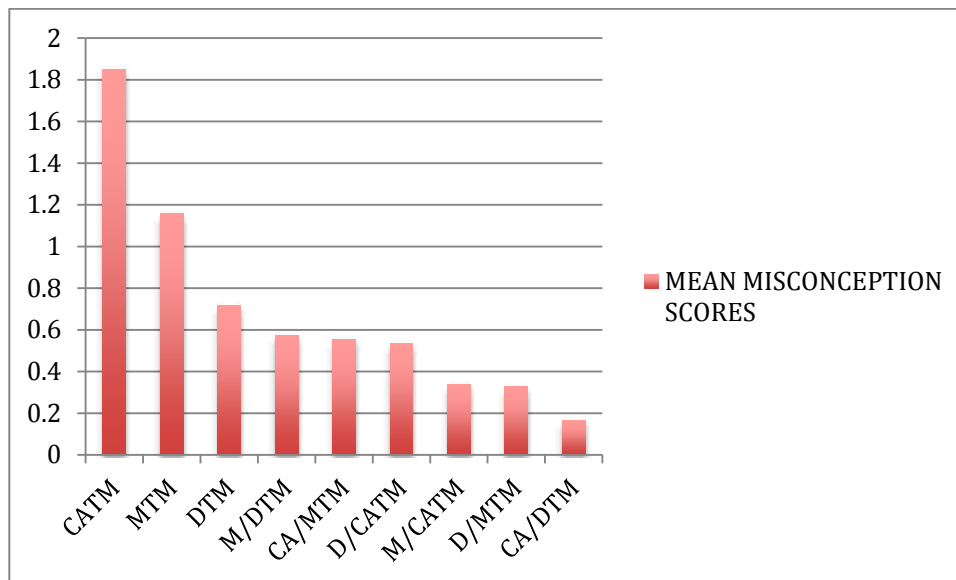


Figure 6.2: Post-test Mean Misconception Scores

Out of a possible 6.5 points CATM had the highest misconception mean score of 1.85 ($SD=1.89$); CA/DTM had the lowest mean score of 0.17 ($SD=0.64$) as summarized in [Table 6.4](#).

The high standard deviations of these means are expected because the misconception scores have a bimodal distribution; either the students had the misconception or they did not. The Tukey

HSD post hoc test showed CATM had significantly higher misconception scores than DTM, CA/DTM, CA/MTM, D/MTM, M/CATM, D/CATM and M/DTM with p-values of 0.007 or less as seen in [Table 6.5](#).

Table 6.4. Misconception Scores

Method	Mean	Std. Deviation	N
CATM	1.85	1.89	37
MTM	1.16	1.93	54
DTM	0.72	1.21	44
M/DTM	0.58	1.52	40
CA/MTM	0.56	1.19	27
D/CATM	0.53	1.32	45
M/CATM	0.34	0.92	47
D/MTM	0.33	0.92	49
CA/DTM	0.17	0.64	24
Total	0.71	1.44	367

Table 6.5. Summary of Tukey HSD Post Hoc for Misconception Scores

(I) Method	(J) Method	Sig.
CATM	DTM	.008
	CA/DTM	.000
	CA/MTM	.007
	D/CATM	.001
	D/MTM	.000
	M/CATM	.000
	M/DTM	.002

6.2 Conclusions

The results of this research show that within the parameters of this study, there was a statistical difference between several of the teaching methods used. Students taught using CATM had significantly lower scores and significantly higher indicators of misconception. However, their poor performance may be due to errors in the computer animation used as well as a bias in the assessment towards the diagrams as discussed in [Chapter 5.4](#). Students were also

observed to become easily distracted after moving from their class to the computer room and when using the computers.

Students who were taught using CA/DTM performed much better with significantly higher scores and significantly lower misconception scores. This however, may be due to the small sample of CA/DTM with N=24, or one class of students. Multiple classes were taught using this method but unfortunately those data sets were thrown out for various reasons explained in [Chapter 5.2](#). It's possible that this method performed better because this class was able to absorb new information better than the other classes.

Narrowing the view to single instructional methods, we can see that CATM scored significantly lower than the other single day instructional methods, but again this may be due to the animation error. Without further research testing different varieties of animations we cannot generalize this result to all moon phase animations, but we can conclude that instruction with our animation was not as effective as the other two single instruction methods. So what is the answer to the first research questions, what single method was most effective for teaching Moon phases? MTM did score higher in misconception scores than DTM, but that may be due to the diagram bias in the test. However, despite the diagram bias, students taught with MTM scored slightly higher on the post-test than students taught with DTM. Overall differences between DTM and MTM were not scientifically significant, and of the three methods tested DTM and MTM were the most effective, however they were not as effective as dual teaching methods.

In answer to the second research question, what combination of two methods was most effective for teaching the phases of the Moon, the data is a little more straightforward. All of the dual instructional methods scored statistically similar in misconception scores and only M/CATM scored significantly lower than the only dual methods on the post-test. This may be

because this is one of the two dual methods without diagrams. The other method without diagrams, CA/MTM may have performed slightly better because CA was taught first followed by MTM. Any misconceptions or misunderstandings the students had after instruction with CATM was possibly corrected after instruction with MTM. With the lower scoring M/CATM method, any misunderstanding the students had after instruction with MTM may not have been corrected but rather strengthened after instruction with CATM. This answers the third research question, does the order with which the dual instruction methods are taught matter? For CA/MTM and M/CATM it does matter.

Focusing again on the second question, which dual teaching method is most effective, we now see that all of the dual instructional methods, except M/CATM did similarly well and were all effective at teaching the phases of the moon with a special emphasis on CA/DTM which had the highest post-test scores and the lowest misconception scores.

So overall what can be recommended to teachers trying to instruct effectively? Looking beyond the best and worst performing methods, there is a broader conclusion that can be derived from these results. We can see this with a simple inspection of averages. Single method instructional methods averaged 7.5 on the post-test while the combined instructional methods averaged 10.6. Students understood the concept better when they were taught with more than one method. This is probably due to increased instruction time and the benefit of seeing information presented in different ways. For instance, when students were taught with just CATM, they did not master the concept of moon phases and may have developed misconceptions from the animation error. But, when followed by another teaching method misconceptions and misunderstandings were remedied and correct concepts strengthened, as evidence in the higher post-test scores and lower misconception scores. To discern which

variable, increased instruction time or the combination of different methods affected the test scores the most requires further research. However for the purposes of this study, I strongly recommend using multiple teaching methods when teaching the phases of the moon. Students will not master the concept as well if instruction depends on one method or activity.

Unfortunately, all of these findings are not entirely conclusive due to the assessment bias and computer animation errors. More research needs to be done to refine the data.

6.3 Additional Observations

In the process of teaching the phases of the moon using different methods, different challenges were encountered with each method.

- **Diagrams** - Although this teaching method is very direct, instructors had to be careful when using a white board or a chalkboard to clearly state if the colored in side of the Moon indicated the shaded or illuminated side of the Moon. The bright white of a white board and the black and white of a chalkboard often confused students. This same problem can occur in black and white worksheets.
- **Models** - Teaching with models can be difficult with a large class because all the students will see a different Moon phase from their desk depending on the location of the “Sun”. For instance, you may be trying to demonstrate a full Moon at the front of the class, and a student sitting right in front of you will see a full moon; but a student on the right side of the room will see a first quarter moon. This also made it difficult for students to complete the worksheet. Instructors took care to tell students to pay attention to the location of the Sun on their worksheet and compare it to the location of the “Sun” in their

model. Students were also encouraged to rotate their worksheets so the images on the worksheet would mirror the location of the Earth, Moon and Sun in their model.

- **Computer Animations** – Most classes that participated in this study were required to transfer to a computer room during instruction for CATM. This transfer was distracting to students, requiring a lot more time to refocus the students on the task at hand. The students also tended to be distracted after instruction, playing with the animation or other programs on their computer, but not completing their worksheet. Students also had frequent problems completing their worksheet with the computers. Because of the changing positions of the Earth, Sun and Moon on the computer screen changed frequently, they did not match their positions on their worksheet. Students were encouraged to note the location of the Sun on their worksheets and then rotate their worksheets to match the position of the celestial bodies on their computer screen as done with the MTM. Another challenge when instructing with CATM, is the program itself distracted the students. They often amused themselves by increasing the rate the moon orbited the earth until it was a blur on the screen. This made it difficult for instructors to keep students on task.

Also of interest was the essay portion of the pre/post-tests. A review of previous research on Moon phases education seen in [Table 1.2](#), lists the misconceptions encountered by other studies. By far, the most common misconception was the eclipse misconception. However, during the course of this study, several other types of misconceptions were observed. These misconceptions were unusual and infrequent but worth noting:

- **Destruction Misconception:** The belief that the Moon is destroyed each month and then gravitationally reformed from the debris.
- **Variable Distance Misconception:** The Moon moves closer and farther away from the Earth causing the changes in the Moon's appearance
- **Moldable Moon Misconception:** The Moon's appearance changes because its physical shape is distorted by gravitational and/or centrifugal force as it orbits around the Earth.
- **Atmospheric Effect:** The Earth's weather and/or atmosphere affect the appearance of the Moon.

6.4 Future Research

More research is needed to conclusively answer which method is the best for teaching the phases of the Moon. This research should be repeated with animations that have the correct scale when viewing the Moon up close. In future studies, students should be assessed by interview instead of a written test to eliminate the diagram assessment bias.

Also, additional research is needed to determine if the increased instruction time or combination of teaching methods was the main attributor to the better test scores. This can be done by teaching the same class over two consecutive days with only one of the three methods and comparing it to the existing data.

Additionally, one more instructional method should be added to this research: teaching with the Moon itself. It is common for teachers to ask students to make observations of the Moon to learn its phases. Students may watch, sketch and/or mark its position and appearance throughout the month. This method is difficult to test because it requires a full month's worth of participation instead of one afternoon. In that time it would be very challenging to maintain the

integrity of the study as well as guarantee consistent student participation. However, a planetarium can be used to simulate several nights of student's observations in a short amount of time all within a controlled environment. This research should be expanded to include instruction of Moon phases with a planetarium.

Overall, this study was not intended to answer why students seem to perform better with one method than another. That is an area that requires further study. This study is intended to form a baseline to compare how different instructional methods affect students learning of Moon phases. This study can now be expanded to include other populations of students and see how they differ. For instance, do hearing impaired students favor a models method for its visual three-dimensional aspect or do they learn better with diagrams? If so, why or why not? This is an area that requires more study.

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APPENDIX A

ALPINE SCHOOL DISTRICT LETTER OF APPROVAL



CONSTITUTIONAL HISTORY

THE CONSTITUTION OF THE UNITED STATES

BY

WILLIAM E. SHUTZ

AND

JOHN H. GARRETT

OF THE UNIVERSITY OF MICHIGAN

ANN ARBOR, MICHIGAN

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APPENDIX B

MOON PHASES PRE/POST TEST

Name: _____ Teacher: _____ Grade: _____ Date: _____

Moon Phases Pre-Test

Answer all of the following questions to the best of your ability.

1. What is your age? _____

2. What is your gender?

- a. Male
- b. Female

Directions for questions: Identify the Moon phases for questions #3-5 by writing the name of the phase underneath the picture in the space provided.

EXAMPLE



Full Moon



3. _____




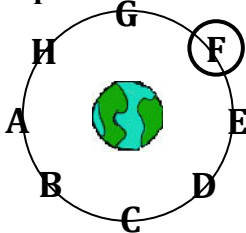
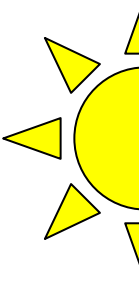

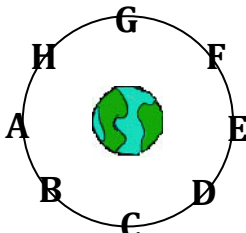
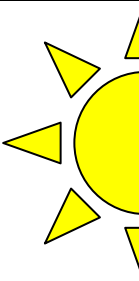

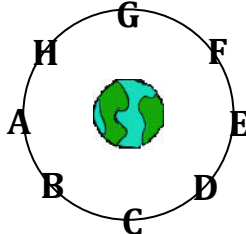
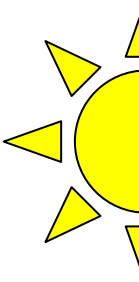
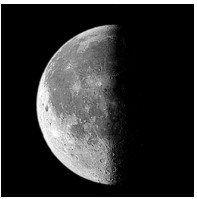
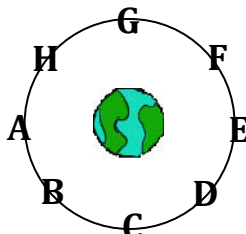
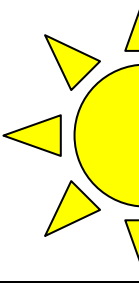

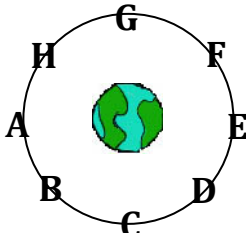
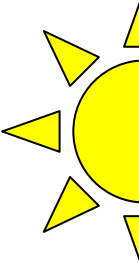
4. _____



5. _____

Directions:

In the right-hand column, circle the position A-H where the Moon would be in its orbit around the Earth for the phase indicated in the left column.

Moon Phase	Moon's Orbit	
<p>Example:</p> 	<p>Example:</p> 	
<p>6.</p> 		
<p>7.</p> 		
<p>8.</p> 		
<p>9.</p> 		

10. Explain why *changes in the Moon's appearance* occur every month with a written paragraph in the space below. Be sure to write clearly and that your explanation is complete.

APPENDIX C

MOON PHASES PRE/POST TEST RUBRIC

Name: _____ Teacher: _____ Grade: _____ Date: _____

Moon Phases Pre/Post-Test Rubric
(14 points possible)

Answer all of the following questions to the best of your ability.

3. What is your age? _____

4. What is your gender?

- c. Male
- d. Female

Directions for questions: Identify the Moon phases for questions #3-5 by writing the name of the phase underneath the picture in the space provided. (One point for each correct word for a total of 6 points)

EXAMPLE



Full Moon



3. FIRST QUARTER



4. WANING CREASCENT

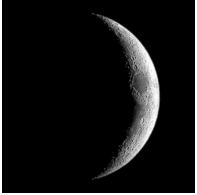
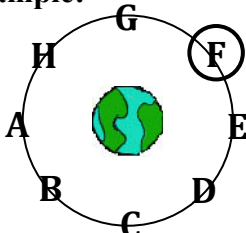
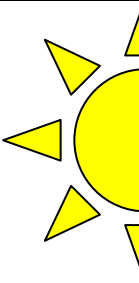

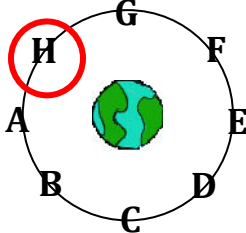
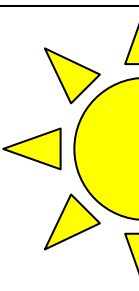
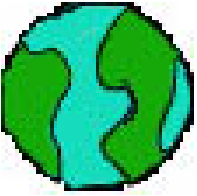
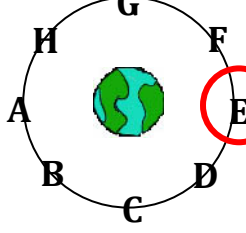
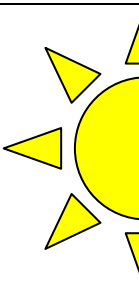

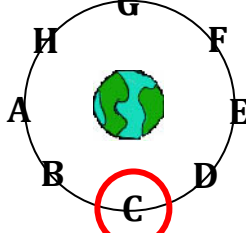
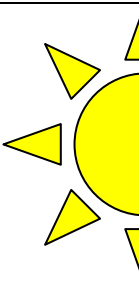

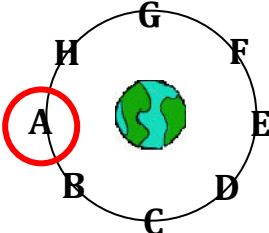
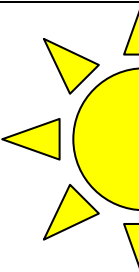


5. WAXING GIBBOUS

Directions:

In the right-hand column, circle the position A-H where the Moon would be in its orbit around the Earth for the phase indicated in the left column.

(two points for each correct position for a total of 8 points)

	Moon Phase	Moon's Orbit	
<p>Example:</p> 	<p>Example:</p>  		
<p>11.</p> 	 		
<p>12.</p> 	 		
<p>13.</p> 	 		
<p>14.</p> 	 		

15. Explain why *changes in the Moon's appearance* occur every month with a written paragraph in the space below. Be sure to write clearly and that your explanation is complete.

(No point values possible. See essay scoring guidelines below)

Essay Scoring

Label the essay responses as either full understanding, inconclusive, or no understanding based on the guidelines below. Additionally, label the test for the eclipse misconception if there is strong evidence for it also using the guidelines listed below.

Essay Scoring Guidelines

Inconclusive – Student indicates a partial understanding of the phases of the Moon in their description, but does not provide a full explanation.

- Describes the Earth and/or Moon is in motion but doesn't describe what they move around.
- Describes the motion of the Earth/Moon is the reason for the changes in the Moon appearance but doesn't explain how.
- Explains that Sunlight shines on the Moon at different angles without explaining how.
- Mention of a shadow on the Moon but doesn't indicate where the shadow is from.

No Understanding – Student does not describe a correctly why the phases of the Moon occur.

- Describes an incorrectly the positions of the Earth, Moon, and/or Sun.
- Describes an incorrectly the relative motions of the Earth, Moon, and/or Sun.
- Describes an incorrectly how the Moon is illuminated
- Question marks drawn or essay section left blank

Full Understanding – Student indicates and full understanding of why the phases of the Moon occur

- Shows a correct understanding of motion and position of the Earth Moon and Sun.
- Shows a correct understanding of how the Moon is illuminated
- No indication of Earth's shadow

Misconception – Student explains the phases of the Moon using the shadow of a planet.

- Mentions Earth blocking the light of the Sun
- Any description of the Earth blocking the Moon from the Sun's light
- Any mention of the Moon being in Earth's shadow
- Description of the full Moon Earth, Sun, and Moon relative positions, but describes it as a new Moon.
- Describes the Moon in full Moon phases when it is in a gibbous position or "peeking out" from behind the Earth.
- Student draws a picture with the eclipse misconception apparent such as a new Moon in the full Moon position.

Example Essay Responses

Student #51512 Post-Test Essay Response

Score: Full Understanding

10. Explain why *changes in the moon's appearance* occur every month with a written paragraph in the space below. Be sure to write clearly and that your explanation is complete.

When the moon is closest to the sun the spot where it's facing the sun is lit up and on the other side it's dark. it changes because whatever angle it is a certain spots will be lit up depending on what angle the sun is and the moon is.

The student clearly understood that half of the Moon is illuminated, half is not and we cannot always see the illuminated half. They also accurately described the Moon reflecting the light of the Sun. Additionally the student explained that the changing angle of Sunlight is the reason for the Moon's phases. Although the student did not mention the motion of the Earth and Moon, there is enough in this description to assume that this student knows how the phases of the Moon occur.

Student #51531 Post-Test Essay Response

Score: Full Understanding

10. Explain why *changes in the moon's appearance* occur every month with a written paragraph in the space below. Be sure to write clearly and that your explanation is complete.

Because the moon goes around the earth and the angle that the light from the sun hits the moon can make it appear from earth that the moon is changing. What causes the moon to glow is the dust on the moon, so when the sun's light hits it, it reflects off and glows.

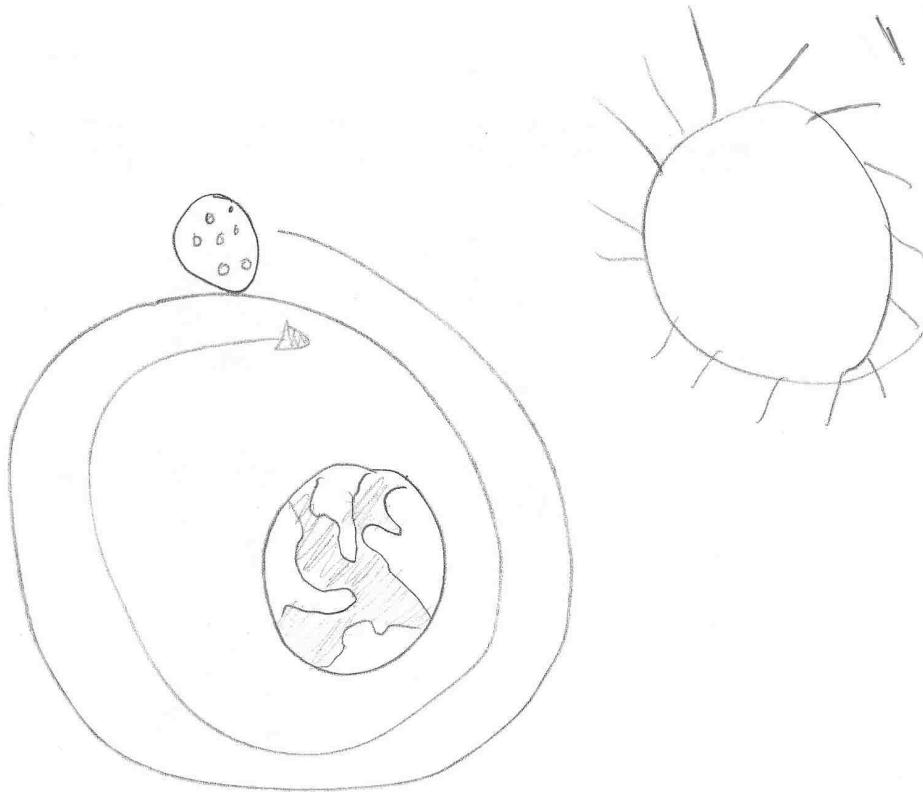
This student has accurately described the motion of the Moon around the Sun and the reason why the Moon shines. Additionally they explained that the angle of Sunlight on the Moon is the reason for the seasons. This is all strong evidence that this student has a full understanding of how the phases of the Moon occur.

Student #51830

Score: No Understanding

10. Explain why *changes in the moon's appearance* occur every month with a written paragraph in the space below. Be sure to write clearly and that your explanation is complete. N.U.

Because when the Moon goes around the earth and the sun stays in one spot will the moon goes around in a circle it changes its shape.

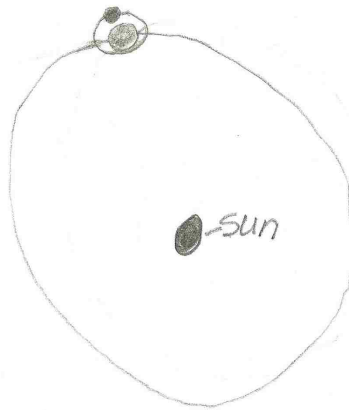


Although the student understood the Moon orbits the Earth, it is clear they did not understand the reason for the changing appearance of the Moon. These changes, instead, are attributed to a change in the Moon's shape. Additionally the picture drawn indicates confusion on the Moon's orbital motion because it is drawn as a spiral.

Student # 51809 Post-Test Essay Response
Score: No Understanding

10. Explain why *changes in the moon's appearance* occur every month with a written paragraph in the space below. Be sure to write clearly and that your explanation is complete. *N.A.*

*Beccas the Earth and moon are always moveing
AND SO the moon's SURFUS is always changing.*



This response is labeled as no understanding because the student was not specific enough in their explanation so no conclusions can be drawn. They indicate that the motion of the Earth and Moon is the reason for the phases, but how the Earth and Moon move is not explained. Despite the additional picture, no conclusions can be drawn because the only element labeled is the Sun. Even a partial understanding of the motion or geometry of the system cannot be determined from this response.

Student # 51822 Post-Test Essay Response
Score: Inconclusive

10. Explain why *changes in the moon's appearance* occur every month with a written paragraph in the space below. Be sure to write clearly and that your explanation is complete.

IN

Because the moon orbits the earth and the sun hits the moon wherever it is that's why we have Full moon every month.

This student's descriptions indicated an accurate understanding of the motion of the Moon. They accurately described the reason why the Moon shines at night and show evidence that they understood the Sun shines on the surface at different angles. However, their explanation was not detailed enough to rule out the possibility of the eclipse misconception, so it was labeled as inconclusive.

Student # 51828 Post-Test Essay Response
Score: Inconclusive

10. Explain why *changes in the moon's appearance* occur every month with a written paragraph in the space below. Be sure to write clearly and that your explanation is complete.

IN

Because, the moon is always going in a circle around the earth but since earth goes around the sun also the moon changes every time.

This student described accurately the Moon and Earth's motion but does not explain how the Moon's phases occur. Although the student clearly had partial understanding, there is not sufficient evidence to determine if they had a full understanding of the concept and the test was labeled inconclusive.

Student #51719 Pre-Test Essay Response

Score: No Understanding/Eclipse Misconception

10. Explain why *changes in the moon's appearance* occur every month, with a written paragraph in the space below. Be sure to write clearly and that your explanation is complete.

Because the earth is
covering parts of the
moon.

Although the student did not mention the Earth's shadow directly; they described the Earth "covering parts the Moon." From this, it can be assumed that the student incorrectly believed the Earth caused the Moon's phases. It is also not unreasonable to assume that the student was describing Earth's shadow covering the Moon. All together this response pointed to the eclipse misconception.

Student #51819 Pre-Test Essay Response
Score: No Understanding/Eclipse Misconception

10. Explain why *changes in the moon's appearance* occur every month with a written paragraph in the space below. Be sure to write clearly and that your explanation is complete.

NU,
The moons reflection from the sun is aligned with the sun, It makes a Full moon. But when the moon is behind the earth, it makes a new moon because it has barely any sun shining on it, It's completley black. When it's on top or the bottom of the earth, it makes half of the sunshine shine on it so one side is clear and one side is completley black.

Evaluating this response was more difficult to score because the student clearly understood the Moon is reflecting the light of the Sun and that the Moon phases are due to the Earth, Moon, and Sun's relative positions. But because the student makes a reference to the Moon being in a New Moon phase when it is "behind the Earth," strongly implies the eclipse misconception.

APPENDIX D

MISCONCEPTION SCORING RUBRIC

Misconception Scoring Rubric

Identify the misconception responses using the key below. Then compile the student's final misconception score using the following formula:

$$A(2)+B(1)+ C(0.5)+D(3) = \text{Misconception Score}$$


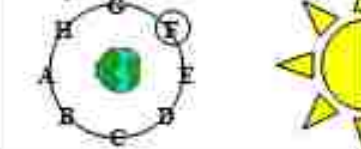








A=1 if misconception response A is selected

B=1 if misconception response B is selected

C=1 if misconception response C is selected

D=1 if misconceptions are detected in the student's essay response.

Directions:
 In the right-hand column, circle the position A-H where the moon would be in its orbit around the earth for the phase indicated in the left column.

Moon Phase	Moon's Orbit
Example: 	Example: 
	
	
	
	

Correct response

Misconception Response A

Misconception Response B

Partial Misconception Response C

Correct response

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APPENDIX E

LESSON PLANS

Moon Phases Vocabulary Terms

Grade Level: 6th

By: Heather Jones

- I. Goal/Standards
 - a. Standard: # 1
 - i. Students will understand that the appearance of the Moon changes in a predictable cycle as it orbits Earth and as Earth rotates on its axis.
 - b. Objective: #1
 - i. Explain patterns of changes in the appearance of the Moon as it orbits Earth
 1. Describe changes in the appearance of the Moon during a month.
 2. Identify the pattern of change in the Moon's appearance.
- II. Specific Measurable Objectives
 - a. Student will know that the appearance of the Moon changes throughout each month
 - b. Student will be able to use correct terms to identify the phases of the Moon
- III. Materials
 - a. Paper
 - b. Pencil
 - c. Pictures of Moon phases on card stock
 - d. Magnets to put pictures of the Moon on the board
- IV. Prerequisite/Vocab.
 - a. Moon phases terms
 - i. Phase
 - ii. Waxing
 - iii. Waning
 - iv. Gibbous
 - v. Crescent
 - vi. Full Moon
- V. New Moon Instructional Procedures
 - a. Initial Activity/ Set
 - i. Ask all the students to draw a picture of the Moon in 3 seconds
 - ii. Have all the students share their pictures (could hold up pictures or show their neighbors their picture)
 - iii. Are all the pictures the same? Why are they different? (The appearance of the Moon changes)
 - iv. The changes in the Moon appearance are called the phases of the Moon
 - b. Core Activity:
 - i. Use a calendar to find the pattern of change in the Moon phases...point out that the cycle takes about one "Moonth" or one month.
 - ii. Show the class that Moon waxes and wanes in a pattern, defining the terms as you go.
 - iii. Use the "right hand wax on, left hand wax off" technique to help students remember if the phase is waxing or waning
 - iv. Discuss why the Moon "shines" at night
 - v. As a class go through each phase of the Moon identifying the correct term for each Moon phase. Have each student fill in the phases of the Moon on a worksheet.
- VI. Assessment

- a. Pre-assessment: Pre-test
- b. During- Quiz the students as a class
- c. Post-assessment: None

Teaching Moon Phases with Computer Animation

Grade Level: 6th

By: Heather Jones

- I. Goal/Standards
 - a. Standard: # 1
 - i. Students will understand that the appearance of the Moon changes in a predictable cycle as it orbits Earth and as Earth rotates on its axis.
 - b. Objective: #1
 - i. Explain patterns of changes in the appearance of the Moon as it orbits Earth
 1. Describe changes in the appearance of the Moon during a month.
 2. Identify the pattern of change in the Moon's appearance.
 3. Use observable evidence to explain the movement of the Moon around Earth in relationship to Earth turning on its axis and the position of the Moon changing in the sky.
 - c. Objective: #2
 - i. Demonstrate how the relative positions of Earth, the Moon, and the Sun create the appearance of the Moon's phases.
 1. Identify the difference between the motion of an object rotating on its axis and an object revolving in orbit.
 2. Model the movement and relative positions of the Earth, Moon, and the Sun.
- II. Specific Measurable Objective
 - a. The student will be able to identify the phase of the Moon
 - b. The student will be able to relate the phase of the Moon with the position of the Earth Moon and Sun.
 - c. Student will understand and can explain the reason the Moon has phases.
- III. Materials:
 - a. Computer Lab
 - b. Animation Program
 - c. Worksheets
- IV. Prerequisite/Vocabulary:
 - a. Moon phases terms:
 - i. Waxing
 - ii. Waning
 - iii. Gibbous
 - iv. Crescent
 - v. Full Moon
 - vi. New Moon
 - vii. Rotate
 - viii. Revolve
- V. Instructional Procedures:
 - a. Initial Activity/ Set
 - i. Intro to Moon phases and terms. See vocabulary lesson plan
 - ii. Quick review of what was learned during the intro lesson
 - b. Core Activity

- i. Teacher introduces the activity by explaining how to use the animation program
- ii. Teacher demonstrates the position of the new, full and quarter Moon phases using the animation program
- iii. Split students into groups of two.
- iv. Give each group a Moon phases worksheet to complete by using the animation program
- v. After students have completed the worksheet, discuss as a class the phases of the Moon and why they occur
- vi. Post-test in one day

VI. Assessment

- a. Pre-assessment: Review
- b. During: Worksheet
- c. Post-assessment: Post-test

Teaching Moon Phases with Diagrams

Grade Level: 6th

By: Heather Jones

- VII. Goal/Standards
 - a. Standard: # 1
 - i. Students will understand that the appearance of the Moon changes in a predictable cycle as it orbits Earth and as Earth rotates on its axis.
 - b. Objective: #1
 - i. Explain patterns of changes in the appearance of the Moon as it orbits Earth
 - 1. Describe changes in the appearance of the Moon during a month.
 - 2. Identify the pattern of change in the Moon's appearance.
 - 3. Use observable evidence to explain the movement of the Moon around Earth in relationship to Earth turning on its axis and the position of the Moon changing in the sky.
 - c. Objective: #2
 - i. Demonstrate how the relative positions of Earth, the Moon, and the Sun create the appearance of the Moon's phases.
 - 1. Identify the difference between the motion of an object rotating on its axis and an object revolving in orbit.
- VIII. Specific Measurable Objective
 - a. The student will be able to identify the phase of the Moon
 - b. The student will be able to relate the phase of the Moon with the position of the Earth, Moon and Sun.
 - c. Student will understand and can explain the reason the Moon has phases.
- IX. Materials:
 - a. Moon phase diagram
 - b. Worksheets
- X. Prerequisite/Vocabulary:
 - a. Moon phases terms:
 - i. Waxing
 - ii. Waning
 - iii. Gibbous
 - iv. Crescent
 - v. Full Moon
 - vi. New Moon
 - vii. Rotate
 - viii. Revolve
- XI. Instructional Procedures:
 - a. Initial Activity/ Set
 - i. Intro to Moon phases and terms. See vocabulary lesson plan
 - ii. Quick review of what was learned during the intro lesson
 - b. Core Activity
 - i. Teacher introduces the activity by explaining The Moon phase diagram
 - ii. Split students into groups of two.
 - iii. Give each group a Moon phase worksheet to complete using the Moon phase diagram.

- iv. After students have completed the worksheet, discuss as a class the phases of the Moon and why they occur
 - v. Post-test in one day
- XII. Assessment
 - a. Pre-assessment: Review
 - b. During: Worksheet
 - c. Post-assessment: Post-test

Teaching Moon Phases with 3D Models

Grade Level: 6th

By: Heather Jones

- XIII. Goal/Standards
- a. Standard: # 1
 - i. Students will understand that the appearance of the Moon changes in a predictable cycle as it orbits Earth and as Earth rotates on its axis.
 - b. Objective: #1
 - i. Explain patterns of changes in the appearance of the Moon as it orbits Earth
 1. Describe changes in the appearance of the Moon during a month.
 2. Identify the pattern of change in the Moon's appearance.
 3. Use observable evidence to explain the movement of the Moon around Earth in relationship to Earth turning on its axis and the position of the Moon changing in the sky.
 - c. Objective: #2
 - i. Demonstrate how the relative positions of Earth, the Moon, and the Sun create the appearance of the Moon's phases.
 1. Identify the difference between the motion of an object rotating on its axis and an object revolving in orbit.
 2. Model the movement and relative positions of the Earth, the Moon, and the Sun.
- XIV. Specific Measurable Objective
- a. The student will be able to identify the phase of the Moon
 - b. The student will be able to relate the phase of the Moon with the position of the Earth Moon and Sun.
 - c. Student will understand and can explain the reason the Moon has phases.
- XV. Materials:
- a. Bright light source: a lamp or work light
 - b. 30 Styrofoam balls on sticks
 - c. Signs for each station
 - d. Worksheets
- XVI. Prerequisite/Vocabulary:
- a. Moon phases terms:
 - i. Waxing
 - ii. Waning
 - iii. Gibbous
 - iv. Crescent
 - v. Full Moon
 - vi. New Moon
 - vii. Rotate
 - viii. Revolve
- XVII. Instructional Procedures:
- a. Initial Activity/ Set
 - i. Intro to Moon phases and terms. See vocabulary lesson plan
 - ii. Quick review of what was learned during the intro lesson
 - b. Core Activity

- i. Teacher introduces the activity by explaining how to use the models
- ii. Teacher demonstrates the position of the new, full and quarter Moon phases using 3D models
- iii. Split students into groups of two.
- iv. Give each group a 3D model (Styrofoam ball) and worksheet to complete
- v. After students have completed the worksheet, discuss as a class the phases of the Moon and why they occur
- vi. Post-test in one day

XVIII. Assessment

- a. Pre-assessment: Review
- b. During: Worksheet
- c. Post-assessment: Post-test

APPENDIX F


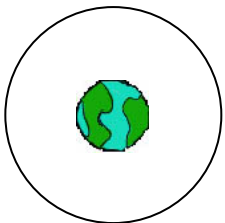
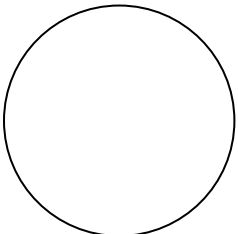
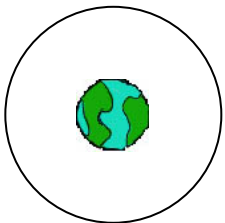
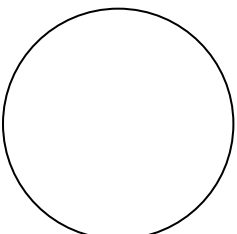
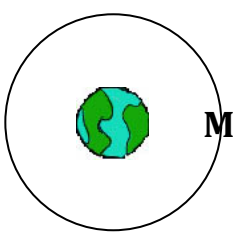

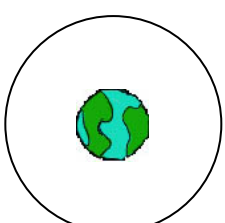
WORKSHEET

Name: _____ Teacher: _____ Grade: _____ Date: _____

Moon Phases Worksheet

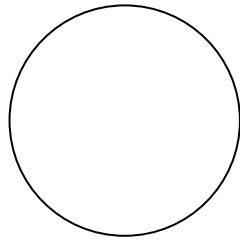
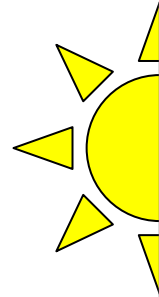
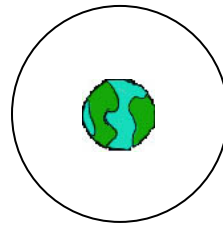
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Direction: Complete the following chart. In the left-hand column, draw the appropriate Moon phase and correctly label it in the spaces provided. In the right-hand column draw the letter “M” to mark the position of the Moon on its orbit for the indicated Moon phase in the left hand column.

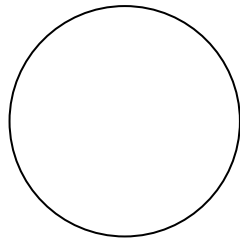
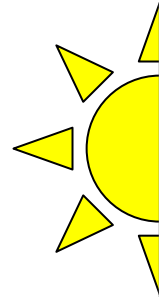
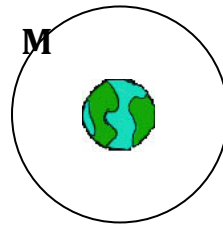
Moon Phase	Moon's Position in Orbit
 1. <u>Waxing Crescent</u>	
 2. <u>Third Quarter</u>	
 3. _____	
 4. _____	



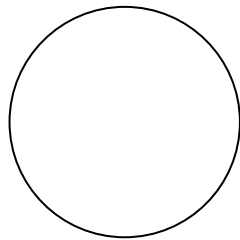
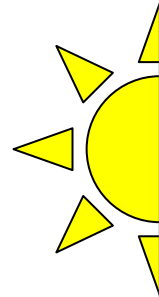
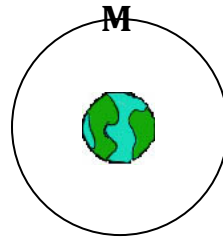
5. _____



6. _____



7. _____



8. Waning Creascent

