Lunar Phases: Uncovering Misconceptions through Conceptual Change

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Lunar Phases:
Uncovering Misconceptions through Conceptual Change

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Plan B Project

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Abstract

The purpose of this project is to research and report findings pertaining to student understanding of moon phases. The action research portion illustrates whether or not students’ perceptions can be changed regarding moon phases if the Conceptual Change Model is used. In order to accomplish such task, I used relevant peer-reviewed literature. Through the action research portion of the project, I implemented multiple hands-on activities. During the Conceptual Change Model, the students experienced each of the six stages first hand and became the primary source regarding lunar phases. Through researching the literature, my findings indicated that children do have misconceptions about the phases of the moon. However, through the action research portion of this study, I found that students were able to increase their understanding of lunar phases from pre- to post-test.
Dedicated to my committee members for all their support; the University of Wyoming and the Science and Mathematics Teaching Center for providing the funds and opportunity; my children, Harvey and Spencer, for sharing their college experience; and all my students—past, present, and future.
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Chapter 1: Introduction

What causes the phases of the moon? Why does the moon shine? Can you see the moon during the day? How does the position of the moon change in the sky throughout the month?

These are questions I pose to students I teach, and I am baffled as to why they do not understand moon phases when this natural shining satellite is so prevalent in their everyday life. What misconceptions prevent students from understanding the lunar phases? Can the Conceptual Change Model help students improve their understanding while learning about the moon and its phases? My desire was to find the answers to these questions to help children understand the phases of the moon.

Background

Nobody knows exactly how the moon formed. One theory posits that,

The moon was formed ~4.5 billion years ago, about 30–50 million years after the origin of the Solar System, out of debris thrown into orbit by a massive collision between a smaller proto-Earth and another planetoid, about the size of Mars. Initially the Moon spun much faster, but because it is not perfectly spherical and bulges out slightly at its equator, the orbit slowed down and eventually became tidally locked—keeping the same face toward the Earth (Heldman, 2008).

Other theories about the moon’s formation include: The Colliding Planetesimals, Co-
formation, Fission, and Capture, but these have been discounted by scientists for major flaws or for having little supporting evidence (Wall, 2014). The moon is Earth’s only natural satellite and plays a significant role in education and science standards.
Where do uniform science standards first appear in America’s history? In 1892, the National Education Association of the United States organized the Harvard Committee of Ten to make college entrance requirements uniform. Between then and our current Next Generation Science Standards (Achieve, Inc., 2013), the United States has gone through a variety of science initiatives. There have been more than 120 years spent on these national trends and initiatives. Through it all, the astronomy component has been woven into the body of science knowledge for student understanding.

In his sourcebook, Curriculum and Instructional Leadership for Systematic Reform, Dr. Norman Herr (2008b) identifies the national trends in regard to science initiatives and reforms. The following is a distillation of his review from chapter 24. In 1950 President Truman helped create the National Science Foundation (NSF). This was an independent government agency supporting research and education in science and engineering. Prior to this, almost all support for science education came from industry and private contributions.

The Soviet Union’s launch of Sputnik 1 in October 1957 caused the government and citizens of the United States to feel inferior in the world’s science arena, thus creating the need for emphasis on education in science and technology. A year later, the National Defense Education Act supported college students by providing financial aid to those pursuing science and engineering degrees.

On July 21, 1969, the Americans beat the Soviets to the moon. Neil Armstrong stepped onto the moon’s surface and declared: “That’s one small step for man, one giant leap for mankind” (Dunbar, 2014). With Armstrong’s placement of the American flag, the United States staked its claim in moon dust, more sophisticatedly known as regolith. With such an
accomplishment, it would seem the citizens of the United States would realize, like no other county, the attributes and facts about the moon orbiting Earth.

Even though the Americas beat the Soviets to the moon, the country’s leaders still saw a need for educational reform and a higher level of set standards. Later, in 1969, the National Assessment of Educational Progress (NAEP) was developed. The National Center for Education Statistics created NAEP as the nation’s report card. The Secretary of Education has been responsible for setting policy, developing the framework, and testing specifications. The assessments provide results on subject-matter achievement. NAEP is still the only national ongoing assessment for America’s students.

In 1983, the report *A Nation at Risk* was released. President Ronald Reagan’s National Commission on Excellence in Education spoke of the need for educational standards and standards-based assessments. They felt that there was a need for a better workforce from students and to assess the quality of teaching and learning. American high schools would now require three years of science for graduation, and the federal government would support curriculum improvements.

In 1990, the National Science Teachers Association (NSTA) recommended that all secondary students study each of the sciences (Earth, Physical, and Life) every year for six years, making an integrated approach to science. This, however, was not fully developed across the country and in 1995, a new comprehensive study the Third International Mathematics and Science Study (TIMSS) documented a gradual decline in performance in mathematics and science. Four years later, “TIMSS charged that American science courses were unfocused and shallow, providing arguments for later reforms” (Herr, 2008b).
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To address such accusations, in 2001 the United States Congress proposed and passed a bill that increased accountability for schools, local educational agencies, and states. This initiative held schools accountable for learning in standards-based reform and performance-based education. Most know the reform as the No Child Left Behind Act. This was originally the Elementary Secondary Education Act (ESEA) that had been developed and passed decades before, but revised as the No Child Left Behind Act, there was a shift in that made this effort punitive.

In a world so connected to science and technology, scientists and engineers are needed for the next generation to tackle national problems such as health, security, and prosperity in a global society. The latest initiative, released in 2013, was the culmination of several years of work beginning with the Taking Science to School (NRC, 2007), a compilation of the most recent research on the teaching and learning of science, and Ready, Set, Science (NRC, 2008) a practitioner’s guide to the research and the Framework for K-12 Science Education (NRC, 2012). The resulting Next Generation Science Standards (NGSS) (Achieve, Inc., 2013) were developed in a collaborative effort by (a) The National Research Council (NRC), (b) The National Science Teachers Association, (c) The American Association for the Advancement of Science, (d) Achieve, and (e) the 26 Lead States.

The NGSS are arranged in such a manner that it extends across disciplines and grades to provide all students an internationally benchmarked science education (NRC, 2012). In the summer of 2015, the state of Wyoming had not yet adopted the NGSS.
Within the Discipline Core Ideas (DCI) of the NGSS (Achieve, Inc., 2013), celestial concepts appear under the heading of “Earth’s Place in the Universe” in two different elementary grade levels: first and fifth. They also appear in the middle school grade band (grades 6-8) (Figure 1).

Figure 1. NGSS standards for students in grades one, fifth, and middle-school.

The performance expectations for first grade students under the Earth’s Place in the Universe:

1-ESS1-1. Use observations of the sun, moon, and stars to describe patterns that can be predicted.
1-ESS1-2. Make observations at different times of year to relate the amount of daylight to the time of year.

The performance expectations for fifth grade students under the Earth’s Place in the Universe:

5-ESS1-1. Support an argument that differences in the apparent brightness of the sun compared to other stars is due to their relative distances from Earth.
5-ESS1-2. Represent data in graphical displays to reveal patterns of daily changes in length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky.

The performance expectations for middle-school students under the Earth’s Place in the Universe:

MS-ESS1-1. Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.
MS-ESS1-2. Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.
MS-ESS1-3. Analyze and interpret data to determine scale properties of objects in the solar system.
MS-ESS1-4. Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth’s 4.6-billion-year-old history. (Achieve, Inc., 2013, p. 68).

Problem Statement
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What keeps students from understanding lunar phases? Is it their developmental stage, the child’s inability to see the moon from a space-based perspective, the inability to let go of misconceptions, or faulty teaching methods?

Stepans (2008), who proposed the Conceptual Change Model, addressed his own childhood misconceptions and spoke of how children conjure up images of how the world around them works. “Every one of our students brings to the classroom his or her stories about the mail and other things in the world” (p.2). The moon, like the correlation to Stepans’ mail, does not magically hop from one phase to another.

There are other concepts that also hinder the learner from lunar understanding. Conceivably, a teacher’s mode of instruction could prevent students from comprehending celestial motion. For example, the perspective from which the moon is viewed plays a part in the comprehension of lunar phases such as viewing the moon from Earth, from space, or from any part in the universe. Using mental visualization of three-dimensional objects from different perspectives requires multiple steps in problem solving. Padalkar and Ramada (2011) found that, “Experimental studies confirm that the child’s understanding of space develops through an interaction between visual and kinesthetic-tactile experiences” (p. 1705).

In Piaget’s findings of Pre-Operational, Concrete Operations, and Formal Operations of child development, he proposes that children under or at the age of eight cannot actually comprehend such abstract concepts as moon phases (Marlowe and Canestrari, 2006). Both age and ability may hinder children from comprehending moon phases.

It is difficult enough to comprehend the Earth’s rotation and orbit around the sun without adding the movement of the moon. When you include the movement of the moon, these
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components may prevent or hinder students from grasping the phases of the moon. Consider the Earth being in constant motion with its 24-hour rotation. Add to that the moon orbiting Earth approximately every 29.5 days while the Earth is orbiting around the sun every 365 days. These concepts are very complex when students try to comprehend the phases of the moon (Plummer, 2009, p. 198).

There are four complicated concepts to be tackled when trying to understand the phases of the moon in this particular study. These include:

1. The labeling of the lunar phases and the drawing of each phase in its correct position around the earth with respect to the position of the sun.
2. The response to rotation and revolution of the moon around Earth.
3. The length of time it takes for the moon to repeat a phase.
4. What a person in another country would see when a person in the United States sees a full moon.

Purpose

The purpose of this research was multi-faceted. First, a literature review was used to reveal ideas pertaining to elementary students’ understanding of moon phases. Second, the Conceptual Change Model was used while working with third grade students to uncover the misconceptions. Then, using a variety of hands-on activities, an investigation was conducted to see if such learning experiences can change their understanding regarding moon phases.
Research Questions

The questions used to guide this research were:

1. What does the literature say about elementary students’ understanding of moon phases?

2. Does using the Conceptual Change Model impact elementary students’ understanding of the moon phases?
Chapter 2: Literature Review

Introduction

To start the literature review, the reader’s understanding of the lunar phases may need refreshing. Smale (1998) explains the phases of the moon in a very comprehensive manner. He states:

We only see the Moon because sunlight reflects back to us from its surface.

During the course of a month, the Moon circles once around the Earth. If we could magically look down on our solar system, we would see that the half of the Moon facing the Sun is always lit. But the lit side does not always face the Earth!

As the Moon circles the Earth, the amount of the lit side we see changes. These changes are known as the phases of the Moon and it repeats in a certain way over and over (p.1).

There are eight such lunar phases: new, waxing crescent, first quarter, waxing gibbous, full, waning gibbous, third quarter, and waning crescent (Byrd, 2014). Like the seasons of the year, they are cyclical. The phases of the moon repeat the pattern month after month.

Furthermore, the moon is unique in that it rotates slowly around once as it orbits around the Earth. In the 29.5 days it takes the moon to orbit once around Earth, it surprisingly only rotates once as well.

Now that the basic understanding of the lunar phases has been covered, the introduction of the major components of the literature review needs addressing. The literature review focuses on three facets: Complications of understanding moon phases, The Conceptual Change Model, and Action Research.
Understanding Moon Phases

What does the literature say about elementary students’ understanding of moon phases? Students enter the classroom with not only their own convictions of how the world works but also what they have picked up from adults, teachers, and different modes of media conveyed to them. Because of this, some of the information they come to school with is not aligned with scientifically accepted views. As Stepans (1996) noted, “Students bring into the classroom ideas and experiences that may be naïve, incomplete, incorrect, or biased” (p. 57). In some cases, students have formed misconceptions regarding moon phases. It is difficult for them to believe one thing when they see something differently.

Complexity. Constructing the scientific explanation for observable astronomical phenomena is difficult for children—even with instruction (Plummer, 2014). The amount of interest a student invests will play a role in learning outcomes. Children’s concrete and abstract thinking abilities contribute to the developmental process. In the researcher’s experience, if the instruction is fragmented, superficial, or interrupted by long periods of time, learning can be compromised. Poorly delivered instruction may cause misunderstandings and/or create misconceptions. With the limited amount of time dedicated to science, students may not receive the necessary time needed to comprehend such an abstract concept as lunar phases. All these components play an important role in whether the child successfully comprehends such a complex concept.

The complexity of lunar phases is not only difficult for children but is difficult for adults as well. Trundle, Atwood, and Christopher (2002) found after giving instruction to pre-service teachers that, “without the instruction, most pre-service teachers were likely to hold alternative conceptions on the cause of moon phases” (p. 633).
Plummer and Krajcik (2010) elaborate on the complexity of the lunar phases. “The moon’s slow orbit causes the moon to rise approximately 50 minutes later every day and results in the slow changing of its appearance in the sky” (p. 779). This pattern is unlike any other celestial patterns with which students are familiar. A change of 50 minutes every day over the course of 29.5 days with eight different phases throughout both day and night is difficult for students to readily see a pattern. The world is filled with patterns and unlike the Gregorian calendar, the lunar calendar and its phases seem to be one of the most intangible.

**Developmental stages.** Students’ conceptions of the phases of the moon are products of their attempts to make sense of their world. Their ideas are often influenced by prior observations or experiences. Children’s first frame of reference is Earth-based, which is the basis of their own celestial observations. “One ability students must master is the creation of mental images from multiple frames of references” (Ashman, 2012, p. 32). Students need to understand a space-based perspective. They need to detach from exclusively using the Earth-based point of view. Simply put, children need to be able to see the sun, Earth, and moon from any point in the universe. This will help them see objects moving in space. Plummer (2014) states, “A full explanation for celestial motion phenomena requires understanding of both the Earth-based and space-based perspectives, and requires the ability to shift between these perspectives to explain why celestial objects appear to move or change as seen from the Earth” (p. 2). When learning about the phases of the moon, one would need to move between both perspectives over the course of 29.5 days to actually see lunar phases transpire. Because of this cycling, students need to be exposed to multiple frames of reference over a long period of instructional time.

Students come to third grade with a range of knowledge, skill, and experience. Their social, emotional, and educational abilities vary from novice to advanced. When learning
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something as difficult as lunar phases, it is important to keep in mind that, “Learning new content, then, does not happen quickly. It requires practice spread out over time” (Marzano, Pickering, and Pollock, 2001, p. 68). Marzano, Pickering, and Pollock further state that in order for a student to master a skill, a great deal of practice would need to be applied. “It’s not until students have practiced upwards of about 24 times that they reach 80-percent competency” (p. 67).

We also need to keep in mind the length of time in which students retain new information. As Rider (2002) poses, “Ask students questions several weeks after completing a unit of study and it’s likely many will have reverted back to their original concepts with little modifications” (p. 51). With the variations of the moon phases, the location in the sky in which they can observe the moon, and the time of day or night in which they see the moon, it is understandable why students may not comprehend lunar phases.

Being able to master mental images from multiple frames of reference is what Ashmann (2012) believes to be the key component in understanding lunar phases and other astronomical phenomenon. Ashmann shows how to use multiple frames of reference to help clear up students’ misunderstandings about how the Earth, moon, and sun affect each other. By being taught in such a manner, students are able to reason their way through an explanation (p. 32). For example, once a student is able to see the moon from a space-based perspective, it is then they have a deeper understanding of the moon phases and are capable of articulating the concept to others.

Misconceptions.

According to Baxter (1989) there are five main misconceptions students between ages nine and 16 hold onto regarding moon phases. The most commonly held notion for the causes of the phases of the moon is that the earth casts a shadow on the moon. Trundle, Atwood, and
Christopher (2007) found through their research that the eclipse model is the most prevalent misconception. The misconception from a child’s point of view is this: The moon is always full, but because there is only a crescent showing, it must be because there is a shadow being cast upon the moon. This idea espouses that the Earth casts its shadow upon the moon creating the unlit portion (p. 596). The simple fact that one hemisphere of the moon is always reflecting the sun is not comprehensible to a child. Since children only observe such a phenomenon on nights with a “full” moon, they may tend to negate the idea, create a misconception, or continue to believe what they already think is true.

When Hermann and Lewis (2003) performed their action research, they used the three-step approach to addressing student misconception: identify, overturn, and replace. They found the same thing as Stahly, Krockover, and Shepardson (1999). Students held onto alternative conceptions even after being exposed to the correct scientific explanation. In the film *A Private Universe* (Pyramid Film and Video 1988), Harvard graduates, students who arguably had many years of exceptional education still held misconceptions regarding the causes of the seasons. The seasons of the year, like the phases of the moon, are complicated multi-faceted concepts.

Stahly, Krockover, and Shepardson (1999) suggest that each time children experience lunar phases, they use their existing cognitive frameworks to give meaning to the experience. Moreover, while adding new information to currently held conceptions, “children may create conceptions that are counter to the scientifically accepted view” (p. 160).

**Instructor’s lack of knowledge.** For some students, it is the lack of knowledge on the part of the instructor that hinders their lunar understanding. Trundle, Atwood, and Christopher (2006) found pre-service teachers lacking in knowledge regarding moon phases. “Results
indicated that, prior to instruction, most pre-service teachers had major deficiencies in knowledge of observable moon phases and the pattern of monthly change in the phases” (p. 87).

Add this to the misconceptions children may learn through misguided and poorly illustrated children’s literature and it is no wonder that Trundle, Troland, and Pritchard (2008) found, “Teachers who use children’s literature that misrepresents the moon may unwittingly promote and/or reinforce alternative conceptions” (p. 18). Beautifully illustrated picture books of the moon created specifically for children’s learning and enjoyment are sometimes represented incorrectly. Trundle, Troland, and Pritchard (2008) conducted a study pertaining to visual and written representations of the moon in children’s literature. Out of the 80 children’s books studied, their findings revealed that many of the books not only misrepresented the phases of the moon but also reinforced alternative conceptions (p. 17). The study revealed of the 772 moon illustrations, 52% were of the full moon. The crescent moon was the next popular, illustrated at 27%. Gibbous, quarter, and new moon phases were represented at 11%, 7%, and 3%, respectively (p. 22). Interestingly, students and adults drew full moons and crescent moons more often than any other phase.

Stepans (2008) noted, “For a large number of adults, science concepts and the world described by special words, formulas, theories, and generalizations remain foreign and unapproachable.” He extends his point in saying, “Teachers, as a group, are no exception to this sense of inadequacy and frustration” (p. 3).

Barnett and Morrnan (2002), who reviewed a research survey from 1988 that was conducted by the Public Opinion Laboratory at Northern Illinois University, “determined that only 45% of United States adults could correctly state that the Earth orbited the Sun and that it took one year to complete the trip” (p. 860). Even though this is not in conjunction with moon
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phases, it is a representation of Earth’s place in the universe and reinforces that lack of scientific knowledge and how the universe works among the general public.

**Misconceptions through textbook illustrations.** Another set of misconceptions students are faced with comes through media sources both in formal and non-formal educational settings. Ashmann (2012) contends, “The majority of concepts in astronomy (including the lunar phases) are three dimensional, yet most diagrams in textbooks and on computer screens are two dimensional” (p. 33). He further claims that, “sometimes a single diagram will depict two different frames of reference” (p. 33). In two-dimensional drawings of first quarter and third quarter moons taken from a space-based perspective, students see the same drawing. It is when the observer looks at the first quarter and third quarter moon from Earth’s perspective that one sees the waning and waxing phases.

**Conceptual Change Model**

**Design.** The Conceptual Change Model is a constructivist-based method of presenting science concepts to students. It attempts to address dissatisfaction with existing views, making new concepts appear plausible or more attractive having explanatory and predictive power (Stepans, 2011). By actively engaging students, the Conceptual Change Model places the student in an environment that encourages them to confront their own preconceptions. If their beliefs are inaccurate, the model progresses towards resolution and ultimately a conceptual change. Students commit to position or outcome. Through interaction and communication, students then expose their beliefs. By working with materials and collecting and analyzing their data, students confront their beliefs. Students then work towards resolution, extending the concept to other situations, and ultimately a conceptual change. From here students go beyond, pursuing new questions.
When students have misconceptions, learning the accepted scientific concept is necessary. Hewson and Hewson (1984) support this by stating, “If this conflict is unresolved, or perhaps not even perceived as such by the student, learning of the accepted view being taught is inhibited” (p. 2).

**Conceptual change model.** The Conceptual Change Model is made of six phases. Designed by Stepans (Stepans, Schmidt, Welsh, Reins, & Saigo., 2005) to enhance learning for students and help teachers recognize and incorporate student prior knowledge into their teaching (p.18). They are shown in Figure 2.
The Conceptual Change Model is not intended to be a linear model. The learner can “loop” or return to previous phases as learning progresses. For example, by returning to the beginning of the model and exposing one’s new beliefs after they have reached the extend the concept phase the learner can strengthen a new conceptual understanding or bring up another misconception needing addressed (Schmidt, Saigo, and Stepans, 2006, p. 20).
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Naïve, incomplete, or incorrect thinking can lead to misconceptions. Stepans (2011) believes that “experiences that are simulated using the Conceptual Change Model challenge students to become aware of these misconceptions and transform them in a meaningful and positive way” (p. 2).

“Learning science is usually not just a matter of adding information and making connections. Students’ prior knowledge is often inconsistent with the scientific knowledge that they are expected to learn” (Smith, 1991, p. 49). Smith further states, “Students’ prior knowledge needs to undergo change for the new scientific ideas to fit” (p. 49).

**Models in comparison.** While researching the Conceptual Change Model, other models of instruction appeared. Roger Bybee and his colleagues condensed research to encompass five memorable words to help science teachers with instruction. They are: Engage, Explore, Explain, Extend, and Evaluate. In the Conceptual Change Model, however, there is a looping or cycling back through the phases. “There are even times when it is natural or desirable to loop back in the process before proceeding to *Extend the Concept* and *Go Beyond*, providing new challenges and experiences to reinforce concepts, deal with new or lingering misconceptions that have been revealed during the lesson, or introduced relate concepts (Schmidt, Saigo, and Stepans, 2006, p. 20).

Colburn (2000) defines inquiry-based instruction as “the creation of a classroom where students are engaged in essentially open-ended, student centered, hands-on activities” (p. 42). Forms of inquiry-based instruction include: structured, guided, open, and the learning cycle.

When comparing the constructivist view of learning, there seems to be commonalities and overlaps among these models. Yet, the Conceptual Change Model goes beyond by uncovering and addressing misconceptions. “Continuous assessment is part of the structure of a
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The literature says a great deal about moon phases. The complexity, student developmental stages, misconceptions, lack of knowledge from teachers, misconceptions through media, and the Conceptual Change Model all direct the researcher towards finding first hand how children view the phases of the moon.

Action Research

O’Brien (1998) contends that Kurt Lewin is the “father” of action research. Lewin was a German social and experimental psychologist and coined the term “action research” in 1946. One of the founders of the Gestalt school, he was concerned with “social problems, and focused on participative group processes for addressing conflict, crises, and change, generally within organizations.”

In a 1957 publication from the Journal of Educational Sociology, Hodgkinson (1957) writes Stephen Corey was the man who put the foundation into action research. “In sum, he would say that action research is research undertaken by those in the field (teachers, administrators, and supervisors) in order to improve their own practices.” He further states, “The main reason for action research is the improvement of practice” (p. 137).

“Action research encourages teachers to think more deeply about their current practices, about the effect of those practices on learners, and about the role of teaching in a democratic society” (Adler, 2003, p. 78). Action research can improve the quality of professional practice. It allows the researcher to reflect upon their practice in a meaningful way. “Teachers, for example, have not only carried out development work for their schools but have also broadened their knowledge and their professional competency” (Altrichter, Feldman, Posch, and Somekh, 2013, p. 6).
In 1996, Richard Winters came up with a number of ethical principles to consider when conducting action research. These are shown in Figure 3.

Figure 3. Richard Winter’s ethical principles for conducting action research (taken from O’Brien, 1989).

1. Make sure that the relevant persons, committees and authorities have been consulted, and that the principles guiding the work are accepted in advance by all.
2. All participants must be allowed to influence the work, and the wishes of those who do not wish to participate must be respected.
3. The development of the work must remain visible and open to suggestions from others.
4. Permission must be obtained before making observations or examining documents produced for other purposes.
5. Descriptions of others’ work and points of view must be negotiated with those concerned before being published.
6. The researcher must accept responsibility for maintaining confidentiality.

There are also some drawbacks to action research. According to Rapoport, (1970) there are three such issues: “First, it begs the ethical/value issues involved in action research; second, it does not attend to the social scientist’s interest in the research but only the client’s; and third, it locates initiatives too exclusively with the client” (p. 499).
Chapter 3: Methodology

Research Questions

The questions used to guide this research were:

1. What does the literature say about elementary students’ understanding of moon phases?
2. Does using the Conceptual Change Model impact elementary students’ understanding of the moon phases?

Methodology of Action Research

Rationale. This action research was conducted using third grade students for two reasons. First, I have been a third grade teacher for a number of years and understand students of this age level and their ability to grasp concepts. I have worked with this particular group of third grade students since September, which lends itself to long-term study. Secondly, third grade students are between the first grade NGSS expectations of lunar phases and fifth grade sun, earth, and moon patterns. Working with third grade students using kinesthetic activities, I wanted to solidify what they currently know and prepare them for what they are about to learn.

Setting. This study was conducted in a class of 21 students in a three-unit school. The rural community consisted of approximately 30,000 people and was located in a western state. The Title-One K-4 school has about 345 students and 57% of the student population falls into the low socioeconomic category. The school is also an English Language Learner (ELL) school; 27% of the population is Latino. Thirteen percent of the population receives specialized instruction under the Individual Disability Education Act (IDEA).

Population. The third grade class in this research project consisted of 21 students, 13 boys and eight girls ranging in age between eight and nine years old. Within this classroom, one
student received special education services, three students received ELL services, and two students had been phased out of the ELL program but were still being monitored. Another student received advanced instruction one day a week in which he was transported to another building for the majority of the day. These demographics are representative of all three third grade classes within the building. During the day, students received instruction for art, music, and physical education from other instructors but remained in the classroom for core subjects of math, language, social studies, and science.

Participants. Instruction was given to the entire class; however, not all students were in the study. At the beginning of the study, as required by the Institutional Review Board (IRB), permission slips were handed out to all 21 students in the class. Only 17 of the 21 students turned in their permissions slips. Of those 17 students, four were selected as participants in the focus group for this study. For the ease of the reader, and confidentiality of the students, pseudonyms were created for the four focus students. They will be referred to as Alice, Billy, Celia, and Dan.

Because this study involved humans and focused on an elementary school age population, careful steps were taken to ensure the safety of the participants. First, letters of support from the building principal and the district’s superintendent were solicited (see Appendix A). The formal IRB process required consent forms and data collection instruments. For the detailed IRB forms, permission slips, and instruments, see Appendix B.

Time constraints were a concern, and interviewing the entire class was unrealistic; therefore, selecting a small sample group of four students to study was the most practical approach. These four students are identified throughout the paper as the focus group. Academic ability and gender were criteria used in selecting the four students. Standardized test scores from
Instruments. Using the language portion of the MAP data, the student who was chosen as academically high ranked in the 97th percentile. This high-ability female student will be referred to as Alice. The two students considered average were ranked in the 66th percentile and 48th percentile, respectively. One was an average-ability male and will be referred to as Billy. The other was an average-ability female and will be referred to as Celia. The low-ability male student ranked in the 15th percentile and will be noted as Dan. Table 1 shows the 17 students in the study and identifies the four focus students.
Lunar Phases: Uncovering Misconceptions through Conceptual Change

Table 1. MAP Percentile Scores for Fall 2014.

<table>
<thead>
<tr>
<th>Student numbers - focus students named</th>
<th>MAP percentile scores Fall 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student 1</td>
<td>98</td>
</tr>
<tr>
<td>Student 2: Alice</td>
<td>97</td>
</tr>
<tr>
<td>Student 3</td>
<td>90</td>
</tr>
<tr>
<td>Student 4</td>
<td>90</td>
</tr>
<tr>
<td>Student 5</td>
<td>89</td>
</tr>
<tr>
<td>Student 6</td>
<td>68</td>
</tr>
<tr>
<td>Student 7: Billy</td>
<td>66</td>
</tr>
<tr>
<td>Student 8</td>
<td>63</td>
</tr>
<tr>
<td>Student 9</td>
<td>61</td>
</tr>
<tr>
<td>Student 10</td>
<td>61</td>
</tr>
<tr>
<td>Student 11</td>
<td>58</td>
</tr>
<tr>
<td>Student 12</td>
<td>56</td>
</tr>
<tr>
<td>Student 13: Celia</td>
<td>48</td>
</tr>
<tr>
<td>Student 14</td>
<td>37</td>
</tr>
<tr>
<td>Student 15</td>
<td>23</td>
</tr>
<tr>
<td>Student 16: Dan</td>
<td>15</td>
</tr>
<tr>
<td>Student 17</td>
<td>12</td>
</tr>
</tbody>
</table>

**Procedures/Data Collection**

The study began late February 2015. Daily instruction was approximately 30 minutes in length, and the unit of lunar discovery lasted roughly four weeks. The Conceptual Change Model was used to actively identify and challenge students’ existing conceptions and skills. Various questions were posed to the students to commit their beliefs. Classroom discussion allowed them to expose their beliefs, while kinesthetic activities confronted their existing ideas. Students extended what they learned to other subjects, other people, and other learning environments.

The Conceptual Change Model was implemented to address the following questions.
Lunar Phases: Uncovering Misconceptions through Conceptual Change

1. Can you identify the eight phases of the moon? (Moon phases)
2. Why do we always see the same side of the moon? (Tidally locked)
3. After you see a full moon, when will you see the next full moon? (Full moon cycle)
4. When a person in the United States sees a full moon, what does a person in another country see? (Earth’s rotation)

Note that after each question there is a summary phrase in parenthesis. I used the summary phrase as headings in the pretest and post-test tables. This made understanding the results of each question much easier to follow.

Each question had instruction lasting approximately 1 week. Here are four specific activities that support the Conceptual Change Model. See Appendix C for a complete description of the Conceptual Change Model lessons and activities for this unit.

1. Earth-based kinesthetic activity (Child’s head as Earth in a 3D replication) (Figure 4)
2. The moon facing Earth: Penny activity (If the Moon were a penny…) (Figure 5)
3. Nighttime and daytime moon observation (Lowell Observatory Moon Clock) (Figure 6)
4. Phases of the moon: Moon-sicles “like popsicles” (Moon on a Stick!) (Figure 7)
Child’s head as Earth in a 3D replication was a discovery lesson used in conjunction with the Conceptual Change Model (see Figure 4). Students were actively involved. By becoming aware of their own thoughts, students were asked to identify the eight phases of the moon. After some “think time,” students were encouraged to think about how they were going to explain to their small groups exactly what they knew about the eight phases. During the investigations, students played an active part in creating the 3D replication and while doing so, groups of two students were asked two to three questions. Once the questions were explained, they each took turns looking through the hole and seeing the eight different phases of the moon. This process continued until all students participated.
If the Moon were a Penny was a hands-on activity used in conjunction with the Conceptual Change Model (see Figure 5). Students were first asked to become aware of their own perception about why we always see the same side of the moon. Then they exposed their beliefs by sharing with their small group and then with the class. When students tested their ideas, they drew a circular object in the center of their paper and by slowly taking the penny (representation of the moon) and keeping the face of Lincoln pointing towards Earth, moving the coin completely around the Earth. Students begin to realize that the moon, which always keeps the same side facing Earth, actually rotates once as it orbits Earth once as well.
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Figure 6. Lowell Observatory Moon Clock.

*Lowell Observatory Moon Clock* allowed the class hands-on practice in addition to going through the six steps of the Conceptual Change Model (see Figure 6). The moon clock was a paper manipulative that showed phases of the moon on a disk that could be positioned to show where the sun and moon phases were located relative to the horizon. During the third week in March when the moon was in its first quarter phase, the students and I would return to the playground shortly after the school day started to view the moon. Before going outside, I asked the students, “After you see a full moon, how long does it take to see the next full moon?” Using the full moon as an anchor, I used the observable first quarter during school hours to get the point across. A week and a half later students and parents would see the full moon at their homes and document their findings. This activity took well over a month to completely go through the waxing crescent phase and the full moon phase.
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Figure 7. Model of a styrofoam ball on a stick.

The *Moon on a Stick* activity used along with the Conceptual Change Model provides students first-hand experience with what the moon looks like in any given phase (see Figure 7). I asked the question, “If people in America see a full moon, then what would people in China see?” Using the Conceptual Change Model, Commit, share, test, accommodate, extend and ask new questions to Earth’s rotation from the moon’s perspective, students begin to understand yet another point of view. It dispels the idea there is a shadow and extends the students’ thinking with what Americans and Chinese see.
Chapter 4: Results

Data was collected from the four focus students for the pretest on the following moon phase questions. The same questions were given to the same four students for the post-test.

1. Can you identify the eight phases of the moon? (Moon phases)
2. Why do we always see the same side of the moon? (Tidally locked)
3. After you see a full moon, when will you see the next full moon? (Full moon cycle)
4. When a person in the United States sees a full moon, what does a person in China see? (Earth’s rotation)

None of the four focus students were able to satisfactorily answer any of the four questions on the pretest. Table 2 shows their results. Please note that Table 2 has the number one in each column and row.

Table 2. Proficiency Results of the Student Pretest.

<table>
<thead>
<tr>
<th></th>
<th>Moon Phases</th>
<th>Tidally Locked</th>
<th>Full Moon Cycle</th>
<th>Earth’s Rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alice</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Billy</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Celia</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Dan</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Key: 1 - novice  2 - partially proficient  3 - proficient

Students who were at the novice level, meaning they did not understand the majority of the content, earned a one. These students answered less than 50% of the total questions correctly.

Students who were partially proficient earned a two and demonstrated an average understanding between 50% and 90% but still lacked complete understanding of the content. Students who were proficient answered the questions with confidence and understanding. These students could answer 90% -100% of the questions.
Findings

When the unit came to an end, the post-evaluation revealed three of the four (75%) students demonstrated a proficient understanding of the moon phases by drawing and labeling the phases of the moon from an Earth-based perspective. Two students went from a novice to proficient in two areas: the moon always facing the Earth (Tidally locked) and the length it would take for a full moon to go through an entire cycle (Full moon cycle). Only one of the students went from a novice to a proficient understanding with regards to what moon phases are seen by Americans and Chinese on any given night (Earth’s rotation). Table 3 shows specific post-test results from the four focus students.

Table 3. Proficiency Results of the Student Post-test.

<table>
<thead>
<tr>
<th></th>
<th>Moon Phases</th>
<th>Tidally Locked</th>
<th>Full Moon Cycle</th>
<th>Earth’s Rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alice</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Billy</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Celia</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Dan</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Key: 1 - novice  2 - partially proficient  3 - proficient
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Figure 8. Student sample of the phases of the moon

Moon phases. Of the focus students, Alice, Billy, and Celia could accurately draw and label the phases of the moon. You can see from Figure 8 that Billy was still slightly confused regarding the shading or non-shading of the new moon. Dan remained novice as his inability to recall information pertaining to the phases other than full moon and new moon did not change. These findings matched Trundle (2010), “Significantly more participants shifted from alternative understanding of the cause of the moon phases on the pretest to scientific understanding on the post-test” (p. 2).

Alice, who was very good at going from one frame of reference to another, pointed out that from the sun’s point of view the moon is always full. I asked her when she learned how to think in such a way, and her response was when they were learning map skills: bird’s eye view, map view, and ground view.

Another focus student (Celia) stated that she had seen the moon the previous night. When I asked her what time she saw it and if she could draw what she saw, she gladly obliged (Figure 9). Together, Celia and I analyzed the drawing, and while we talked about the description of her picture she said, “Well, maybe I drew the picture backwards.”
Dan seemed to forget the phases and needed prompting throughout the lesson. The vocabulary words such as waxing, waning, crescent, and gibbous were unfamiliar to him even after instruction. He had difficulty recalling them without prompting.

Tidally locked. After assessing the four focus students with the question: “Why do we always see the same side of the moon?” Alice and Celia could clearly articulate the fact that the moon revolves around Earth counterclockwise all the while facing Earth. Both students could explain that even though the moon is always half lit from the sun’s reflection, we on Earth do not actually see this phenomenon. Their drawings revealed their understanding (see Figure 10).
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When asked, Billy could accurately explain the moon’s rotation and revolution but became confused as to what we on Earth actually see throughout the course of a month. In addition, Billy could not recall the names of the particular phases when placed in orbit around Earth and left his drawing incomplete. Dan knew the moon revolved around the Earth but did not remember in which direction, nor could he recall the names of phases. He understood there was a full moon and a new moon, but could not place them in the correct position.

**Full moon cycle.** Of the four focus students, Alice and Billy accurately produced evidence within their final assessment demonstrating why we only see one side of the moon on any given day or night. It was apparent that they knew the correct answer from the activity using the penny with Lincoln’s nose always facing the Earth. Their arrows helped support their answer. Celia and Dan, who could not answer correctly, had no explanation. Even though they drew the penny, they showed no further evidence of comprehension. Alice, Billy, and Celia correctly described the lunar cycle being one month long. Alice even applied additional information stating that the first and third quarter moons lasted one of the four weeks within the moon cycle. She clearly understood the fact that there were four quarters in one cycle. Dan seemed to guess by saying it would reappear next year.

Through the Conceptual Change Model, students became more aware of their own cognition. One student noted, “I had the waxing and waning confused because now I know the moon goes around counterclockwise.”

**Earth’s rotation.** Only Celia demonstrated accuracy in explaining why people see the same moon in both the United States and China. Alice, Billy, and Dan suggested the moon they see in the United States would appear opposite in China as it is on the opposite side of the earth.
Analysis

The pretest results from the four focus students indicated little to no understanding of any of the four activities representing the phases of the moon. Throughout the two-month science unit focusing on the phases of the moon, the activities using the Conceptual Change Model did help support an increase. This is shown as data from the posttest.

Of the four questions, the moon-phase activity had an increase of 75% from novice to proficiency. This appeared to be the most successful with regard to increased understanding. The tidally locked activity had an increase of 50% from novice to proficiency. The full moon-cycle activity also had an increase of 50% from novice to proficiency. The last activity, Earth’s rotation had an increase of 25% from novice to proficiency. This activity showed very little increase from pretest to posttest, as Ceilia had the only increased score.

By going through activities using the Conceptual Change Model, Alice, Billy, and Celia were able to start to work towards resolution in understanding the concept. Dan, however, showed no growth. The four focus students demonstrated results similar to results found through research, meaning; students do not thoroughly understand the concepts behind the phases of the moon.
Chapter 5: Discussion

The purpose of this chapter is to summarize the study that was conducted. Included in this summary are a review of the purpose of the study, a restatement of the research questions, the research methodology used, and a summary of the study results, conclusions and discussion. Recommendations for further research and possible studies conclude this chapter.

Summary

The purpose of this research was to review literature pertaining to elementary students’ understanding of moon phases. It also implemented the Conceptual Change Model while working with third grade students in uncovering misconceptions. Then, using a variety of hands-on activities, action research was conducted to see if such learning experiences could change student understanding regarding moon phases.

The questions used to guide this research were:

1. What does the literature say about elementary students’ understanding of moon phases?

2. Does using the Conceptual Change Model impact elementary students’ understanding of the moon phases?

The method in which the study was conducted was to focus on four students within a classroom of third graders. Of the four students one was of high ability, two were of average ability and one was of low ability. Two were girls and two were boys. The criteria used for selecting the focus groups came from the language portion of the previous Fall MAP scores.

Four questions were given as a pretest before instruction, and the same assessment as a posttest was given after instruction. These four questions are as follows:
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1. Can you identify the eight phases of the moon? (Moon phases)
2. Why do we always see the same side of the moon? (Tidally locked)
3. After you see a full moon, when will you see the next full moon? (Full moon cycle)
4. When a person in the United States sees a full moon, what does a person in China see? (Earth’s rotation)

The data was collected, placed into tables, and the findings were both summarized for each question and analyzed as a whole.

Discussion, Implications & Limitations

I agree with Stepans (2011) when he suggests students come to the classroom with their own set of theories about how science works, and it is very difficult to change such concepts. Whether a classroom student, a college undergrad, parent, teacher, or professor, we tend to believe our first-hand experiences, common sense, what we have seen, read, or been told. Right or wrong, it is difficult to change what we believe to be true. In addition to our preconceived ideas on how science works, being able to comprehend the rotation and orbit of Earth around the sun has its own conceptual understandings. When you add to that the concept of the moon’s rotation and orbit around Earth occurring simultaneously through a 24-hour period over the course of a 29.5 day lunar cycle, not all students grasp information long enough to put it together.

I was surprised to find the literature review agreed with my action research findings. Our findings were similar in that very few students completely understand the phases of the moon. The Conceptual Change Model began to help students work towards resolution but several cycles of the model were not implemented because of time constraints. Students like Dan would
refer back to original beliefs even after hands-on experience in which he could clearly see and articulate the correct understanding.

From this action research project, I found trying to replace prior conceptions with new knowledge about the phases of the moon to be difficult. The patterns were not as evident as other concepts I teach. As time passed, this group of focus students started learning, questioning, and transferring their new knowledge. For example, students could connect first quarter and third quarter to money and even to the clock (quarter past and quarter til); however, the second quarter did not represent half. The half was actually what we teach as the full moon. This confused them. Another confusing concept was the representation between the new moon and full moon. The students could not remember if they color the circle in for the full moon or leave it blank for the new moon.

The 29.5-day cycle is like no other. It is not a complete month nor is it a group of ten, and it cannot be divided by the eight phases. It appears 50 minutes later each night. The moon is tilted at a four-degree angle. There are so many concepts unrelated to each other, it is difficult to teach students such abstract concept in such a short amount of time.

During the two different months of instruction in which we were able to actually view the waning phases of the moon in the morning before school started, clouds would interfere, which created gaps in my instruction. I felt students had a difficult time believing me because I could not show them this observable phenomenon from one day to the next. The students had to “hang on” to information way too long for complete understanding. As noted in the literature review, students will have reverted back to their original concepts with little modifications. (Rider, 2002. p. 51).
During the course of the school day, science time would vanish. The 30-minute time frame never seemed long enough, and interruptions such as mandates, curriculum needs, and school-wide functions encroached upon science.

Another limitation is not much science is being taught at the school in which I work. Our state has not yet adopted the NGSS. Even though some districts have taken on the responsibility of teaching the NGSS, our district has not. Students are not coming to third grade equipped with basic science awareness. Understanding moon phases is a difficult concept, and when students are coming to the lesson with very little science background additional support is needed. The NGSS first grade expectation is to use observations of the sun, moon, and stars to describe patterns that can be predicted. (see table 1). With this lack of science instruction children are coming to third grade with gaps in what they should have already been taught. Concepts such as shadows and “point of view” need addressing. Terms such as before, after, spin, and counterclockwise needed to be reviewed or taught.

Kinesthetic activities such as the 3D simulation allowed for hands-on experiences. It also supported the Conceptual Change Model in allowing students to test their ideas by putting their head through the hole and seeing for themselves what the moon looks like as it orbits Earth. By putting a Styrofoam ball on a stick and taking it outside with the moon clock, students could actually replicate the moon in the sky with the ball in their hand. The penny activity also allowed for students to replicate the actual lunar phenomenon, yet the students themselves did not have the ability to gain understanding for any length of time. It was during one particular activity that Alice mentioned she finally understood the lunar concept. Yet it was this same individual who did not understand what people in China see when people in America see a full moon. Billy and
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Celia would explain their thinking but then would become confused. Dan was unable to connect any new information to existing knowledge.

I discovered these concepts were too difficult for students of this age to understand. Their cognitive development, as supported by the literature, is not yet ready for such abstract and difficult concepts. The developmental appropriateness of these concepts for the students I worked with was above their ability. Time better spent while working with students of this age and ability level would be to focus on particular aspects and/or small sets of concepts. The best way to use the new understandings I have about this topic and my students would be to focus on the concepts that the moon cycles through the phases year round, year after year. Another concept that would better fit their cognitive development would be that the moon could be seen during the day and night time.

Perhaps the reason students didn’t show significant growth is supported by (Marzano, Pickering, and Pollock, 2001). “Learning new content, then, does not happen quickly. It requires practice spread out over time” p.68). Or maybe Piaget’s findings of Pre-Operational, Concrete Operations, and Formal Operations of child development is correct when he proposes that children under or at the age of eight cannot actually comprehend such abstract concepts as moon phases (Marlowe and Canestrari, 2006). Even Stepans’ (1996) thoughts of, “Students bring into the classroom ideas and experiences that may be naïve, incomplete, incorrect, or biased” (p. 57). In some cases, students have formed misconceptions regarding moon phases. It is difficult for them to believe one thing when they see something differently. Whichever the case, the four focus students I taught did not show significant growth in understanding phases of the moon.

Hermann and Lewis (2003) stated, “Teachers may be surprised to find, as I was, how similar their students’ results are to the research results, and also how prevalent these
misconceptions are among students” (p. 55), and I couldn’t agree more. I anticipated much higher results using the Conceptual Change Model. With the many opportunities to expose beliefs, to work with materials, and to discuss results with peers, I thought more students would be able to demonstrate the phases of the moon more accurately and with confidence. The results I found verified what the research says. As supported by the data, the vastness of space, the perspective of view, and the different speeds of rotation and revolution regarding aspects of the moon phases is extremely complex.

I support the research that states students who cannot nimbly transition between various frames of reference struggle with making sense of celestial information being presented. (Plummer, 2014). From my observation, students who cannot go from one frame of reference to another cannot grasp such phenomenon and are more at risk for developing misconceptions. In contrast, students who can spring from one frame of reference to another quickly seem to function at a much higher level of understanding not only in science but in other subjects as well. As Plummer (2014) states, “A full explanation for celestial motion phenomena requires understanding both the Earth-based and space-based perspectives, and requires the ability to shift between these perspectives to explain why celestial objects appear to move or change as seen from the Earth” (p. 2).

**Recommendations for Future Research**

There have been a number of questions that arose through this project: How can 21st century technology with 3D simulations help students understand the phases of the moon. How could we use digital apps pertaining to the phases of the moon to support correct scientific conceptions? How does modeling really impact student understanding when connected to 3D
simulations? I need to know more about the connections between technology and students’ cognitive development.

Another question I’d like to know more about is this: What does the research say about perspective in astronomy? I looked into this topic during the process, but not as deeply as I would have liked. There is so much more to learn about seeing celestial objects from different perspectives. This one idea could turn into an enormous study. If the answers were found, we as educators could help students see the moon in its eight phases as it rotates and orbits Earth in a whole new light. Using apps that can take the viewer into a space-based perspective could allow students to see more than an earth-base perspective.

Ponder this with me for a moment. Do we perpetuate misconceptions when we ask students what they think they know about such a concept as the phases of the moon? They do not have the experience to make up an answer when it comes to abstract celestial questions. Since they do not know, yet are so eager to please, they come to the most likely conclusion possible. It is at that very instant, in my mind since doing this research, that those students create a logical and plausible misconception. I agree with Trundle, Troland, and Pritchard (2008) when they say, “In part, the inability to explain the phases of the moon may lie in how this concept is introduced to students” (p. 18). I also support Tweed (2009) when she writes,

Once we know what ideas our students bring with them, then we can use our pedagogical content knowledge to know how best to present concepts, identify where students may go wrong in their thinking or have gaps in understanding, and determine effective methods to help our students engage meaningfully with their preconceptions and the science concepts. (p. 53)

Perhaps, for some students, it is actually the pre-assessment that creates such
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misconceptions. The Conceptual Change Model lends itself to pre-assessing students in hopes of finding the individual’s level of knowledge. I think we need to be very careful when asking students questions. Can questions develop misunderstanding when asked? Instead of asking children about concepts that they know nothing about, perhaps we should give them the allowance to “opt out,” hence creating a blank canvas to which the artist can draw.

Conclusion

In conclusion,

1. What does the literature say about elementary students’ understanding of moon phases?

2. Does using the Conceptual Change Model impact elementary students’ understanding of the moon phases?

The findings in this study support what the literature says about elementary students’ understanding of moon phases. Third grade students approximately nine years of age are not cognitively developed to comprehend such abstract concepts. Some students revert back to original beliefs even after instruction convinces them otherwise. Learning new content requires practice spread over time. Misconceptions are created even during instruction, and students sometimes become confused because there are so many new concepts unrelated to what they know or have been taught. Understanding moon phases is very difficult.

The Conceptual Change Model does impact elementary students’ understanding of the moon phases as shown from the results from the pretest to the posttest. However, this study was not conducted to the degree the model requires. Due to time restraints, I was unable to do the necessary checks for understandings and then follow through with the looping back to the beginning steps when students were confused or had misconceptions. There were some instances
in which students were gleaning insight yet more time was needed to help students such as Billy, Celia, and Dan. The fourth question, which referred to what moon phases are seen by Americans and Chinese on any given night, needed several cycles of the model.
References


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Appendix A

APPENDIX E

PERMISSION LETTER FROM SUPERINTENDENT

School District #

November 17, 2014

Institutional Review Board

Please note that [redacted] has the permission of [redacted] to conduct a study, Can kinesthetic activities and investigations of perceptions change elementary school students’ understanding of the moon phases?

[redacted] students to support the investigation through a unit of Astronomy. They will be given a parental permission form to take home and return to school if they would like to participate. After the parental permission form has been returned, the student will be asked to sign a student assent.

The plan is to provide a pre-test, give kinesthetic instruction, and conclude with a post-test. This is to be completed approximately one month after IRB approval and no later than the end of the 2014-2015 school year.

[redacted] to provide to our office a copy of the [redacted] IRB-approved, stamped consent document before recruiting participants.

If there are any questions, please contact my office.

Signed,

[redacted]
APPENDIX F

PERMISSION LETTER FROM BUILDING PRINCIPAL

November 17, 2014

Institutional Review Board

Please note that [redacted] has the permission of [redacted] to conduct a study, "Can kinesthetic activities and investigations of perceptions change elementary school students' understanding of the moon phases?"

[redacted] students to support the investigation through a unit of Astronomy. They will be given a parental permission form to take home and return to school if they would like to participate. After the parental permission form has been returned, the student will be asked to sign a student assent plan. The plan is to provide a pre-test, give kinesthetic instruction, and conclude with a post-test. This is to be completed approximately one month after IRB approval and no later than the end of the 2014-2015 school year.

[redacted] has agreed to provide to our office a copy of [redacted] IRB-approved, stamped consent document before [redacted] recruits participants.

If there are any questions, please contact my office.

Signed,

[redacted]
Appendix B

PARENTAL CONSENT

RESEARCH STUDY

Description of the Research

I would like to invite your child to participate in a research study conducted by me, [Name] in the Masters of Science in Natural Science Program. Your child was selected as a possible participant in this study because they fall within the age range of study and are enrolled in class. By doing this study, I hope to learn more about how children think about the phases of the moon, and how hands-on activities affect their learning.

What my Child will be Asked to Do

Once you decide to allow your child to participate, the student’s science unit will consist of a short pre-test, instruction regarding lunar concepts, and a post-test. Each assessment will take approximately 20 minutes. Activities will last 2-3 weeks using multiple hands-on activities. Students will create a moon model like the model from http://www.astrofoto.org/node/899. Students will create and manipulate a moon sicle such as the one found at http://www.exploringnature.org/db/detail.php?dbID=42&detID=3581. Students will watch videos, read books, create posters, and continue to watch the actual moon outside during the day. For the instructional portion of this unit I will be providing hands-on activities of the moon phases to better support their understanding. The time spent for this unit will be no more than the usual time allotted for science instruction. In other words, class will be conducted as usual. Students choosing to participate will have their pre-test and post test analyzed. The data will help me evaluate my instruction and identify student understanding of the lunar phase concept. The unit should take no more than three weeks in third grade at Overland Elementary. I would like to access the students’ school file, including IEP or 504 plan for research purposes.

Risks and Possible Benefits

There will be very little inconvenience or risk involved in this study, as it is observational. The risks might be that the student or students might feel uncomfortable. If your child does feel uncomfortable in any way, you or they may ask at any time to be taken out of the study. There is no cost for participating, and this study will help further our knowledge about some of the instructional strategies we provide during science.

Protection of Privacy and Confidentiality
Lunar Phases: Uncovering Misconceptions through Conceptual Change

Your child’s name will not be used in any way during this study. The information that is obtained in connection with this study will be kept confidential by using a coding procedure so that your child is not identified by name. The information should be stored on a pass-word protected computer for no more than 9 months at which time all papers will be shredded. No other person besides the researcher will have access to the information. The PI or project director shall maintain, in a designated location, the signed informed consent forms and the written research summary, relating to research which is conducted for at least three years after completion of the research. Participation is voluntary, refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled, and you may discontinue participation at any time. I would like to access the students school file, including the students IEP for research purposes.

Choosing to be in the Study

Your child’s participation is voluntary. Your decision whether or not to allow your child to participate will not affect you or your child’s relationship with the school or its staff in any way. If you decide to allow your child to participate, you and/or your child are free to withdraw your consent and discontinue participation at any time without being a problem.

Contact Information

If you have any questions about the study, please feel free to contact, Dawn Anderson, 352-3260 at Overland Elementary, or her University of Wyoming advisor, Dr. Diana Wiig, at 307-977-5218. If you have questions about your rights as a research subject, please contact the University of Wyoming IRB Administrator at 307-766-5320.

Consent

Your signature indicates that you have read and understand the information provided above, that you willingly agree to allow your child to participate. You and/or your child may withdraw your consent at any time and discontinue participation without penalty, that you will receive a copy of this form, and that you are not waiving any legal claims.

Signature ___________________________ Date ____________
I'm your teacher and as you know I'm working on my masters in Science and I want to study how students learn. I would like you to help me with my project. The unit should last about 2-3 weeks, and we will be working on lunar phases; that is understanding how the moon works. It's going to be exciting as there will be all kinds of hands-on activities and everyone will participate.

There will be a pre-test and post-test, like usual and many hands-on activities. We're going to use special kind of point of view to understand how the moon rotates and revolves. Just remember, you do have to participate but don't have to be part of the study, so let me know in between classes if you'd rather not be part of the paperwork.
Appendix C

Child’s Head as Earth in a 3D replication

Objective: The 3D replication will allow students to see that from the sun’s point of view the moon is always full. They will also be able to see the phases of the moon from an earth-based perspective as they turn their body counter-clockwise.

Vocabulary:
These vocabulary words are to be used by the teacher one hundred times throughout the lesson. Students will be expected to use them when speaking.
- New moon
- Waxing crescent
- First quarter
- Waxing gibbous (if you scramble the first three letters in ‘gibbous’ you get BIG)
- Full moon
- Waning gibbous
- Third quarter
- Waning crescent

Materials:
- Scissors
- 8 ping pong balls
- Styrofoam ball
- Black marker, yellow marker
- Hot glue gun w/ glue stick
Lunar Phases: Uncovering Misconceptions through Conceptual Change

Large stiff cardboard
Ruler

**Procedure:**
Bring all the materials into class and allow the students to assemble the 3D replication. Eight students color half of the ping-pong balls black two students color the Styrofoam ball yellow. Four students use scissors and cut the cardboard (glue supports underneath if necessary). Teacher measures out from the center circle the same amount eight equally spaced times around the center of the center circle and marks a dot with a pencil. Glue the sun in place. Make sure to tell the student Earth rotates counter-clockwise. Show them which way that is. Something else that is important for students to understand is that their face is the part of Earth that we live on.

**The Lesson:**
Making sure everyone is engaged ask a student who is holding a ping-pong ball to pick a friend to help answer questions. ONLY have that child and his/her friend answer 2-3 questions before hot gluing the ball into place and letting those two students see for themselves what they accomplished.

Here is a list of questions to choose from while asking students to place a ping-pong ball on the board.
- Where do you want to put your ping-pong?
- Do you have it facing the correct way?
- What does the sun see?
- What does “Tommy” see who is standing on the opposite side of the 3D replication?
- Put your head in the hole and tell me what you see now?
- Take your friend and draw what you see on the chalkboard.
- Identify that phase.
- Show me how you know there are four quarters in a month.
- Show me how you know there are four weeks in a month.
- Face the sun. Understand it is noon, without moving your head can your eyes see a waxing crescent?
- Is the moon fully lit when it’s a full moon or is it only half lit?
- How many days does it take to go from a 3rd quarter moon to a waning crescent?
- What time of the day would you see a waxing crescent?
- Can you see a new moon at midnight?
- How often do we see a new moon?

After everyone has experienced having his or her head in the hole, allow students share by filling in the blank, “I use to think.........., but now I know.......” Write down information that will help guide your teaching for tomorrow.
Lunar Phases: Uncovering Misconceptions through Conceptual Change

CONSTRUCTIVIST LESSON PLAN FORMAT

CONCEPTUAL CHANGE MODEL

1. Students become aware of their own preconception about a concept.
   Can you identify the eight phases of the moon?
   Think Time - Explain as many phases as you can.
   - Draw pictures for additional help

2. Students expose their belief by sharing explanations in small groups and with the entire class.
   As they talk among their group, listen to them.
   Explain the full moon.

3. Students test their ideas by making observations. Working in small groups, they discuss the results of their test.
   Have students take turns donning the 3D replication.
   Ask them to make at least 3 statements about what they now see.

4. Students work toward resolving conflicts between their perceptions and their observations through class discussion.
   See if students original perceptions have changed.
   Listen for any misconceptions.
   Focus on necessary reteach.

5. Students extend the concepts and try to make connections between what they have learned in class and in other situations.
   Have students fill in the blank, "I used to think... but now I know..."

6. Students are encouraged to pursue additional questions and problems of their choice related to the concept.
   Ask students to share their ideas about what they still wonder about.

If the Moon were a penny...

Activity
Mission 1

Objectives:
- To understand the ways in which objects move around themselves and one another.
- To explore the unique phenomena about how we see the Moon from Earth.

Initial Questions:
1. What does it mean if an object rotates?
2. What does it mean if an object revolves?

In this activity, we are going to model the rotation and revolution of the Moon around the Earth by using two coins.

Materials
One penny, one other larger coin, marker, table

Procedure:
In order to mimic the way the Moon moves around the Earth:
1. Obtain two coins – a penny to represent the Moon and another coin larger in size to represent the Earth.
2. Place the two coins on a table or desk.
3. Choose a particular place on the edge of the "Moon" as a reference point and mark it with a small mark.
4. Now, move the Moon around the Earth to make one complete circle, but be careful to always keep the spot you picked pointed at the Earth.

You have just made a model of the way the Moon moves in relation to the Earth.

Questions:
1. In your model, how many times did the "Moon" revolve?
2. How long does it take for the Moon to revolve around the Earth?
3. In your model, how many times did the "Moon" rotate?
4. How long does it take for the Moon to rotate?
5. What do you notice about the time it takes for the Moon to revolve and the time it takes for the Moon to rotate?
6. What does this mean about how we see the Moon from Earth? Repeat the activity, paying special attention to your mark on the penny. Pretend you are on the coin representing the Earth. What would you see as the Moon rotates and revolves?

Credits: This activity was adapted from Madison Metropolitan School District Planetarium and Observatory, http://www.madison.k12.wi.us/planetarium/moonel/moontoq.htm
Lunar Phases: Uncovering Misconceptions through Conceptual Change

CONSTRUCTIVIST LESSON PLAN FORMAT

CONCEPTUAL CHANGE MODEL

1. Students become aware of their own preception about a concept.
   Question to pose: "Why do we always see the same side of the moon?"
   (Be able to respond in detail)

2. Students expose their belief by sharing explanations in small groups and with the entire class.
   As the "Share-out" continues listen to the "four-focus" students as they explain to the group their rationale behind the posed question, "Why do we always see the same side of the moon?"

3. Students test their ideas by making observations. Working in small groups, they discuss the results of their test.
   Follow the lesson plan steps for "If the moon were a penny..."

   (Make sure students understand terms such as: rotate, revolve, model)

4. Students work toward resolving conflicts between their perceptions and their observations through class discussion.
   Go back-to the "four-focus" students ask each student how their thinking has changed.

5. Students extend the concepts and try to make connections between what they have learned in class and in other situations.
   What other situations have you been in when you rotate as well as revolve?

6. Students are encouraged to pursue additional questions and problems of their choice related to the concept.
   Possible thoughts: What's on the back side of the moon?
   Has the moon always faced Earth this way?
   How come 29.5 days?

LOWELL OBSERVATORY

MOON CLOCK

OBJECTIVE: The moon clock will allow your students to know where the moon is in the sky at any time of day or night once given its phase.

MATERIALS: ✓ Scissors
✓ Brads

PROCEDURE: 1. Cut out both parts of your moon clock.

2. Place your direction finder (portion with E, S, an W) on top of your moon phase cutout. Place a brad through the ☿ for both parts at once.

3. Hold your moon clock so that the direction finder portion has the words horizon right side up, or make sure the house and tree are upright. This portion of the moon clock represents the ground at your feet.

4. Review the phase of the moon for the day of the activity (consult your daily newspaper.) Place that phase of the moon directly above the south (S) arrow on your direction finder. Read the time above the arrow, and check that all the students have the same time. The time shown is when that phase of the moon will be highest in the sky. Note the position of the sun. Is it day or night? If the sun is below the horizon line it is night.

5. Place the phase of the moon so it is above the letter E. E represents the eastern horizon. Now read the time above the South (S) arrow. This is the time that particular phase of the moon will rise. Repeat this step for the W. This represents when the moon will set.
Lunar Phases: Uncovering Misconceptions through Conceptual Change
Lunar Phases: Uncovering Misconceptions through Conceptual Change

CONSTRUCTIVIST LESSON PLAN FORMAT

CONCEPTUAL CHANGE MODEL

1. Students become aware of their own preconception about a concept.
   After you see a full moon, how long does it take to see the next full moon? (commit to writing)

2. Students expose their belief by sharing explanations in small groups and with the entire class.
   Share their ideas with group members then call on students to share with the entire class.

3. Students test their ideas by making observations. Working in small groups, they discuss the results of their test.
   Go out side in the mornings during a waxing crescent.
   Using the moon clock observe the moon as its position in the sky relative to the sun

4. Students work toward resolving conflicts between their perceptions and their observations through class discussion.
   This takes a month and you'll have to use support from the internet to show what phase the moon is in during the month until the next waxing crescent can be seen.

5. Students extend the concepts and try to make connections between what they have learned in class and in other situations.
   Full moon observation at home. (1 1/2 weeks after daytime viewing. Parent participation)

6. Students are encouraged to pursue additional questions and problems of their choice related to the concept.
   Possible ideas: How many days between a waxing crescent and a 1st quarter

Moon on a Stick

A M.A.R.S. Resource Document

Object: Learn about the phases of the moon.
Age: 7 years and older

Materials - For each participant you will need:
- a ping pong ball
- a short dowel (about 8” long) or a pencil
- some flat gray paint
- glue or wood putty

Preparation:
1. Attach the dowel or pencil to the ping pong ball by doing the following: Poke a hole in the ping pong ball. Insert the dowel or pencil until it touches the far end of the ball. Glue or putty the dowel at the point were it enters the hole. Let dry.
2. Coat the ping pong ball with flat gray paint. Spray paint is the easiest type for this, but it requires a well-ventilated area. Apply a few coats and let dry.

Activity Requirements:
1. A "moon on a stick" for each participant.
2. A morning with a bright sun low in the sky, or a bright horizontal light source such as a flood light or spot light.

Activity:
1. Go outside to the low morning sun, or turn on your horizontal light source.
2. Hold out your "moon on a stick" at arms length with the ping pong ball pointing up. You are now the Earth and the light source is the sun.
3. Imitate the phases of the moon:
   - Start with your "moon" extended toward the "sun." The side of the "moon" facing toward you is completely in shadow. This is a New Moon.
   - Slowly turn to the left until you are turned halfway away from the "sun." The "moon" is now showing you a waxing quarter, or a First Quarter Moon.
   - Turn completely away and you see a fully lighted side of you "moon." This is a Full Moon.
   - Continue turning until you are halfway toward the "sun." Your "moon" is showing you a waning quarter, or Last Quarter Moon.
Continue turning until your "moon" is extended toward the "sun." You have completed one cycle of phases, which normally takes 29.5 days. Your "moon" is new again and ready to begin another cycle.

Here are different phases that you can try to simulate. They are listed in the order of a phase cycle:

- new moon
- waxing crescent
- waxing quarter, or first quarter
- waxing gibbous
- full moon
- waning gibbous
- waning quarter, or last quarter
- waning crescent
- new moon, again

Don't forget:

- total solar eclipse: the moon completely covers the sun
- total lunar eclipse: the moon is completely in the shadow of the Earth (your head)

When they ask why we don't see a lunar eclipse and solar eclipse every month, mention that the moon is tilted 5 degrees to the ecliptic (the plane of the sun's orbit), and so does not line up on the ecliptic every time it passes through a new or full phase.

Once you have gone through the phases, make a game out of it by calling a phase out and seeing who can simulate it first. Have fun with your "moon on a stick".

For more astronomy activities, check out www.marsastro.org, the website of the Museum Astronomical Resource Society (MARS Astronomy Club), Tampa, Florida.
月球棒

Lunar Phases: Uncovering Misconceptions through Conceptual Change

CONSTRUCTIVIST LESSON PLAN FORMAT

CONCEPTUAL CHANGE MODEL

1. Students become aware of their own perception about a concept.
   Ask the question, "I people in the United States see a full moon, what would people in China see?"

2. Students expose their belief by sharing explanations in small groups and with the entire class.
   Listen as students explain their thinking noting concepts needing further investigation.

3. Students test their ideas by making observations. Working in small groups, they discuss the results of their test.
   Have created enough "moon on a stick" and hand out to each person. Together go outside during the morning hours when the moon is visible and close to the horizon. (Hold the moon stick at arm's length. Turn your body away from the sun. You now become the earth and the light source is the sun and the ring part fall is the moon.)

4. Students work toward resolving conflicts between their perceptions and their observations through class discussion.
   The students should make the connection that both Americans and Chinese see the same moon because as the Earth turns, 1/24th (round off this) the moon takes 29.5 days.

5. Students extend the concepts and try to make connections between what they have learned in class and in other situations.
   Posing how students connect this activity to something in their real life.

6. Students are encouraged to pursue additional questions and problems of their choice related to the concept.
   Possible questions: What does the Sun see when it looks at the moon? How about about people in Europe?