### UNDER ONE BIG SKY:

# ELEMENTARY PRE-SERVICE TEACHERS USE INQUIRY TO LEARN ABOUT THE MOON, CONSTRUCT KNOWLEDGE, AND TEACH ELEMENTARY STUDENTS AROUND THE WORLD VIA THE INTERNET.

#### A DISSERTATION

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BY

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#### **DEDICATION**

This dissertation is dedicated to my family:

to my maternal grandmother, whose stories of teaching in a one-room Kansas schoolhouse apparently influenced me more than I realized;

to my mother Lucille and my late father Donald, who first showed me the world and then gave me the good sense to use it well;

to my older son, Jonathan, who taught me tenacity and humor,

to my younger son Geoffrey, who showed me the true meaning of courage under fire;

and my beautiful daughter-in-law Angie, who taught me strength and faith, and gave me

my grandsons, Owen and Deacon. Their gift to me and to the world is hope.

Most of all, this is dedicated to my husband Mike. He is my constant inspiration, best friend, and my whole universe. His loving patience and support kept me writing when I wanted to quit. Together, there isn't anything we can't do.

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**ABSTRACT** 

**DISSERTATION:** Under One Big Sky: Elementary pre-service teachers use inquiry to

learn about the moon, construct knowledge, and teach elementary students around the

world via the Internet.

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Abstract

This study examined the content knowledge and pedagogical content knowledge

(PCK) constructed by a group of 24 pre-service elementary teacher participants as they

learned about the moon's phases, inquiry learning, and use of the Internet message boards

as a teaching tool as a part of their science teaching methods course. The MOON Project

(More Observations On Nature), an exploration of inquiry teaching via e-learning,

matched the pre-service elementary teacher participants with schoolchildren in grades 4-8

around the world. Upon completion of a 4-week moon observation phase, the participants

led the schoolchildren in a discussion of their observations via Blackboard<sup>TM</sup>.

This mixed methods study followed a quasi-experimental non-equivalent control

group design. The participants' content knowledge, pedagogical content knowledge and

perceptions about their knowledge were documented using questionnaires, essays, and

tests as they entered this experience and again as they exited. Qualitative and

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quantitative methods and analysis established that the increase in pre-service teachers' content and pedagogical content knowledge (PCK) as well as their perceptions of the knowledge gained was statistically significant at the conclusion of the project. However, they took away understandings of why the moon changes shape that were basic at best and fraught with a statistically significant increase in misconceptions. None of the instruments supported the pre-service teachers' perceptions of increased PCK. The preservice teachers had mixed perceptions about teaching over the Internet, mostly due to the degree to which their elementary student groups responded with focus to questions and discussions or, in some cases, participated at all. The findings and recommendations speak to teacher educators about the methodology used in teacher education programs.

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#### **CHAPTER 1 INTRODUCTION**

This study examined the content knowledge about the moon acquired by a group of pre-service elementary teachers as they learned about the moon's phases through their own observations and inquiry. Their content knowledge and perceptions about their knowledge were documented as they entered this experience and again as they exited. Their knowledge and perceptions were measured by a 15-Item Instructor-Created Questionnaire, by 4 Basic Moon Phase Knowledge Questions, and by 2 Reflective Essays given both before and after an extended inquiry project. A Moon Knowledge Application Test provided additional insight into the misconceptions the participants held both before and after the inquiry experience. The Moon Knowledge Application Test showed the elementary pre-service teachers' applications of this learning as they located and described misconceptions on a commercially available moon phase worksheet.

The elementary pre-service teachers observed the moon for 1 month as participants in inquiry learning. During this time, they received instruction about inquiry teaching and learning and about the motion and phases of the moon in their elementary science methods class. They then applied their learning by teaching small groups of elementary students around the world using asynchronous Internet messaging as a vehicle for their discussions. The pre-service teachers and the elementary students they interacted with were participants in a larger study known as The MOON Project (More Observations on

Nature), an externally funded multinational exploration of inquiry teaching via elearning. The current study is one of several undertaken to determine The MOON Project's effectiveness.

# The Need for the Study

Inquiry learning and teaching can be precursors to constructing knowledge about the natural world. The general public holds many misconceptions of nature; if schools are expected to produce science literate citizens, teachers themselves must be science literate. Elementary teachers currently practice various methods of teaching science. Each method holds merit, and most children attend schools employing various combinations of these methods. Yet these children graduate and continue through adulthood without knowing how to critically evaluate policy about technology, the environment, legislative issues regarding science research, or even their own health.

Missing from their education is a cadre of science literate teachers. Children are more likely to achieve higher levels of scientific literacy when taught by teachers who themselves are science literate and possess the pedagogical skills to share this understanding with their students (Bianchini & Colburn, 2000; Brunkhorst, 1992; Goodrum, Hackling, & Rennie, 2001; Greenwald, Hedges, & Laine, 1996; Yager, 1966).

Teachers' deep understanding of scientific concepts, teaching with technology, and pedagogical content knowledge (PCK) constitute a fair proportion of the literature. There is little research published to date that examines the impact of these three pieces taken together on elementary teacher science literacy and PCK.

The literature indicates that students as well as their instructors have a hard time understanding the causes of the phases of the moon (Atwood & Atwood, 1997; Atwood & Atwood, 1995; Brunsell & Marcks, 2005; Driver, Squires, Rushworth, & Wood-Robinson, 1994; Trundle, Atwood, & Christopher, 2002). The National Science Education Standards (NSES) (National Research Council, 1996) for Grades K-4 in Earth and Space Science state that "students should develop an understanding of objects in the sky and changes in earth and sky" (p. 130). According to the same Earth and Space Science standards for students in grades 5-8, "all students should develop an understanding of Earth in the solar system" (p. 158). This study explores the answers to these questions: Do pre-service teachers, themselves, possess these content understandings? Do they have the pedagogical skills to help their future students construct an up-to-standards understanding of these ideas?

The NSES also include "science as inquiry" as one of eight categories in their content standards. Common sense suggests that a quality teacher with a solid understanding of content, PCK, and inquiry teaching would be more likely to help students reach standards. The NSES (National Research Council, 1996) teacher standards state "teachers of science plan an inquiry based science program for their students" (p. 30).

Clearly, a competent, quality teacher must have the content knowledge, PCK, and the understanding of and ability to facilitate inquiry learning in students (Shymansky, Kyle, & Alport, 1983; vonSecker, 2000), as well as a working knowledge of the necessary technology for these standards to be realized in the classroom. However, actually measuring teacher quality is not such a simple common-sense task.

One attempted measure of teacher quality was developed by The National Board for Professional Teaching Standards (NBPTS) as National Board Certification. This process has been shown to identify teachers who have a positive impact on students as measured by standardized test scores (Goldhaber & Anthony, 2004). National Board Certification is a voluntary, rigorous process involving independent, anonymous assessment of the teacher's classroom videos, evaluation of the teacher's analysis of student work and the ability to show student growth as a result of the teaching, the identification and correction of student misconceptions, contextual analysis of lessons by the teacher, and reflection by the teacher, all providing evidence that the teacher can apply the NSES in the classroom in a manner that is most appropriate for a particular group of students at that time and in that setting. There is also an assessment center examination measuring content knowledge, PCK, and the analysis and remediation of student misconceptions.

It follows from both the NBPTS and the NSES that exemplary teachers should be content-knowledgeable, possess PCK, be proficient at teaching by inquiry, and be proficient with computer and message board technology. Exemplary teachers should specifically possess:

- 1. A high degree of science literacy including the Nature of Science and content (in this case, the moon) (Yager, 1966).
- Pedagogical skill at facilitating scientific inquiry among students (Bianchini & Colburn, 2000; Brunkhorst, 1992; Goodrum et al., 2001; National Research Council, 2000).
- 3. Appropriate proficiency with electronic communication methods needed to lead discussions with students (Boone & Anderson, 1995).

4. The ability to recognize and remediate misconceptions among both students and themselves (Tamir, 1983).

Much research has been undertaken with each of these individual ideas (Brunkhorst, 1992), yet no literature to date examines possible relationships among content knowledge, learning to teach using inquiry and the Internet, pre-service teacher learning, and pre-service teacher perceptions of important pedagogical skills.

The theoretical framework on which this study was based is rooted in three suggestions from the literature. First, independent studies suggest that to most effectively develop excellent teaching skills, pre-service teachers should be taught as they are expected to teach (Lim, 2001; Parker & Heywood, 2000; Sprinthall, 1995). Second, elementary teachers lack content and science process skills especially in inquiry learning to adequately develop these skills in their students. Third, while secondary teachers generally have a good understanding of their subjects, K-6 teachers show many misconceptions, citing the difficulty of some topics or the lack of need for such knowledge (Kikas, 2004). It stands to reason then, that knowledge newly constructed by pre-service elementary teachers learning to teach using inquiry over the Internet might replace their existing and possibly incorrect knowledge or their strongly-held misconceptions.

Although there is clearly a need among the general population for the understanding of natural phenomena, it is not unusual for people to lack such understanding (Schneps, 1988; Yager, 1991). In 1996, the National Science Board found that although 40% of all Americans expressed an interest in science and engineering, most of these Americans had no real idea how science operates. Only 2% of the adults surveyed knew that scientists

develop and test theories. Twenty-one percent did not understand the relationship of scientific methodology to the development of theories, but were able to describe the importance of a control group in experiments. Thirteen percent did not understand the need for a control group, but could describe science as based on careful and rigorous measurements. A full 64% of the American public surveyed had no clear understanding of science as the development of theory, the importance of a control group in experimentation, or the role of precise measurement and careful comparisons as a basis for scientific findings. A fundamental understanding of the basic premises of science is needed by anyone who needs to make decisions about the environment, funding space travel and other research, the use of technology, and even personal health. According to this and other studies about Americans' knowledge of the nature of science, most citizens are unable to use science in making such decisions.

#### **Astronomical Knowledge**

Astronomy in particular, is basic to public science literacy. There are many common, easily debunked myths based on a lack of understanding of astronomical concepts. One myth popularized by mainstream media in the spring is that an egg can be made to stand on end only at high noon on the vernal equinox (try this; with practice it can be made to work as well on most any day at most any time, depending on technique.) Another myth is that the Coriolis effect causes flushed toilets to spin in opposite directions in the Northern and Southern Hemispheres. Some physicists have found this to happen in sinks left standing and allowed to drain a few drops at a time over 3 weeks, but concur that in toilets, water is forced in at one direction or another regardless of hemisphere. The

reason for the sky's blue color puzzled physicists for years. People still believe that the sky is blue because it reflects the color of the oceans, or that the red light from the sun scatters as it strikes dust in the atmosphere. The correct explanation for the sky's blue appearance was quantified when Lord Raleigh described the scattering of blue light from the sun as the light strikes nitrogen molecules in the atmosphere (Plait, 2002).

It is common knowledge that the moon and the sun are astronomical bodies and that the sun is visible as it lights the day, while the moon is visible at night after the sun has set. While most people acknowledge that the moon changes shape or that it rises and sets at different times during different seasons, very few can describe the patterns observed. Still fewer can explain these patterns (Bailey & Slater, 2003-2004; Barnett, 2002; Callison & Wright, 1993; Schneps, 1988; Trundle et al., 2002) even though the National Research Council (1996) has stated that knowledge of the sun, the moon, and their patterns in the sky is important and basic for students as young as the elementary grades.

Even graduates from an academically prestigious university could not correctly explain the cause of seasons, when asked. The classic video, *A Private Universe* (Schneps, 1988), made at a Harvard University graduation shows young graduates and faculty being asked the question, "Why is it warm in the summer and cold in the winter?" Twenty-one out of 23 people interviewed incorrectly stated that summer is warmer because the earth is closer to the sun. The correct answer is, of course, that the tilt of the earth (which remains constant as the earth orbits the sun) puts each hemisphere at an angle to receive maximum sunlight during the season we know as summer. The increased radiation from the sun results in a temperature increase. The distance from the

earth to the sun varies very little; Earth is actually a little closer to the sun in January than it is in June.

Astronomical concepts, then, account for a large portion of science misconceptions. Within the field of astronomy, misunderstandings about moon phases take many forms. One commonly held misconception of moon phases is the belief that the shape changes of the moon, known as phases, are caused by the shadow of the Earth falling on the moon. When the moon is almost completely in the Earth's shadow, it is a thin crescent we call a new moon. When the moon appears full, it is reasoned that the moon must be completely out of the Earth's shadow. Alternative and equally incorrect conceptions are that different fractions of the moon are lit by the sun at different times or that planets cast a shadow on the moon.

The natural place to begin the exploration of misinformation leading to conceptual misunderstandings of natural phenomena by the general public is to examine an initial source of early learning about astronomy. This source of early learning about astronomy is most likely those who teach astronomical concepts to children in elementary school. Pre-service teachers as well as practicing elementary teachers have been found to harbor their own misconceptions about the greenhouse effect (Groves & Pugh, 1999), concepts in physics such as the process of heat transfer (Aiello-Nicosia & Sperandeo-Mineo, 2000) and motion (Halim & Mohd. Meerah, 2002), vision (Gregg, Winer, Cottrell, Hedman, & Fourneir, 2001), chemistry concepts such as solutions (Halim & Mohd. Meerah, 2002), and the nature of science in general (Abell, 2001; Howes, 2002). They also harbor misconceptions about the moon and moon phases (Atwood & Atwood, 1997; Atwood & Atwood, 1995; Trundle et al., 2002). Not surprisingly, these elementary teachers and

pre-service elementary teachers are among the adults who also are lacking in their understanding of the business and nature of science.

# **Science Literacy**

Since Sputnik's launch in 1957, various committees and task forces (Carnegie Forum on Education and the Economy Task Force on Teaching as a Profession, 1996; No Child Left Behind Act of 2001; The National Commission on Excellence in Education, 1983), have studied science literacy in the United States. One result has been a concerted effort to determine the most effective teaching strategies for promoting science literacy among students. Science literacy, a term introduced in 1958 (Hurd, 1958; McCurdy, 1958), has no universally accepted definition (DeBoer, 2000), yet fostering it is a task conventionally left to teachers during times when preparation of students for the future requires more and different knowledge and skills than teachers currently receive from their schools of education (Darling-Hammond, 1997). Generally speaking, having science literacy denotes that

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. Scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social conversation about the validity of the conclusions. Scientific literacy implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed. A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it (National Research Council, 1996, p. 23).

The term science literacy will be used in this study to describe the learning of both preservice teachers and their students. Science literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately (Schneps, 1988) and to form science habits of mind. Scientific habits of mind are the thought processes needed to understand the Nature of Science (NOS) as interconnected and validated ideas about the physical, biological, psychological, and social worlds that are particular ways of observing, thinking, experimenting, and validating ideas (American Association for the Advancement of Science, 1990). NOS has been referred to as the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of science knowledge (Lederman & Zeidler, 1987; McComas, 1998). Other common descriptions include science as a body of knowledge, a method, and a way of knowing (Lederman, 1992). It is generally agreed that there is more agreement than disagreement in various descriptions, particularly at the practical application level for the elementary science teacher.

Knowing and understanding science concepts and content, that is, possessing content knowledge is important if one wishes to share this knowledge. Content knowledge, or subject matter knowledge, is the information about a concept and the manner in which the information is structured in the teacher's own way of understanding. A teacher must also know the specific curriculum to be taught and must understand how to best implement the prescribed activities with the materials available. Additionally, an effective teacher must also possess "pedagogical content knowledge," or according to Shulman (1986), the ability to go beyond "knowledge of subject matter per se to the dimension of subject matter knowledge for teaching." Going beyond the knowledge of subject matter and curriculum would include knowing the places where students stumble,

diagnosing student difficulties and misconceptions, and remediating appropriately when necessary. This interplay between rich understanding of content and concepts, understanding of and ability to implement curriculum, and a strong mastery of the teaching skills and methods (pedagogy), combined with the skill to make decisions about the best plan for a given student at a given time has been shown to be important in student learning (Goldhaber & Anthony, 2004; Halim & Mohd. Meerah, 2002).

### **Inquiry Learning and Teaching**

Inquiry teaching (or the methodology needed to foster inquiry learning) has been described since the early 1900's (Dewey, 1910). Rather than prescribe a strict instructional methodology, Dewey described a preferred educational outcome - citizens whom we would consider to be science literate. As a contrast to lecture, memorization of facts, and simply duplicating laboratory work, Dewey wanted science taught in a manner that engaged students in thinking about their work and thus, their constantly changing world. Dewey's ideas have resurfaced over the last several decades as inquiry teaching and learning.

Inquiry learning, at its simplest, takes place when a scientist or student notices a phenomenon and begins to ask questions about it. According to the National Science Education Standards, inquiry in science is

... a multifaceted activity that involves making observations; posing questions, examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations (National Research Council, 1996, p. 23).

Inquiry teaching encompasses all methods used in the classroom to foster inquiry learning in students. Inquiry teaching methods include a continuum starting with asking open-ended questions to facilitating a completely studentdesigned investigation. Direct instruction is usually limited to introducing a concept, explaining something causing difficulty, or reinforcing something that all students should know. In science, experiments are commonly laboratory or field investigations including some type of data collection and analysis. Inquiry learning is not limited to this type of original research. It may include many means of information-gathering by students and many sources of data and knowledge including what is already documented by others. The teacher's role is to guide, facilitate, and support learning rather than to simply deliver the information by lecture. The teacher may assist the student in finding and evaluating resources, by acting as a sounding board as students develop research questions, hypotheses and experimental designs, or interpret their findings. Inquiry teaching involves choosing or developing a variety of lessons that invite and expect students to become actively involved in their learning process. The goal of inquiry teaching is to produce inquiry learning in students because inquiry learning is both an important science skill and an effective means by which students can make their learning their own.

Students form, or construct, their own interpretations and understandings of phenomena as they proceed through inquiry work. (Lowrey, 1997) These understandings described as knowledge that has been actively built up by a learner as opposed to having been transmitted from another source is known as

constructed knowledge. A classroom is said to be constructivist in nature when the teacher focuses students on changes in thinking, and stresses logic and fundamental principles as opposed to memorization of unrelated facts (Cobb, 1988; Driver, 1989; Tobin, Tippins, & Gallard, 1994; vonGlaserfeld, 1987).

#### Constructivism

Constructivism is a learning theory (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Noel, 2000; Shymansky, 1992; vonGlaserfeld, 1987; Yager, 1991) that describes knowledge as being actively built by the learner, not directly transmitted from another source. Constructivism has gained acceptance among educators as they work to develop models of effective teaching practices. Constructivist teachers hold that student-constructed knowledge benefits the student because the knowledge is personalized and incorporated into the student's own cognitive schema. The knowledge of others may influence the student's construction or reconstruction of knowledge, especially if the student is working in a social or community setting as is usual in the classroom.

Constructivist learning generally fits one of two broad categories or brands (Staver, 1998): social constructivism as described above, or radical constructivism. As defined by the radical constructivist Ernst von Glasersfeld (1989), constructivism is a "set of beliefs about knowledge that begin with the assumption that a reality exists but cannot be known as a set of truths because of the fallibility of human experience."

Radical constructivism as a developmental theory is rooted in Jean Piaget's (1970) Genetic Epistemology Theory. This theory used the term *genetic* in the sense of the more currently used term *developmental* in a model to describe how children built up knowledge (von Glaserfeld, 2001). Radical constructivism makes the claim that no two minds equally identify an experience so the learning or knowledge gained by each mind would now be unique. Because there is no universal knowledge, then there is no knowable reality. Each learner would have constructed his own unique knowledge or conception (De Zeeuw, 2001). Because there is no reality, a radical constructivist would accept each alternative conception as reality for that learner. Agreement with the knowledge constructed by others would not be necessary.

# **Misconceptions**

Constructed knowledge, then, is a gateway for alternative conceptions in learners. Scientists are not so accepting of such alternative conceptions when they are in contradiction to the conceptions that are commonly held by the science community. An alternative conception becomes a misconception to scientists. Some science education researchers distinguish *misconceptions*, or a misunderstanding a student derives from instruction, from an *alternative conception* that a student has formulated as a result of life experiences and brings with him to instruction (Driver & Easley, 1978).

Knowledge constructed by the learner may become a misconception due to misunderstanding or lack of understanding. A misconception may arise as a naïve idea

about an everyday experience. Misconceptions may also be passed along to students by teachers (Yip, 1998). In this study, the term *misconception* was used because the astronomical concepts studied have no known accepted alternative conceptions at the level of pre-service elementary teacher study. The term, *misconception* was used by the instructor of the science methods course in which the participants were enrolled.

Once a concept, correct or not, has rooted itself in someone's framework of knowledge, it can be very difficult to change (Driver & Easley, 1978). High school students interviewed in *A Private Universe* were found to have their own private theories of which their teachers were unaware as they conducted lessons. At least one student perceived by her teacher to be very bright and high performing harbored an initial misconception about the moon's path around the Earth. She was able to correctly revise her private theory after 2 weeks of instruction. However, this student was not, when asked, able to revise her private theory about the moon's phases. Would it be likely for this student to carry her conception of moon phases into a classroom, should she become a teacher? The misconceptions about moon phases held by pre-service elementary teachers and changing those conceptions is the focus of this study.

### Science, Technology, Society, and Education

Technology has become integral to both science and society. Classrooms are joining society in this way at an increasing rate as instructional technology is commonly used in an attempt to enhance student achievement. Technology literacy may be defined as the ability to use relevant technologies in a class or job (Linn, Davis, & Bell, 2004). Students need technology literacy to take advantage of not only educational opportunities, but in

their personal lives and careers after graduation. Elementary teachers play a big role in helping students become technologically literate, so teachers must, themselves, possess this literacy.

Technology may be used in an instructional setting to deliver information in an interactive environment. As a tool for inquiry, the Internet may be a source for data collection, data analysis, and communication about and sharing of the data. A software application may be used to collect or analyze data, but communication is often done via e-mail, a website or database, or if a group of people is involved, an asynchronous Internet message board system may be used as an online meeting place. Blackboard<sup>TM</sup> is one such web-based messaging system used by many learning institutions to facilitate discussions among specific groups of learners who can post written responses to a given prompt and then respond to one another's posts. Blackboard's<sup>TM</sup> asynchronous messaging capability provides the flexibility to "meet" on a reserved website and leave discussion message posts for one another at times convenient for the posters. The posts are then read and responses left by the reader for the original poster.

An online environment should provide more than a gathering place. The environment should nurture members' individual growth and foster a connection of members that is beneficial to all (Siemens, 2003). In this study, pre-service teachers are charged with maintaining such an environment while also facilitating elementary students' inquiry discussions as they share their collected data about the moon.

# **Description of The MOON Project**

Pre-service teacher participants in this study took part in an inquiry-based experience through their science methods class. This experience, The MOON Project, connected elementary and middle school students around the world with pre-service elementary teachers in a long-term (14-week) investigation of the Moon. The experience provided an opportunity for the students to share their observations with one another and with the preservice teachers via the Internet using Blackboard™. Pre-service teachers from eight universities in three countries and approximately 400 elementary school students from seven states and eight countries took part in The MOON Project over several semesters.

The MOON Project was funded by grants from the Diversity Associates Project of a large public Midwestern university and NASA. There was no cost to teachers, students, or school districts to participate. A computer, an Internet connection, and access to Blackboard ™ were the only tools needed. The MOON Project was begun in the Spring of 2001 with initial objectives to:

- 1. prepare teachers to use the power of the Internet to teach science through inquiry for a culturally diverse mix of children in Grades 3-8.
- immerse pre-service teachers and children in Grades 3-8 in a long-term investigation of a natural phenomenon so that they would simultaneously learn about nature and strengthen their skills and dispositions as inquirers (Smith, Trundle, & Lee, 2003).

The MOON Project consisted of two phases. In Phase I, the elementary students and their classroom teachers observed the Moon in their own home school classrooms in accordance with the MOON Project Student Handbook (Appendix A) while the pre-

service teachers did the same in their university science teaching methods course. During this time, the pre-service teachers and the teachers in the home schools worked through the MOON Project Teacher Handbook (Appendix B). The teacher handbook contained a timeline of the project, expectations for student observations, student observation forms, weekly discussion topics, and Internet use guidelines for students.

Like the elementary students they would soon be teaching, the pre-service teachers made their own observations of the moon as it moved through at least one complete cycle. The pre-service teachers then linked with elementary students around the world through discussion groups on Blackboard<sup>TM</sup> for Phase II.

The Blackboard™ groups consisted of 8-10 students from each of several elementary schools around the world, with only1-2 students from any single school so that the groups were culturally diverse. One pre-service teacher was assigned to each Blackboard group and led those students through 10 weeks of inquiry discussions to compare the observations made during Phase I. The two phases totaled 14 weeks of observation of the moon cycles and a discussion of their ongoing inquiry through Blackboard™ conversations.

Schools around the world do not define age and ability range by the same system of grades K through 12 as does the United States, nor are teachers certified according to these same age group divisions. Even within the United States, schools may include grades K-6, 3-5, 3-6, or 6-8. For these reasons, the ages of children varied from school to school. The MOON Project goals met the NSES Content Standard D, Earth and Space Science, for both grades K-4 and for grades 5-8. In this study, "elementary students" ranged in age from 8 to 13.

### **Purpose of the Study**

This study has four premises that help to define its purpose. The first premise is that observing the moon and its patterns in the sky over time will help pre-service teachers increase their knowledge of and correct misconceptions related to the moon's phases and changing location in the sky. The second premise is that teaching about the moon by inquiry to elementary students around the world via asynchronous message boards will help pre-service teachers, themselves, learn inquiry skills and the pedagogy needed to teach about the moon by inquiry over the Internet. The third premise is that pre-service teachers will correctly perceive a gain in their knowledge of the Moon and in their ability to teach inquiry to students over the Internet. The fourth premise, by implication, is that teachers will have the technological proficiency needed to deliver the instruction to students in a technologically appropriate manner. These premises were examined through analysis of the experiences of one sub-set of the pre-service elementary teachers participating in the MOON Project.

#### **Methods of the Study**

Four types of data were collected from pre-service teachers enrolled in one section of a science methods course at a large Midwestern university. This experimental group was given a 15-Item Instructor-Created Questionnaire over their knowledge of the moon during the first week of class. At the same time, they completed 4 Basic Moon Phase Knowledge Questions. After a brief introduction to The MOON Project, pre-service teachers responded to the following two reflective essay prompts:

1. When I think about teaching students in the MOON Project via the Internet, I.....

# 2. When I teach about why the moon changes shape, I.....

Midway through the course, the experimental group was given the Moon Knowledge Application Test. This test was an illustration meant to explain the phases of the moon as represented by drawings of moon, sun, and earth in various phases found on a commercial website for children. As an application of their learning, the pre-service teachers were asked to describe at least two conceptual errors on this website that purportedly explained moon phases for children. They were given the same 15-item instructor-created questionnaire and 4 Basic Moon Phase Knowledge Questions again at the conclusion of their participation in The MOON Project. Finally, the elementary preservice teachers responded to the same 2 reflective essay prompts at the conclusion of their participation in the project.

Responses on the pre and post 15-Item Instructor-Created Questionnaire and 4 Basic Moon Phase Knowledge Questions were evaluated for a gain in content knowledge and changes in number and type of misconceptions. The application of knowledge gained as the ability to recognize and explain common misconceptions about moon phases and movement of the moon was assessed by responses on the Moon Knowledge Application Test. The pre-service teachers' perceptions of their learning and the pedagogical content knowledge needed to teach children by inquiry over the Internet were derived from the two reflective essays.

A control group was composed of 21 pre-service teachers enrolled in a different section of the same elementary science methods course. The control group completed the 15-Item Instructor Created Questionnaire at the beginning and at the end of their course. They did not complete the other instruments used in this study due to logistics and

instructor preference. They did not participate in an inquiry learning experience such as The MOON Project during their course.

# **Data Analysis**

Pre-service teachers' understandings of the motion of the moon were examined as follows:

- Responses on the 15-Item Instructor Created Questionnaire from both the
  experimental and the control groups were scored and compared statistically to
  determine if there was a gain in participants' general content knowledge about the
  moon.
- 2. Experimental group participants were ranked by their scores on the 15-Item Instructor Created Questionnaire. Free response answers on the pre and post 15-Item Instructor Created Questionnaire and the Basic Moon Phase Knowledge Questions pre-test were then compared using content analysis for patterns of misconceptions and conceptual change and for basic knowledge constructed about the phases of the moon.
- Applications of the experimental group's learning as determined from the analysis
  of a commercial student website were examined for correct conceptual
  understanding and misconceptions.
- 4. The experimental group's responses to 2 reflective essay questions before and after participation in The MOON Project were examined qualitatively to determine the pre-service teachers' perceptions of teaching by inquiry and their ability to teach by inquiry over the Internet (PCK).

5. The experimental group's actual learning as determined from the analysis of the pre-tests and post-tests were compared to their essay question responses to determine agreement between what the pre-service teachers thought they learned and what they actually did learn (i.e., perception vs. reality).

#### **Statement of the Problem**

The lack of scientific literacy in the general public lies in the preparation of elementary teachers to teach science. Elementary teachers often do not receive sufficient preparation in inquiry and have insufficient content knowledge fraught with misconceptions, passed on to their students. Did The Moon Project provide the preparation needed to inform the pre-service elementary teachers' content knowledge, their understanding of learning and teaching by inquiry, or change any of their misconceptions? Did the pre-service elementary teachers acknowledge these changes when they reflected on their learning?

### **Research Questions**

This study was an attempt to answer the following question: How does participating in an inquiry investigation and then leading elementary students through the same investigation contribute to the acquisition of content knowledge, pedagogical content knowledge, and inquiry teaching skills in pre-service elementary teachers? More specifically, the study asks:

1. Does pre-service teachers' content knowledge increase as a result of participation in the MOON Project?

- 2. Does pre-service teachers' perception of their knowledge increase as a result of participation in the MOON Project?
- 3. Does pre-service teachers' perception of their ability to use the Internet as an effective teaching tool increase as a result of their participation in The MOON Project?
- 4. Does the number of pre-service teachers' misconceptions about the moon decrease as a result of their participation in The MOON Project?

# **Limitations of the Study**

- 1. The study lacked demographics regarding pre-service teachers' high school science backgrounds. Their teacher preparation program required a basic course in physics and that information was available, but it was not known which if any of the participants had taken a high school physics or astronomy course or had any other astronomy education previous to enrolling in the science methods course.
- The study lacked opportunity for the researcher to interact personally with the preservice teachers for the purpose of clarification on any written responses to the measurement instruments used.
- 3. The study provided no opportunities to question the pre-service teachers or to follow them into their eventual classrooms and to ask about their practice.
  Additional questions about their teaching would have included:
  - a. What are you doing differently in your classroom because of your participation in the MOON Project?
  - b. Are you teaching differently about the moon?

- c. Can you give examples of decisions you made about teaching using inquiry as a result of your participation in the MOON Project?
- 4. The MOON Project Teacher Handbook contained several errors that went uncorrected during this part of the study. The Handbook only alluded to a definition of *rotation* on page 10 where an arrowed diagram illustrated the statement "The Moon's orientation rotates clockwise in the northern hemisphere." *Revolution* was not called by that name in the Handbook, although the concept was very important in the discussions of the movement of the moon across the sky. It was either assumed by the Handbook author that pre-service teachers were familiar with this term or it was planned that the pre-service teachers and elementary students would "discover" this phenomenon. Definitions of both *rotation* and *revolution* are included in the glossary of this chapter for purposes of interpreting student responses in the data.
- 5. Not all of the pre-service teachers' group postings were available on Blackboard™ at the end of the semester. Either the pre-service teacher Blackboard™ administrators removed them before the course ended, or the posts did not exist in the first place. Classroom teachers sometimes became involved with The MOON Project only to later learn that their students would not have access to Blackboard™ for discussion purposes.
- 6. The instruments used had no formal validity or reliability data to support them.

  The instruments were developed by the course instructor to suit his course requirements as a measure of the learning about the moon by the pre-service teachers.

- 7. Pre-test and post-test content knowledge were the only data available from a control group section of pre-service teachers who did not participate in the MOON Project.
- 8. The control section had a different instructor than did the experimental MOON Project section. Details about the content instruction received by the control group were not available.
- 9. There was no opportunity to use control data in the pilot study (5 previous methods classes that included The MOON Project and from which test/retest reliability data for Instrument #1 were drawn).

#### **Definition of Terms**

Except where noted, the definitions are operational definitions constructed by the researcher for the purpose of this study.

- Alternative conception a difference in the idea held by an individual or group of individuals from the generally accepted idea. Usually derived by the individual from his own specific observations or life experiences and brought to instruction (see *misconception*.) Not used in this study due to the instructor's use of the term *misconception* throughout the science methods course.
- Attitude a predisposition to respond positively or negatively toward things, people, places, events, and ideas (Simpson, Koballa, Oliver, & Crawley, 1994, p. 211).
- Asynchronous messaging individuals can contribute to a discussion at their leisure over the Internet by using specially designed software; convenient across time zones because it is not necessary for all parties to be available at the same time.

- Belief the general acceptance or rejection of basic ideas (Simpson et al., 1994).
- Blackboard™ web-based messaging system used by many educational institutions to facilitate discussions among specific groups of learners who can post written responses to a given prompt and then respond to one another's posts.
- Conception a general idea inferred or derived from specific observations or instances.
- Conceptual Change generally defined as learning that changes an existing conception (belief, idea, or way of thinking).
- Constructivism the assimilation of data into information which, when applied in a useful manner, becomes knowledge.
  - knowledge that is actively built by the learner, not directly transmitted from another source (Driver, Asoko et al., 1994).
  - includes such teaching strategies as invitation to inquiry, exploration, proposing explanations and solutions, taking action through decision-making, application of new knowledge and skills, sharing of information, and asking new questions (Yager, 1991).
- Critical thinking the use of scientific data to find the preferred explanation (National Research Council, 1996).
- Grounded theory systematic, flexible guidelines for collecting and analyzing qualitative data for the purpose of constructing a theory arising from and grounded in the data itself (Charmaz, 2006).
- Inquiry the methods and activities that lead to the development of scientific knowledge (Schwartz, Lederman, & Crawford, 2004); a set of interrelated processes by which scientists and students pose questions about the natural world and

investigate phenomena for the purpose of acquiring knowledge and understanding concepts (National Research Council, 1996). In this study, the term *inquiry* describes the acquisition of data, and the term constructivism is used to define the organization of data into information and the creation of knowledge from that information.

*Knowledge* – an awareness and collection of facts.

- Misconception an idea held by an individual or group that is different from and in contradiction to the generally accepted idea; taken in this study to be derived incorrectly by an individual from his own interpretations of instruction or directly from the instruction itself.
- Nature of Science interconnected and validated ideas about the physical, biological, psychological, and social worlds that are particular ways of observing, thinking, experimenting, and validating ideas (American Association for the Advancement of Science, 1990); the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of science knowledge (McComas, 1998).
- Orbit the usually elliptical path described by a celestial body as it revolves around another body.
- Pedagogical Content Knowledge the whole of the knowledge a person has of the subject concerned, as well as knowledge of the learning and the teaching of that subject (Shulman, 1986).

- Perception the model created by an observer as he gathers data in an attempt to understand and explain the phenomena; the model may shift as the observer gathers more information.
- Pre-service teachers elementary education undergraduate students enrolled in an elementary science methods course.
- Rotation the process of turning around an axis; applies to both the Earth and the moon.
- Revolution orbital motion about a point, as distinguished from rotation about an axis;

  Applies to both the Earth and the moon.
- Science Literacy literacy with regard to science (Roberts, 2007).
- Scientific Habits of Mind a manner of thinking in which scientific reasoning is used to construct knowledge, draw conclusions, and/or make decisions.
- Scientific Literacy the ability to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately (National Research Council, 1996). Properties of literacy, namely literacy that is scientifically sound regardless of content domain (Roberts, 2007).
- Shadow a dark figure or image cast on the ground or some surface by a body intercepting light (National Board for Professional Teaching Standards, 2004).

#### **CHAPTER 2**

#### REVIEW OF THE LITERATURE

### LITERACY IN SCIENCE

# History and Development of the Concept

The concept of literacy in science is deeply rooted in the earliest records of science education. It is there in the descriptions of science courses (National Society for the Study of Education, 1932); in the articulation of science curriculum (Downing, 1931); in the development of science textbooks (Dale, 1931); and in almost every aspect of science education research (Matala & McCollum, 1957).

A review of elementary and secondary education in the early 1900's indicates that textbooks and student interest surveys drove content selection in both elementary and secondary schools (Dale, 1931). At that time, simply knowing facts and concepts sufficed for science literacy. Secondary educators then began to debate whether laboratory experiments performed by students or those done as demonstrations by instructors yielded greater learning (Downing, 1931). Soon after, a report from The Committee on Science Teaching (National Society for the Study of Education, 1932) emphasized thinking, problem solving, and generalizing skills, citing research which supported children's abilities to think, problem solve, and generalize. Discrepancies

between educational practices and students' intellectual skills pointed to the need for change. This led to perhaps the earliest data-driven changes in elementary science programs (Powers, 1935). In studies focused on the moon, Haupt (1948; 1950) probed children's thinking skills with questions seeking a connection between children's fascination with and understanding of natural phenomena.

In 1951, Max Beberman led the University of Illinois Committee on School Mathematics in the initiation of a reform of secondary school mathematics later known as "new math." The "new math" consisted of a set of lessons to be taught in a set manner by specially trained teachers. Not to be outdone, science educators followed suit in 1956 as Jerrold Zacharias initiated the Physical Science Study Committee for the creation of materials and training of teachers in physical science. This committee found its purpose after the October 1957 launch of Sputnik. The launch served as a wake-up call to Americans, who began to perceive a threat to their security (Bybee, 1997). The American public now felt a need for literacy in science that would result from solid science education.

A review of science education research literature written during this time found trends leaning toward an emphasis on science in everyday life in the elementary grades.

Textbooks were written and re-written, teachers began to plan cooperatively, and prepackaged science curricula began to surface in the form of activity workbooks. This emphasis was also toward both the vertical integration of the K-12 science curriculum and the inclusion of K-12 science curriculum enrichment opportunities (Mallinson & Mallinson, 1961). K-12 science education had new goals and began to take on a new purpose. The term *science literacy* was introduced in the late 1950's (Hurd, 1958;

McCurdy, 1958). Hurd used the term in reference to newly formatted science education goals. During the next decade, the term *science literacy* became synonymous with greater content knowledge (Carlton, 1963). *Scientific literacy* surfaced as a buzzword in the 1970's as attention turned to the goal of producing responsible citizens (Gallagher, 1971). Technology soon came into the picture as the National Science Teachers' Association (NSTA) Board of Directors adopted a position statement entitled "Science - Technology – Society: Science Education for the 1980's" (National Science Teachers Association, 1982). Technology and its integration with science became an additional goal of science education.

The 1990's brought the American Association for the Advancement of Science's Project 2061 publication, *Science for All Americans*. This book suggested a focus on learning outcomes involving the natural world; the interdependence of science, mathematics and technology; and their respective strengths and weaknesses. The book emphasized depth of understanding and thinking. Soon after, the President of the United States, the nation's governors, and the U. S. Congress all identified the need for reform in math and science as one of six national goals needed to meet economic and educational challenges which threatened our worldwide leadership (Yager & National Science Teachers Association, 1993). Finally, in 1996 the National Academy of Sciences published The National Science Education Standards (NSES) (National Research Council, 1996). The content standards in this document were to be met through a process of inquiry leading to the construction of new knowledge by the students, themselves. Students who met these standards would be considered scientifically literate. Such literacy was valued as a vital aspect of participation in a modern democratic society

(Trumper, 2001). In this way, no child would be left behind; and all Americans would be expected to achieve the goal of science literacy by the time they graduated from high school (American Association for the Advancement of Science; No Child Left Behind Act of 2001,").

## Science Literacy vs. Scientific Literacy

Neither scientists nor science educators have agreed upon universal definitions for the terms science literacy or scientific literacy, useful as such definitions would be to this study. Both terms are discussed in the literature, often with little apparent distinction.

Paul DeHart Hurd (1958) first introduced the term science literacy. Decades later, Hurd (1998) referred to thinking skills as scientific literacy.

Project 2061 used the term scientific literacy when *Science for All Americans* was first published in 1989. The 1990 Oxford University Press edition of the book changed the term to science literacy. Douglas Roberts noticed this change when writing a chapter on the topic for The Handbook of Research on Science Education (Abell & Lederman, 2007). Roberts wrote to F. James Rutherford, founder of Project 2061, inquiring about the reason for the change. Rutherford replied in early 2003, stating that science literacy referred to "literacy with regard to science" and that scientific literacy referred to "properties of literacy, namely literacy that is scientifically sound no matter what content domain it focuses on" (p. 731). Roberts combined the terms into the inclusive abbreviation 'SL,' used in the chapter he wrote, to "express what should constitute the science education of all students. It is well known in the science education community that no consensus exists about the definition of SL" (Roberts, 2007, p. 729).

Shamos (1995) argued that simple recognition of a few scientific terms, concepts, or issues did not make one "science literate." Most students do not achieve sufficient understanding of science to evaluate current issues, largely because their shallow level of understanding does not include the depth of thought needed to transfer understanding to new situations. For this reason, Shamos preferred the term scientific *awareness* to scientific literacy when used to describe most people's state of science knowledge.

The NSES lists qualities of a person possessing scientific literacy. The Standards state that being scientifically literate means that a person can ask, find, or determine answers to questions derived from curiosity about every day experiences. It means that a person has the ability to describe, explain, and predict natural phenomena. Scientific literacy entails being able to read with understanding articles about science in the popular press and to be able to engage in social conversation about the validity of the conclusions. Scientific literacy implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed. A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately (National Research Council, 1996). More briefly, scientific literacy has been loosely described as "the knowledge and understanding of scientific concepts and processes required for personal decision-making, participation in civic and cultural affairs, and economic productivity" (Center for Science Mathematics and Engineering Education Staff, 1998, p. 21).

A single definition would need to embrace all uses of the term found in documents containing and supporting science standards. DeBoer (2000) predicted the difficulty of a

definition due to the broad implications and expectations for related science education components to change over time. Change or not, simply meeting the expectations as listed in the NSES has provided sufficient challenge for science educators. For educators, science literacy sometimes refers to content and publications in educational materials, while scientific literacy more often refers to a way of thinking about the natural world. The term science literacy is used in this study in reference to all aspects of science education, including content and thinking skills.

### **Importance of Science Literacy for the General Public**

Survival in society is more achievable if citizens are able to read, write, and comprehend what they read, but to be knowledgeable in matters of science is not necessarily critical to perform adequately at a basic level in society. Whatever the definition of science literacy as it pertains to children, it is generally accepted that skills implied by the broad description of science literacy enrich lives by allowing citizens to better understand the world around them. These skills help people make informed decisions, contribute to society in various ways, and thus live a more personally fulfilling life in an enriched society (American Association for the Advancement of Science, 1990).

It is important for the general public to be science literate because they make decisions regarding their own health, the health of others, public issues, and their own behavior with respect to issues such as littering, smoking, choosing appropriate medical treatment, the wise use of water, and energy, diet, and exercise (Hackling, 2002). For example, a science literate adult can comprehend the issues surrounding fluoridation of water,

installation of nuclear power plants, or measures needed to control disease. This adult could then potentially become part of a labor force requiring science literacy of its members (Schwab, 1960). Science literacy may also imply the ability to respond in a meaningful way to technical issues in our lives and in a political world (Ayala, 2004). Many Americans, perhaps as many as 95% (Goodstein, 1992), are not considered to be science literate by any definition because they lack understanding of the world around them and cannot use scientific reasoning in decision-making as part of their daily lives.

### **State of Science Literacy in Schools**

The United States, once *A Nation at Risk* (The National Commission on Excellence in Education, 1983), clearly intended to become *A Nation Prepared* (Carnegie Forum on Education and the Economy Task Force on Teaching as a Profession, 1996) and then vowed to Leave No Child Behind ("No Child Left Behind Act of 2001,"). A Nation at Risk outlines concerns with the education system prior to 1983. The study found that in the United States over the years 1964-1978, significantly fewer students took courses past Algebra I, more than one or two courses in science or languages, and that the curriculum in these courses was diluted. Graduation requirements became more relaxed, requiring less rigorous coursework. Students in the United States spent much less time on homework in mathematics, science, and language courses than did their counterparts in other countries. In the field of natural sciences, fewer than half of the entering college freshmen met or exceeded the recommended two years of high school study in biology and physical sciences ("This Year's Freshmen: A Statistical Profile," 1999). Low teacher salaries failed to attract top high school graduates to teacher education programs. Pre-

service teachers spent much more time in education courses as opposed to taking courses in academic fields of study.

Americans began to insist that educators pick up the pace in the classroom and asked policymakers to fund the efforts to improve science education. The next round of reports set goals for improvement in science, mathematics, and technology education. One such report from the Carnegie foundation, *A Nation Prepared*, was released on May 15, 1996 and set the bar for quality in education. The report included 4 goals:

- 1. Remind America of its economic challenges.
- 2. Recognize education as the foundation of economic growth, equal opportunity, and a shared national vision.
- 3. Reaffirm the teaching profession's importance in establishing standards of excellence in education.
- 4. Point out the window of opportunity for reforming education in the next decade.

Attainment of the latter three goals was expected to support the first goal, resulting in nationwide improvements in education. The Carnegie Foundation set to work on the third, most important and seemingly most attainable, goal.

## **Science Literacy and Teacher Quality**

The Carnegie Foundation's arguably successful journey toward their third goal was begun in 2004 with funding for the creation of the National Board for Professional Teaching Standards (NBPTS). The function of the NBPTS was to implement the report's

recommendation to place a quality teacher in every classroom. The NBPTS mission was to advance the quality of teaching and learning by:

- Maintaining high and rigorous standards for what accomplished teachers should know and be able to do.
- 2. Providing a national voluntary system certifying teachers who meet these standards.
- Advocating related education reforms to integrate National Board
   Certification in American education and to capitalize on the expertise of
   National Board Certified Teachers.

The NBPTS devised a rigorous approach to professional development, resulting in National Board Certification for approximately 50% of the teachers who, today, complete the professional development process. The Board developed a linked set of professional standards that provide systematic evidence of practice assembled in a highly structured portfolio that can be assessed by standardized evaluation methods based on these standards (Darling-Hammond, Berry, Haselkorn, & Fideler, 1999). A teacher in candidacy for National Board Certification must submit three portfolio entries based on their classroom, including videos and student work samples—one entry based on professional, community, and family collaboration. Teachers also take a four-hour test covering content, standards, and pedagogy. The commentary, analysis, and reflection accompanying each entry must demonstrate the teacher's knowledge of content standards, pedagogy, knowledge of students and how they learn, and the ability to plan rich lessons that work together to build student learning. The fourth portfolio entry

provides evidence of the teacher's contributions to the professional community and communication with parents and the school community. Most importantly, the portfolio and assessments must demonstrate the teacher's ability to positively impact student learning and to identify and remediate their misconceptions. Creating the portfolio and taking the examination typically takes one year, but may take as many as three years. Numerous studies have shown teacher quality is positively impacted by this professional development process (Goldhaber & Anthony, 2004).

While teachers nationwide worked to meet the new national standard, the government rolled out the No Child Left Behind Act of 2001, a federal education law aimed at closing achievement gaps between various student groups. The law focused on accomplishing accelerated student progress and closing achievement gaps between the sexes, as well as between ethnic and socio-economic groups in several ways. Schools were asked to improve accountability, implement effective school improvement and student options, and fairly and accurately assess student progress. These measures were expected to not only ensure that high schools prepared students for college and the workplace, but also to drive progress through decisions informed by reliable, accurate data. Additional elements of a high-achieving school system would address the needs of English language learners, strengthen early childhood education, and improve support for migrant students. The Act called for high standards for every student in every state, and for highly qualified teachers to lead every classroom. Clearly, this new legislative action was another attempt to improve science literacy among students nationwide.

# **Components of Science Literacy**

The general components of science literacy that may be derived from the literature through history are as follows:

- 1. The ability to use content knowledge and facts (Carlton, 1963).
- 2. The ability to find answers to everyday questions (National Research Council, 1996).
- 3. The ability to describe, explain, and predict natural phenomena (National Research Council, 1996).
- 4. The ability to read with comprehension articles about science and discuss socially the validity of those conclusions (National Research Council, 1996).
- The ability to pose and evaluate arguments based on evidence (American Association for the Advancement of Science, 1990; Ayala, 2004; National Research Council, 1996).

The components of science literacy guided the educational theory used to plan instruction to produce science literate future citizens. Taken together, the five components listed above surface in three types of activities teachers plan for use in K-12 classrooms:

- 1. Active learning and teaching (Inquiry).
- 2. Construction of knowledge by the learner (Constructivism).
- 3. Development of scientific habits of mind (Nature of Science).

Since the launch of Sputnik in 1957, these three concepts, along with supporting content knowledge, have become the theoretical foundation of science education in the classroom. The role of each as it affects the learning needed by a science literate

population is fundamental to the study of pre-service teachers learning about science and pedagogy. Pre-service teachers, themselves, must acquire knowledge about natural phenomena through inquiry learning, must construct their own knowledge, and must apply scientific habits of mind before such skills can be taught in their future classrooms.

# The Science Literacy Cycle in Classrooms

Children who are to grow up to be science literate adults must learn to construct accurate knowledge about the natural world by learning to cultivate scientific habits of mind. This learning is expected to begin in the elementary grades. Table 2.1 compares findings from three different studies about the time spent on science in elementary school classrooms from 1950 to 1994.

Table 2.1 Number of minutes spent per day on science

Study Author	Grade Level	<u>1950</u>	1985- 1986	1987- 1988	<u>1990-</u> <u>1991</u>	1993- 1994
Mallinson Weiss	K-3	23		26.4	27.6	32.8
Perie	K-3		18	20.4	27.0	32.0
Mallinson Weiss	4-6 4	29		34.8	33.6	38.4
	4-6		29			

In the 1950's teachers reported spending 1.9 hours per week (23 minutes per day) in the primary grades and 2.4 hours per week (29 minutes per day) in the upper elementary grades on science instruction, although administrators and curriculum coordinators considered 2.7 hours per week to be desirable (Mallinson & Mallinson, 1961). A report of the 1985-86 national survey of science and mathematics educators found that U.S.

schools averaged 18 minutes of science per day in grades K-3 (1.5 hours per week) and 29 minutes per day in grades 4-6 (Weiss, 1987). A study of time spent teaching core subjects showed that science was taught an average of 26.4 minutes per day in first grade classrooms during 1987-88, increasing to 27.6 minutes in 1990-91 and then to 32.4 minutes per day in 1993-94. At the same time, 4<sup>th</sup> grade students received an average of 34.8 minutes of science instruction per day in 1987-1988, 33.6 minutes per day in 1990-1991, and 38.4 minutes in 1993-1994 (Perie, Baker, & Bobbitt, 1997). While these studies suggest slightly more time was spent teaching science in grades 4-6 by the 1990s, the increases were far from significant. In addition, the studies did not describe the methods of science instruction that were being used.

Meanwhile, enrollment in high school and college science courses dropped consistently through the 1980's (Evans, 1985). The United States has some of the world's top research facilities but college students receive only minimal exposure to basic science courses. Lagowski (1987) blames this trend for science illiteracy. Perhaps at least part of the remedy for our science illiteracy lies in spending more time teaching science in the early grades. Time spent in science instruction alone does not, however, insure an increase in learning. The time might simply not have been spent in meaningful or effective activities or in activities that increased learning as measured by standardized tests.

The development of science literacy begins in early childhood and is greatly impacted by elementary through junior high school teachers (Goldhaber & Anthony, 2004; Greenwald et al., 1996) and the environments created by these teachers (Brunkhorst, 1992). A teacher who understands scientific concepts, possesses the skills described by

science literacy, and who also has the ability to teach these concepts and skills should be able to effectively facilitate classroom time spent on science. Unfortunately, many classrooms are often managed by teachers who may or may not be well prepared to teach science and whose attitudes towards science range from enthusiastic to hostile (Goodstein, 1992).

Teachers, even those who teach young children, must know about science, and they must know how to teach science. Critics of the state of science literacy in young people today point out that this is not the case in many schools and fuel their position with data from reports such as The Nation's Report Card (O'Sullivan, Lauko, Grigg, Qian, & Zhang, 2003) and This Year's Freshmen: A Statistical Profile (1999). Although it is assumed that teachers know the content they are hired to teach, teachers often lack the necessary background especially in the physical sciences. During the 1999-2000 school year, only 55% of all high school students received physical science instruction from a teacher with a major or minor in the physical sciences; the figure in middle schools was 18%. Amazingly, nearly 50% of all middle school students that school year received science instruction from a teacher without a major or minor in any science or science education field (Goodstein, 1992).

The goal of teacher education is to prepare pre-service teachers to most effectively lead students toward the goal of science literacy. Weiss (1987) found only 27% of elementary teachers stated they felt well qualified to teach life science while 16% felt well-qualified to teach physical or earth science. A survey conducted by the National Science Foundation in 1990 found that 22% of all participating elementary teachers felt "very well qualified" to teach science, while 66% stated that they felt "very well

qualified" to teach reading (National Science Foundation, 1990). The teacher is the single most important influence on students' attitudes toward science (Westerback, 1982). A teacher whose attitude reflects a lack of confidence in his own understanding can be expected to communicate to students an attitude that science is difficult.

Brunsell and Marcks (2005) administered the Astronomy Diagnostic Test (ADT) to 142 K-12 teachers. The ADT is a diagnostic survey developed by the multi-institutional Collaboration for Astronomy Education Research (CAER) for undergraduate, non-science majors taking their first astronomy course. Elementary teachers had a mean score on the ADT of 35% (SD = 13), middle school teachers had a mean score of 50% (SD = 16), and high school teachers had a mean score of 64% (SD = 12). The researchers also found teachers' views were inconsistent with contemporary conceptions of the Nature of Science (Gallagher, 1991; Lederman, 1992).

As elementary students, many teachers were, themselves, introduced to science by teachers who may not have had an adequate science background. Unfortunately, research shows that regardless of the type of schooling received, misconceptions learned in the early grades are often strongly held into adulthood (Gregg et al., 2001). Pre-service teachers enter their formal preparation program with individual personal histories, perceptions, and classroom experiences. These teachers-to-be carry their learning (whether or not the learning is in agreement with knowledge commonly held by the scientific community) to their own classrooms and share it with elementary students. Teachers' incorrect or superficial understanding of content prevents them from presenting lessons that might encourage students to ask questions the teachers cannot answer (Gess-Newsome, 2001).

#### THE NATURE OF SCIENCE

A student wishing to become science literate as an adult needs to be able to think about science in the manner of a scientist. The Nature of Science (NOS) as a term describes this thinking as an interconnectedness and validation among ideas, ways of observing, thinking about, experimenting with, and validating the physical, biological, psychological, and social worlds (American Association for the Advancement of Science, 1990). Although "science as a way of knowing" has been the desired outcome of science instruction for at least four decades (American Association for the Advancement of Science, 1990), most people still do not understand scientific methodology well enough to discuss major scientific discoveries or theories (Edwords, 1986). Opportunities to learn such scientific habits of mind are necessary if students are to grow up to be science literate adults. To help learners develop such habits, science educators often rely on the inquiry learning process and the resulting knowledge that the learners construct.

### INQUIRY TEACHING AND LEARNING

Inquiry skills and the ability to construct knowledge in a manner that is in agreement with concepts currently held by the scientific community are important tools for a student. Inquiry learning promotes the acquisition of such information through investigations based on questions about the world. The nineteenth century saw a period of acquisition of science knowledge as simply an accumulation of fact, be that knowledge biological, physical, or mathematical in nature. Scientists sought facts and reported what they saw (Schwab, 1960). John Dewey (1956) was concerned that students were not flocking to the sciences and suggested that this was because "science has been taught as

the accumulation of ready-made material with which students are to be made familiar" (p. 121).

The mid-1900's brought an outcry for reform in science education, and that reform no longer found a simple increase in facts to be sufficient. The discovery of radioactivity and the launch of Sputnik had added fuel to the scientific revolution begun by Copernicus. True learning of basic concepts needed to be periodically revised by inquiry, due to the amount of information that had accumulated. The focus shifted toward learning to learn; if students needed to possess skills in inquiry, teachers would need to be able to teach these skills (Schwab, 1960). Science as inquiry involves engaging students in the kinds of cognitive processes used by scientists when asking questions, making hypotheses, designing investigations, grappling with data, drawing inferences, redesigning investigations, building theories, and revising hypotheses. Even with research suggesting the superiority of other methodology, most students were still exposed only to traditional didactic teaching methods through the 1960's and 1970's (Harms & Yager, 1981; Stake & Easley, 1978; Weiss, 1978). Fortunately, by mid 1980, some teachers had begun to shift away from a didactic classroom presentation of student memorization and testing (Anderson & Smith, 1987).

The American Association for the Advancement of Science (1990) suggested that science teaching be inquiry based. Teachers should

"start with questions about nature, engage students actively, concentrate on the collection and use of evidence, provide historical perspectives, insist on clear expression, use a team approach, not separate knowing from finding out, and deemphasize the memorization of technical vocabulary." (pp. 205-206).

Research indicated that inquiry should be central to science education (Boyer Commission on Educating Undergraduates in the Research University, 1998; DeBoer, 1991; Tamir, 1983), and that inquiry was more successful than lecture or other types of direct instructional strategies (Anderson, 1997).

In late 1996, the National Research Council released the National Science Education Standards. A focus on inquiry was a prominent part of the standards in both the abilities students needed to design and conduct scientific investigations and their ability to understand science as practiced by real scientists. The NRC listed "Learning as an Active Process" as one of four guiding principles to ensure that teaching would be consistent with the nature of scientific inquiry. The standards document generated five essential features for inquiry-based teaching along a learner-based continuum:

- 1. Learners generating investigable questions.
- 2. Learners planning and constructing investigations.
- 3. Learners gathering and analyzing data.
- 4. Learners explaining their findings.
- 5. Learners sharing and justifying their findings with others.

Bybee and DeBoer (1995) generalized the goals of science education into learning goals and suggested that inquiry learning was an important means to achieving all three. These goals were to a) acquire scientific knowledge; b) learn the procedures or methodologies of science; and c) understand the applications of science, especially with respect to the relationship between science and society.

Somewhere past lecture-memorize-test and lab practicals, but not quite yet to research as done in the research laboratory, versions of hands-on "activitymania" (Moscovici &

Nelson, 1998) began to take place in elementary schools while high school students spent increasingly greater amounts of time with cookbook-style laboratory work. The high school labs were generally directed by teachers or textbook laboratory manuals from the purpose to the last concluding question. The focus was often simply a verification of content covered in class in hopes of getting the right answer (Abell, 1999). In both elementary and secondary schools doing science did not always equate to thinking about science to acquire scientific habits of mind.

Inquiry is generally recognized as an active learning process in which students answer research questions through activities and data analysis that lead to the development of scientific knowledge. A commonly agreed upon purpose of inquiry learning is to move students beyond hands-on experiences and actively engage them in discovering phenomena, exploring possibilities, and making sense of scientific ideas. To be useful in promoting science literacy, inquiry skills must be incorporated into the science curriculum. One definition calls inquiry "an educational activity in which students individually or collectively investigate a set of phenomena—virtual or real—and draw conclusions about it" (Kuhn, Black, Keselman, & Kaplan, 2000). Implementing inquiry learning in classrooms had become the challenge.

## **Implementing Inquiry**

The lack of clarity in defining inquiry learning makes inquiry teaching tough to implement. Inquiry can take place on different levels. Tafoya, Sunal, & Knecht (1980) defined four levels of inquiry science teaching:

- 1. Confirmation activities that require students to verify concepts through a given procedure.
- 2. Structured inquiry activities that provide students with a guiding question and procedure to follow.
- 3. Guided inquiry activities that provide students with a guiding question and suggested materials, with the students designing and directing the investigation.
- 4. Open inquiry activities that require students to generate their own research question, choose their own materials, and design their own investigation.

A slightly modified, four-level model of inquiry developed by Bell, Smetana, and Binns (2005) is shown in Table 2.2 below. It indicates with an 'X' which of three critical inquiry components is provided to students by the teacher.

Table 2.2 Four-level Model of Inquiry

Information given to students					
Level of Inquiry	Question?	<b>Methods?</b>	<b>Solution?</b>		
1 (Confirmatory)	X	X	X		
2 (Structured)	X	X			
3 (Guided)	X				
4 (Open)					

Although other researchers (Bonnstetter, 1998; deJong & vanJoolingen, 1998) have used different terms to name the various levels of inquiry, descriptions of what is done at each level remain virtually identical.

The National Science Education Standards describes the role of the teacher in an inquiry classroom as that of coach, facilitator and modeler of the learning process and the role of the student as that of a self-directed learner.

The Learning Cycle provides a natural transition to inquiry teaching. Asking open-ended questions during discussions or having students create their own data tables for "cookbook" labs are good starting points for implementing inquiry in the classroom (Colburn, 2000; Colburn & Clough, 1997). Re-working such familiar labs as inquiry experiences helps teachers understand the difference between inquiry and what they already do (Huber, 2001). Simple demonstrations or hands-on activities can be presented to students with encouragement to ask questions instead of simply lecturing on the scientific explanation (Martin-Hansen, 2002).

Eick, Meadows, and Balkcom (2005) suggest scaffolding inquiry experiences for students, beginning with activities that require more direction from the teacher and gradually shifting to activities that are more student-directed. An example of steps that scaffold from a teacher-provided question to the learner formulating his own question include the teacher asking questions to help the learner sharpen a question or allowing a learner to select from several teacher-provided questions.

To further facilitate the inquiry learning process for students, a teacher can "inquirize" lessons using a version of the 5E Learning Cycle model (Everett & Moyer, 2007). In this model, a question is gleaned from a demonstration or lab. An activity for students is identified and presented to the students as a question. Students are engaged via demonstrations and investigations. Explanation occurs as students are supported in the analysis of their findings. Application to another concept or to a real-world problem is used for extension and evaluation.

Wherever its level, scientific inquiry is intended to help learners develop or construct new scientific knowledge. Building new knowledge usually follows such an investigation. Knowledge created in this way takes the form of a conceptual framework constructed to make sense of new information and integrates it with what a student already knows. The inquiry learning done by the pre-service teachers in the present study most closely fits the definition of structured inquiry. The inquiry learning done by the elementary students online through Blackboard™ was most likely somewhere between guided inquiry and structured inquiry.

## **CONSTRUCTIVISM**

Constructivism is a learning theory which describes knowledge as being actively built by the learner, not directly transmitted from another source (Driver, Asoko et al., 1994; Noel, 2000; Shymansky, 1992; vonGlaserfeld, 1987; Yager, 1991; Yager & National Science Teachers Association, 1993). Constructivism, as it describes learning in children, has gained acceptance among educators as they work to develop models of effective teaching practices. Constructivist teachers hold that student-constructed knowledge benefits the student because the knowledge is personalized and incorporated into the student's own cognitive schema. The knowledge of others may influence the student's construction or reconstruction of knowledge, especially if the student is working in a social or community setting as is usual in the classroom. The learner alone ultimately constructs his own knowledge.

According to Roscoe (2004) individuals construct and accept new knowledge and integrate this new knowledge, in one of 3 ways:

- 1. They integrate the new knowledge directly into what they already know (assimilation).
- 2. They compare the new knowledge and adjust what was known before if it was incorrect (accommodation).
- They reject the new knowledge or modify it to work with the old, incorrect conception.

Once a concept, correct or not, is accepted and integrated into a learner's framework of knowledge through the processes of assimilation or accommodation, it can be very difficult to change (Brownlee, Purdie, & Boulton-Lewis, 2001; Driver & Easley, 1978). When given the opportunity to think about or construct knowledge, students of all ages do not necessarily construct their knowledge in agreement with the knowledge accepted by the scientific community.

#### **MISCONCEPTIONS**

Constructivism allows not only opportunities for a learner to construct concepts as accepted by the science community, but also provides opportunities for the construction of alternative conceptions. The knowledge constructed by a learner may become an alternative conception or misconception due to misunderstanding, lack of understanding, or simply because the learner has a naïve idea about an everyday experience. Scientists are not so accepting of such alternative conceptions when they are in contradiction to the conceptions that are commonly held by the science community.

Misconceptions may also be passed along to students by teachers (Yip, 1998). Some science education researchers distinguish *misconceptions*, or a misunderstanding a student derives from instruction, from an *alternative* conception that a student has formulated as a result of life experiences and brings with him to instruction (Driver & Easley, 1978). In this study, the term *misconception* was used because the astronomical concepts studied have no accepted alternative conceptions at the level of pre-service elementary teacher understanding. Additionally, the term, *misconception*, was used by the instructor of the science methods course in which the study participants were enrolled.

## TEACHER CONTENT KNOWLEDGE AND PEDAGOGY

The relationship of the teacher to student learning is of great interest to teacher educators. The goal of elementary science teacher education programs is to produce teachers capable of providing a foundation in the basic concepts of science. Although students ultimately control their own learning, the influence of the teacher has been shown to significantly impact student learning in several ways. The teacher controls what will be taught and how it will be taught. The teacher's skill in choosing and implementing methodology can help or hinder student achievement. Teaching teachers how to make decisions regarding the interpretation and implementation of curriculum and methods coupled with teaching them to use these tools effectively is a major focus of teacher education today (Mallinson & Mallinson, 1961).

Shulman (1987) suggested seven types of knowledge that are essential for excellent teaching. These types are (1) content knowledge; (2) general pedagogical knowledge; (3)

curriculum knowledge; (4) pedagogical content knowledge (PCK); (5) knowledge of learners and their characteristics; (6) knowledge of education contexts; and (7) knowledge of education ends, purposes, and values. In addition to content knowledge, teachers must possess the pedagogical content knowledge to make that knowledge comprehensible to students (Shulman, 1986). According to Driehl, Verloop, & deVos (1998), variations on Shulman's initial conceptualization of PCK have appeared in the literature. Two components had universal agreement: the knowledge of learners and their characteristics; and general content knowledge for the specific topic to be taught. A science literate teacher would possess both content knowledge and the pedagogical content knowledge and skills to facilitate the construction of appropriate knowledge and skills in children.

Thorough knowledge and deep understanding of a concept are fundamental to the ability to successfully teach the concept (Traianou, 2006). Teachers are generally expected to have deeper content knowledge than they expect to teach: in the case of this study, knowledge of the moon's phases and their cause.

Science literacy for teachers can be broadened to include the skills described for the general public, but also must include pedagogical skills. A teacher with PCK can adapt his or her own understanding into a form that is communicated to a learner in such a way as to be incorporated into the learner's own knowledge and understanding. Knowledge and use of the learners' own backgrounds and preferred means of learning are important facets of such communication (Howes, 2002).

Educational methodology is widely thought to affect student learning (Cross, 1976). Historically, various methods have been used to teach students about natural phenomena.

Current teacher education programs utilize a variety of methods to instruct pre-service teachers in pedagogical content knowledge as well as skill in teaching scientific inquiry (Bianchini & Colburn, 2000; Boone & Anderson, 1995; Shymansky, 1992). Educators of students at all levels have drawn from educational theory when formulating teaching methods. One method is inquiry-based instruction, often a starting point for the construction of knowledge that is new to the learner.

## **Pre-service Teachers and Inquiry**

(Westerlund & Stephenson, 2002) found that pre-service teachers taught using techniques that phased them gradually into inquiry gave the process favorable reviews. At the end of the process, these pre-service teachers stated that they felt confident about changing traditional cookbook labs into inquiry labs once they had their own classrooms Many studies support the use of inquiry learning in science education at every level. An inquiry based investigation that ends once the data is collected and analyzed may not be sufficient for the construction of correct knowledge.

In a study by Abell (2001), pre-service teachers investigating the moon as part of their science methods course were found to be able to generate patterns of the moon's behavior by using their observations, but did not see a relationship between the work they had done and the nature of science as practiced by scientists. In the study, the participating pre-service teachers did not reflect on their learning aside from drawing a conclusion based on their data. It is this opportunity to reflect after learning that turns a hands-on activity into a minds-on experience.

Modeling a concept is one possible outcome of scientific inquiry. In a physics course training pre-service teachers by modeling, the pre-service teachers needed much hands-on involvement with the concept to get a feel for the phenomena they were expected to model with their own students. The pre-service teachers faced many difficulties themselves in the modeling process. Instead of constructing their model from the empirical data they collected (as was the intent of the inquiry task), most searched for model features in their previous physics knowledge. The pre-service teachers became aware they were doing so only after having the opportunity for meta-reflection on their learning experience (Aiello-Nicosia & Sperandeo-Mineo, 2000).

Children are very capable of developing sophisticated understandings of astronomy concepts and can replace misconceptions with correct knowledge if they are provided the opportunity to examine and reflect on the inquiry activities used to construct their knowledge (Barnett, 2002). Engaging in scientific inquiry alone did not enhance conceptions of the Nature of Science, whether in students, teachers, or scientists, unless a research context set the perspective and significant opportunity for reflection was provided (Schwartz et al., 2004). University content faculty sometimes choose to make changes in their own teaching style (Van Sickle & Kubinac, 2002). These changes may be the result of reflection by the faculty member on his/her teaching practice.

Pre-service teachers bring their own science background including conceptions, beliefs, and attitudes, but especially misconceptions and a lack of science literacy, into their teacher education programs. The teacher education literature shows that many teacher education programs are ineffective in uncovering, much less dispelling, student teachers' entrenched beliefs (Tisher, 1987).

(Halim & Mohd. Meerah, 2002) found that pre-service teachers dealt with student misconceptions in one of three ways:

- 1. Pre-service teachers were unaware of likely student misconceptions.
- 2. Pre-service teachers who anticipated student misconceptions did not also consider them while teaching or when providing remediation.
- 3. Pre-service teachers who presented elaborate teaching and remediation strategies might or might not base those strategies on a correctly-held concept.

## THE MOON AND MOON PHASES

From the work of Copernicus to the launch of Sputnik, current space travel and discoveries about our universe (as regards astronomy) have been an important part of science literacy. Science literacy, according to the strictest meaning, includes some knowledge about the moon and the cause of the moon phases. Basic knowledge includes the direction of the moon's motion about the Earth, the resulting phases of the moon and their causes, and the similarity of these phenomena from any point of view on the Earth. The motion of the Earth around the Sun is also basic knowledge. The thinking skills described by science literacy provide tools for applying basic knowledge and using reasoning to construct meaning from basic observations. One application of thinking and reasoning skills is the explanation for the moon appearing in the same phase worldwide at the same time with the only difference being an "upside-down" moon in opposite hemispheres. Another reasoning skill is the ability to explain the existence of different phases using conceptually accepted models of the motion of the Earth and Moon.

The Earth rotates to the East. East is a cardinal direction and may be calculated anywhere on a rotating astronomical body. Clockwise or counterclockwise can only be applied to a body in rotational motion once the side of the rotational plane from which the motion is observed is specified. For example, if an observer is in the Northern Hemisphere, counterclockwise and East describe the same direction. Right or left could be used if the observer were facing a specified pole. To an observer facing North, right is in the same direction as East or clockwise. To an observer facing South, left is in the same direction as East or counterclockwise. No matter where on Earth an observer stands, he would correctly describe the Earth's rotation as to the East. Accordingly, the moon revolves around the Earth to the West. The moon appears to move East to West in the sky, but actually moves West to East due to the Earth's rotation being faster than the moon's revolution. The moon rotates from West to East as it revolves around the Earth. The moon makes one rotation per revolution around the Earth. From Earth, the same side of the moon is always visible.

One half of the moon always faces the Sun, so at least one half of the moon is always receiving sunlight; but due to the moon's rotation, the illuminated part is not always the same part that is visible to anyone on Earth.

The moon displays a continuum of phases during the time from full moon to full moon. The names and descriptions of the eight basic moon phases are shown in Figure 2.1 below (Boyd, 2010).

Figure 2.1 Moon Phases

Picture	Name	Description
	New moon	None of the moon is visible because the opposite side of the moon is illuminated by the sun. The moon is nearly between Earth and the sun, passing a bit above or below the sun as seen from the Earth. If it were directly between, a solar eclipse would take place. The moon rises when the sun rises. It sets when the sun sets. It crosses the sky with the sun during the day. The moon is obscured by the sun's glare.
)	Waxing crescent	A thin crescent of light appears along the moon's eastern edge the night after a new moon. Sunlight reflected from the Earth onto the moon (earthshine) makes the remaining portion of the moon faintly visible in the west just after sunset. The moon moves eastward in its orbit each night, farther and farther from the sun. The moon is in line with the Earth and Sun.
	First quarter	Half the full moon is visible. The term "quarter" describes the moon being one quarter of the way through the synodic month. The quarter moon rises at noon and is high overhead at sunset. It sets around midnight. The moon is at right angles to a line between the Earth and Sun, as viewed from above.
	Waxing gibbous	Smaller than a full moon; termed "waxing" because the visible portion is increasing. The moon is now moving away from the sun as seen from Earth. It rises between noon and sunset and sets soon after midnight. It appears high in the east at sunset and can be seen during the day because a large part of the illuminated side of the moon is facing Earth and the sun's glare isn't obscuring it.
	Full	Seven days after the first quarter, the moon is on the side of the Earth opposite the sun. The entire sunlit side is visible to an observer on Earth. As the sun sets in the west, the full moon rises in the east. As the sun rises, the moon sets. A lunar eclipse must occur at full moon because this is the only time the Earth's shadow can fall on the moon.
	Waning gibbous	The waning gibbous moon rises on the eastern horizon between sunset and midnight and sets after sunrise, being very visible in the west during the morning.
	Last quarter	The moon is now three quarters of the way around its orbit of the earth. It rises around midnight, appears highest in the sky at dawn, and sets around noon. The moon moves noticeably closer to the sun each day, becoming once again obscured by the sun's glare.
	Waning crescent	The moon is nearly back to the line between Earth and the sun. It can be seen in the east before dawn. At dawn, the moon becomes obscured by the sun's glare although it is moving just ahead of the sun in the sky and sets in the west several hours before sunset. When light reflected from the moon is no longer visible, the moon is once again a new moon.

During the new moon phase, the moon is not visible to an observer. A first quarter moon is named because at this time, the moon has completed a quarter of its orbit but only half of the moon's face is visible to an observer on Earth. The term crescent is from a Latin word meaning "to grow," so the term crescent is correctly used to describe a waxing, or growing, moon.

According to the NSES (National Research Council, 1996), a learner in grades K-4 should be able to

identify sequences of changes and to look for patterns in these changes. As they observe changes, such as the movement of an object's shadow during the course of a day and the positions of the sun and the moon, they will find the patterns in these movements. They can draw the moon's shape for each evening on a calendar and then determine the pattern in the shapes over several weeks. These understandings should be confined to observations, descriptions, and finding patterns. Attempting to extend this understanding into explanations using models will be limited by the inability of young children to understand that earth is approximately spherical. They also have little understanding of gravity and usually have misconceptions about the properties of light that allow us to see objects such as the moon. (Although children will say that they live on a ball, probing questions will reveal that their thinking may be very different) (p. 134).

According to the same standards, a learner in grades 5-8 should additionally be able to explain that "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 (p. 160)."

# **Moon-related Misconceptions**

Despite the study of science during formal education, most people still have misconceptions about nature (Schneps, 1988; Yager, 1991) and especially about phases of the moon (Haupt, 1948; Haupt, 1950; Vosniadou, Skopelite, & Ikospentake, 2004). Two-thirds of students chosen from a graduation line at Harvard University gave

incorrect scientific explanations for earth and space science concepts such as why the earth grows hotter in the summer and the cause of the seasons (Schneps, 1988). It is no surprise that first grade children hold misconceptions about the solar system and the moon (often confusing science with myth and describing observations in terms of misconceptions passed on to them by others) as children so young are not generally able to create the complex explanations for moon phases they describe (Barnett, 2002; Haupt, 1948; Haupt, 1950; Vosniadou et al., 2004).

Any time information is collected and assimilated through personal observation or experience, as with observations of astronomical phenomena made by both children and adults, concepts may be constructed which contradict knowledge as accepted by the scientific community (Barnett, 2002; Hannust & Kikas, 2007; Kikas, 2004). Piaget (1930) described the progression of children's understandings of the motion of the moon, sun, stars, and clouds. Each stage of understanding was fraught with misconceptions. Children at an average age of 5 lumped clouds, rain, wind, the moon, sun, and planets into one entity he termed "heavenly bodies." Children explained that "heavenly bodies" followed humans as they walked. Six-year-old children attributed the cause of movement to God or to man and also added that the bodies moved because they "wanted" to follow. By about age 7, children transferred causation to other objects, such as wind, rain, day, or night but maintained the involvement of the bodies. At about age 8, children attributed the motion of "heavenly bodies" to wind, heat, and lack of daylight produced by the bodies themselves. Not until age 10 did children attribute motion to purely mechanical causes, such as the wind.

Haupt (1948; 1950) examined the beliefs of 25 children in the first grade both before and after instruction about the moon. He described children's misconceptions about the moon's composition (cheese), its size (big as a star, big as a thumbnail), its motion (the moon does not move), and the cause of its phases (clouds cover the surface and make it look like a face), many occurring after instruction. His study found few instances of the explanations described earlier by Piaget. Other examples of misconceptions were: clouds cover the moon causing the appearance of a face, there can be no water on the moon because the sun "burns" it all up, and the moon is the size of a thumbnail or a star. Haupt also recorded misconceptions about the moon's movement including that daylight, humans walking, clouds, wind, and the Earth were responsible for the motion of the moon. Children in Haupt's study also thought that the sun had 2 sides, one being the moon. The children described different shapes of the moon and knew that there was a pattern for the different shapes. They attributed the change in shapes to the same physical phenomena that caused the moon to move.

Children between the ages of 5 and 7 in particular (Hannust & Kikas, 2007) easily acquire factual information about the shape of the Earth but also tend to over-generalize this knowledge into misconceptions as they attempt to make sense of the information. Misconceptions often result from children's attempts to construct meaning from the pieces of information they do understand, both from their own observations and experiences and from the information given to them by others (Vosniadou et al., 2004).

Students in grades 1 through 4 (ages 5-7) often do not have a valid understanding of the Earth being round vs. spherical (Hannust & Kikas, 2007); the direction, cause, and relationship among the movement of the Earth, moon, and Sun (Kang & Howren, 2004);

and usually explain moon phases as caused by the Earth's shadow (Trundle, Atwood, & Christopher, 2007).

Textbook diagrams may contribute to misconceptions about the moon. A drawing cannot entirely model the actual three-dimensional arrangement or motion of the Earthmoon-Sun system. Some drawings show the moon as revolving around the Earth in a circular orbit at the equator rather than showing the Earth inclined on its axis with the moon's orbit being elliptical. The relative sizes of the moon, Earth, and Sun are not proportional in most textbook diagrams. Consequently, some children have been found to interpret these drawings as showing day and night rather than the moon phases. (Dove, 2002).

The cause of moon phases is the most common misconception about the moon for all students, grades 1 through college (Barnett, 2002; Hermann & Lewis, 2003; Schneps, 1988; Taylor, 1996; Trumper, 2001; Trumper, 2006; Trundle et al., 2002). The cause of moon phases is also the most common misconception for pre-service elementary teachers.

Trumper (2001) found that pre-service elementary teachers had the lowest response rate (23%) in a 16-item basic astronomy questionnaire, lower than even middle school students. He suggested a constructivist approach to teaching astronomy might be beneficial. Brunsell and Marcks (2005) administered the Astronomy Diagnostic Test, a 19-question multiple-choice test written in everyday language to determine conceptual understanding, to 142 science teachers. Nine of the questions asked about the moon and the cause of moon phases. Only 18% of the elementary teachers responded correctly. There are many studies showing what students and their teachers know, but little is

known about the impacts of teaching by inquiry over the Internet on the construction of knowledge.

#### **TECHNOLOGY**

Computers were first integrated into classrooms during the mid-1980s as tools for word processing and running tutorial software with varying opportunities for student interaction (Jonassen & Reeves, 1996). In 1999, 99% of all public school teachers reported having computers available somewhere within their schools, with 84% reporting that computers were available in their classrooms (US Department of Education, 2000). The availability of the Internet permitted students to pose a question of interest and explore websites for answers. As e-mail became available first to classroom teachers and then to students in some schools, questions could be posed directly to experts in the field of interest with almost immediate response times. Students could also use available software tools to word process their findings or to create a presentation to share with others, making the computer a tool for constructing learning rather than just a tutor or an encyclopedia (Owens, Tester, & Teale, 2002).

Advances in software and website interactivity facilitated the sharing of student-constructed learning. This, in turn, required teachers to be competent in the use of technology and the benefits and limitations of its use (Boone & Anderson, 1995; Davies & Rogers, 2000). Specific examples of skills needed by teachers are the use of word processing and presentation software, the use of email and listserves, the use of the Internet for finding lesson ideas and sites appropriate for students (Rasmussen & Norman, 2004), the ability to produce and integrate media, the ability to design websites

for delivering content, the ability to choose new electronic products, and the ability to teach these skills to students (Mishra & Koehler, 2006). As an extreme, Dee (2004) contemplated the paperless elementary classroom after the paperless office became a business possibility.

There are differences in the ways in which technology is used by new and by more experienced teachers. Russell, Bebell, & O'Connor (2003) found that newer teachers selfreport a higher level of comfort with technology than do older teachers, but use technology more in preparation than they do in the classroom. More experienced teachers self-report lower comfort levels with technology and use it less frequently in planning, but more frequently for delivering instruction. Teachers teach in the way they were taught, perhaps transferring their own classroom experiences to their practice (Ball, 1990; Lortie, 1975). Pre-service teachers must learn to use technology in their future classrooms. Otero et. al. (2005) suggest teacher education faculty have the responsibility of facilitating this learning by modeling, by direct instruction, and by facilitating discussion communities among pre-service teachers. The knowledge of technology and how and when to use it and teach with it was termed Technological Pedagogical Content Knowledge (TCPK) by Mishra and Koehler (2006). Teacher education programs must also foster a positive attitude toward technology in pre-service teachers. A negative attitude toward technology use can have a negative impact on learning (Koohang, 1987; Tairab, 2001).

Many types of technology have been used in pre-service teacher education. There are tutorials to assist with learning content at most any level, interactive tools, writing tools, tools for creating websites, tools for working with media, and tools for performing

mathematical functions (Oppong & Russell, 1998). Technology has been used to improve pedagogy. Pre-service teachers who analyzed videotapes of their mentor teachers showed greater skill in identifying and interpreting evidence of exemplary teaching than did their counterparts who only received feedback on their own student teaching (Beck, King, & Marshall, 2002). Many college courses currently have at least a minimal online component.

Technology in the form of computer-mediated communication has the advantage of allowing the nearly instantaneous sharing and analysis of data outside of a traditional face-to-face classroom setting via electronic tools such as Blackboard™ (Hew & Cheung, 2003). Observations and data can be shared, discussed, and analyzed almost instantaneously, giving way to collaborative communities of researcher-learners who may be geographically distant from one another. When communicating by asynchronous postings on a message forum such as Blackboard™, relaxed timing and the knowledge that what is written will remain for others to consider often provides the time and motivation for students to think more carefully than engagement in a face-to-face discussion (Harasin, 1989).

Asynchronous collaborative learning has introduced new challenges in education at all levels. Students might not always have access to a computer connected to the Internet. Assessing knowledge construction by participants in an on-line learning community isn't effectively accomplished using traditional methods such as tests, quizzes, or writing papers (Derry & DeRussel, 1999). The use of electronic tools gives a new perspective to inquiry learning and teaching in that interactions are limited to the text that is transmitted.

#### DATA ANALYSIS IN EDUCATIONAL STUDIES

Implementing a research method that will yield meaningful data has plagued educational scholars from the beginning of empirical educational research (McCall, 1923). Many educational researchers have used traditional scientific methodology to gather quantitative data, with useful results. Quantitative data consist of measurements, amounts, and comparisons of magnitude describing the characteristics or behaviors of the population. Surveys, test scores, observations of possible influences, and other data collection tools are used to gather information and then produce a statistical description of that particular circumstance using accepted methods of statistical analysis. Hypotheses are tested and other researchers can easily reproduce methods. Quantitative data can be used to support or reject a possible correlation. Quantitative studies are most useful when they produce generalizable results. Quantitative methods are purposely constructed to eliminate variables that threaten the validity of the experimental design, a near impossibility in educational research using human subjects. Quantitative analysis, however, does not allow these variables to be examined to determine their possible influential impact on the participants and ultimately on the experimental outcome. The researcher remains distant and objective from the participants as a means to remove bias and validate results. Science-based research as carried out in an educational setting does not account for cultures, social interactions, gender, and other unnamed, un-measurable influences (Lather, 2004). Providing for the examination of these variables in education research may aid in understanding the needs of the current education system.

According to Corbin and Strauss (2008), qualitative research is "a process of examining and interpreting data in order to elicit meaning, gain understanding, and

develop empirical knowledge" (p. 1). Qualitative research is multifaceted, interpretive, and uses case studies, personal experience and historical documents to describe problematic moments and their meanings in people's lives (Denzin & Lincoln, 1994). Qualitative research methodology examines and considers data such as stories, explanations, anecdotes, essays, and interviews. Qualitative analysis describes kinds of characteristics without attempting to measure or compare. Rather than leave unexplained gaps caused by limitations of scientific hypothesis testing, the qualitative researcher can begin to understand possible causes for such gaps. Recommendations for further study can be made, recommendations that would not have been possible from numerical data alone.

## **Quantitative Study and Human Research Methods**

Educational settings provide unique limitations with respect to assigning students to either the experimental group or the control group. Classrooms are often already set up, and the researcher must use the classroom group as is. It is also not usually possible to simply withhold instruction from a control group. For these reasons, methods from the quasi-experimental design group are sometimes the best choice. The researcher can, at a minimum, control who is measured and when measurements are taken. Results can be reported with acknowledgement to the variables that cannot be controlled.

Although quasi-experimental designs do not include the opportunity for the researcher to choose and group participants at random, some designs contain a control or comparison group. All designs have one or more uncontrolled variables. The advantage to quasi-experimental designs is that they can be realistically applied to real groups of

real learners in genuine academic settings. Much information can still be obtained about these groups of learners with the understanding that some uncontrolled variables might also have an influence. It is for this reason that many education researchers have begun to combine both quantitative and qualitative methods. The purpose of adding qualitative data collection and analysis to a quantitative study is to allow for deeper exploration of such variables for the purpose of seeking further insight and possible explanations.

# **Qualitative Research in Education**

The groundwork for qualitative research lies in both Chicago Interactionism and the philosophy of Pragmatism. Interactionism is a generic social paradigm describing the meanings attached to social interactions as central to society (Reynolds & Herman-Kinney, 2004). Interactions in this context refer to responses made to the perceived meaning attached to the actions of another person (Blumer, 1969). Chicago Interactionism grew from a pledge made by the University of Chicago's first president, Rainey Harper. He pledged to make investigation the primary work of the university and instruction only a secondary charge. George Herbert Mead, a philosopher and sociologist at the University, laid the groundwork for what would later become the symbolic Interactionist School of Sociology. Mead and his colleague John Dewey had earlier founded the Chicago School of Pragmatism as a laboratory school in which to experimentally test theories of education. Mead brought his immersion in social interactionism to the School. Dewey brought an understanding of the methods and reasoning used in scientific research, enriched by his realization of the value of anecdotes to such research. Philosophies from both men combined shaped Pragmatism as an

accumulation of collected knowledge, the source of said knowledge unimportant. Pragmatism, then, is the philosophy of considering practical consequences and real effects to be vital components of meaning and truth (Thomas, 2003).

From pre-1900 until about 1950, most published research was either purely qualitative or purely quantitative. In the 1960's these two forms of research were first combined in a "mixed methods" approach, often to provide independent sources of data to triangulate, or independently verify, results. Qualitative methods were used to triangulate quantitative data, or quantitative methods could be used to triangulate qualitative analyses. The qualitative and quantitative data could be collected one before the other or simultaneously. For example, in a design referred to as Dominant-Less Dominant, either a qualitative or quantitative method was primary with the other method used only in support or explanation (Clark & Creswell, 2007).

Development of qualitative methods continued through the 1970's into the mid 1980's. Conflict around the use of qualitative methodology also grew among researchers, including those in social science and education fields (Guba & Lincoln, 1994).

Education researchers tended to belong to one of two paradigms, positivist (quantitative) or constructivist (qualitative). Some researchers worked only with the traditional quantitative, or empiricist, approach. Others found the need for methodology supporting the constructivist/qualitative orientation, thus embracing emerging qualitative methods such as phenomenology, ethnography, and grounded theory (Guba & Lincoln, 1994).

One area of conflict between qualitative and quantitative researchers was the validity of data collected in a study. Real-world effects, more easily controlled in a laboratory setting, on research design and methodology were a validity concern in the sciences,

social and behavioral sciences, and in education. Qualitative research designs recognized and accounted for limitations, and then demonstrated outcomes that were often triangulated or verified by quantitative studies.

#### **Mixed Methods in Education**

During the later 1980's, these debates came to a head and then began to reconcile. Pacifists in education research proposed the new paradigm known as the Compatibility Thesis (Howe, 1988). Howe's new concept of pragmatism, compared quantitative and qualitative methods. Since the methods were comparable, researchers could make use of both. Strong agreement for the thesis came from Brewer and Hunter (1989) and Reichardt and Rallis (1994). The Compatibility Thesis later evolved into the Mixed Methods approach as it became increasingly clear that more could be accomplished when "several points of view came together to discuss differences" (Clark & Creswell, 2007).

Numerous cases involving the pragmatic paradigm supported qualitative and quantitative research as being compatible (Tashakori & Teddlie, 1998).

In qualitative research, experimental design can evolve throughout the collection and analysis of data because information that arises during the process can redirect the work (Corbin & Strauss, 2008). Questions arising during data collection can be examined alongside the statistical analysis to help uncover meanings valuable in addressing the research question and in making recommendations for solutions. Qualitative research affords the researcher an opportunity to question data in ways that are not possible with statistics alone. Because research on education involves both empirical data and the individuals who generated the data, investigating the external variables surrounding the

individuals often exposes new ideas about the data that can lead to new solutions to the research question.

In an example of a mixed-method study Gerber, Cavallo, and Mareck (2001) used interviews with teachers to explain student results on the Classroom Test of Scientific Reasoning. The Informal Learning Inventory was used to compare the impact of students' informal learning experiences with the impact of experiences in a classroom rich in inquiry learning. The researchers identified classroom inquiry learning experiences as a variable and used it to separate students into two groups. They were able to determine that inquiry teaching had a larger impact on the scientific reasoning skills of students who had had fewer informal learning experiences.

Later, Harwood, Hansen, and Lotter (2006) developed the Inquiry Teaching Belief (ITB) instrument to afford researchers several ways to monitor teacher beliefs. They analyzed data collected from the instrument before and after the teachers implemented inquiry teaching in their classrooms. Since the ITB was designed to integrate well with qualitative analysis protocols such as observations and interviews, participating teachers with unexpected results (outliers) could be interviewed or asked to reflect on their experience or to explain their responses. Such responses were used to refine the instrument for future use.

(Hohenshell & Hand, 2006) used interviews, tests, and surveys for triangulation in a study of high school biology students' perceptions of the purpose of different writing tasks in building different science skills such as analysis, logic, and conceptual understanding. Responses to interview questions and surveys established differences between students' perceptions of the quality of their work and their actual learning as

determined by two different posttests measuring mastery of the same concepts. The qualitative data collected suggested the students in the experimental group correctly perceived increased learning while the control group students correctly perceived little change in their learning.

Qualitative data analysis is a process of bringing order, structure, and meaning to the masses of information collected for an educational study. It is an attempt by the researcher to summarize the data in a dependable and accountable manner (Bloomberg & Volpe, 2008).

#### **GROUNDED THEORY**

Grounded Theory is a specific qualitative research methodology developed by Glaser and Strauss (1967) for the purpose of building theory from data. Theories that are "grounded in data" in this way were more recently described as "theoretical constructs derived from qualitative analysis of data" (Corbin & Strauss, 2008 p. 1).

Grounded theory has as a general goal the creation of conceptual frameworks, or theories, through inductive analysis constructed from the data. Methods include systematic yet flexible guidelines for collecting and analyzing data. Early data are studied and sorted into categories that emerge from initial study. The categories are labeled with descriptive codes so they can be sorted and compared. The researcher then follows up on the emergent concepts in an appropriate way; for example, using interviews, questionnaires, or reflections. Additional data collected and analyzed helps shape the relationships that are found (Charmaz, 2006 pgs. 2-3).

Grounded theory is useful as a "bridge" between case studies and large-scale surveys, as used by Taber (2000; 2001) in the creation of a diagnostic instrument for use in exploring learners' understanding of the formation of chemical bonds. Tabor found an advantage in the use of grounded theory, resulting from a breadth not provided by individual case studies and an insight not uncovered by quantitative methods alone.

Eklund-Myrskog (1998) used a qualitative study of students' conceptions of learning in both nursing education and mechanical education as a starting point for a grounded theory analysis. They used grounded theory to explain similarities in how students in different disciplines interpreted their learning.

Martin, Mintzes, and Clavijo (2000) used the "constant comparison" procedure (Glaser & Strauss, 1967, p. 106) to expand upon newly-emerging research on knowledge restructuring and change in science learning. Both agreement with previous studies and new findings surfaced from their analysis of a series of concept maps created by students at four different times in an ocean science class. They found that students' integration of new concepts lagged behind the growth of an overall knowledge framework, suggesting that a significant amount of rote learning took place in the course that was heavily front-loaded with content. Students who showed deeper content understandings were also more likely to have greater self-awareness and were better able to monitor, regulate, and control their own learning.

#### **CHAPTER 3**

#### METHODS OF RESEARCH

The purpose of this study was to determine the impact of learning and teaching by inquiry on pre-service elementary teachers' knowledge about phases of the moon and teaching by inquiry over the Internet. As participants in a science methods course, these pre-service elementary teachers used visual observations, classroom instruction and discussion, and an online, asynchronous message board environment with elementary and middle school students around the world to learn and teach about the moon through scientific inquiry. As part of their coursework, the experimental group of 24 pre-service teachers participated in The MOON Project, an inquiry-learning module described in the introduction to this study. A second section of the science methods course was used as a control group, as those 21 pre-service teachers did not participate in The MOON Project.

The experimental group of pre-service teachers interacted with elementary and middle school students from Indiana, Ohio, Alaska, California, Arizona, England, Australia, and Qatar via BlackBoard™. The students ranged in age from eight to twelve and were enrolled in grade levels corresponding approximately to grades three through eight in the United States. The school in Australia was a private school. The school in Qatar was an American school for children of international diplomats. One school in Indiana was a

laboratory school associated with the College of Education at a teaching university. The remaining six schools were public.

The study focused on the pre-service teachers' gain and perceived gain in both content knowledge and technological pedagogical content knowledge as a result of their participation in The MOON Project. This chapter details the methods and data collection instruments employed.

#### **Timeline**

The MOON Project was a 14-week inquiry module taught as part of a regular semester-long elementary science methods course. It was not the only topic of instruction included in the course syllabus, but it was the only field experience opportunity the college students had to interact with and teach children.

During Phase I of the project, Instrument #1, the 15-item Instructor-created Questionnaire and Instrument #2, the 4 Basic Moon Phase Knowledge Questions were given to the experimental group, prior to any course instruction. Instrument #1 was also given to the control group at this time.

A week later, the experimental group completed Instrument #3, two Reflective Essays. The essays were submitted electronically to the course instructor who then removed student names and assigned code numbers before forwarding the essays to the investigator. At about this same time, the pre-service teachers began recording daily observations of the Moon. These observations continued until they had seen at least one full Moon Cycle. The elementary/middle school students and teachers with whom the

pre-service teachers collaborated made the same observations in their own home school classrooms during approximately the same weeks.

In week 5 of Phase I, the pre-service teachers worked through the MOON Project
Teacher Handbook, included here in Appendix B. The Handbook contains a timeline of
the project, expectations for student observations and student observation forms, weekly
discussion topics, and Internet use guidelines for students. Also included in the Handbook
is a list of ideas that "emphasize observations and patterns in observations" of the Moon
while de-emphasizing "interpretations of why the Moon does what it does." The MOON
Project Teacher Handbook was also a resource for the elementary/middle school
classroom teachers whose students were participating in the project. A Student MOON
Project Handbook, (Appendix A) was used by the children to help guide their work.

Just before the beginning of Phase II, the experimental group took the Moon Knowledge Application Test, a tutorial found on the Crayola website that inadvertently contained a number of errors. The pre-service teachers were to explore the tutorial and identify at least two of the six mistakes. This test was used to determine participant readiness to detect and discuss moon phase misconceptions with the children.

At week 6, Phase II began, and the pre-service teachers each led a team of 8-10 elementary or middle school students via discussion groups on Blackboard<sup>TM</sup>.

Blackboard<sup>TM</sup> is a web-based messaging system used by many educational institutions to facilitate discussions among specific groups of learners who can post written responses to a given prompt and then respond to one another's posts. The elementary/middle school students used asynchronous message boards on Blackboard<sup>TM</sup> to discuss and compare the

observations made during Phase I in an attempt to discover patterns in the Moon's movements and positions.

At the end of Phase II, the experimental group once again completed Instruments #1, #2, and #3. The control group retook Instrument #1. Table 3.1 below summarizes all of the events that occurred during the MOON Project's two phases.

Table 3.1: Timeline of The MOON Project

Week #	Phase I Observation	Phase II Internet			
1	15-item Instructor-Created Questionnaire & 4-item Basic Moon Knowledge Questions administered.				
2	Introduction to Moon Project; Reflective Essays assigned.				
3-6	Moon observations begun for both pre-service teachers & children; MOON Project Teacher Handbook introduced.				
5	Moon Knowledge Application Test administered.				
6		Internet discussions begun.			
13		Internet discussions ended.			
14		15-item Instructor-Created Questionnaire & 4-item Basic Moon Knowledge Questions Administered; Reflective Essays assigned.			

During the approximately 7-8 weeks of Blackboard<sup>™</sup> discussions, pre-service teachers posted 1-3 questions per week, and the elementary students responded. An example of a post is shown below:

Hello everyone! Welcome to the Moon Project. I would like to start off our discussion by asking some questions about what you have been observing about the moon. Please respond to each of the questions with three or more sentences.

- 1. What can you tell us about yourself that will help us to get to know you?
- 2. What have you been observing about the moon recently?
- 3. What do you think the moon will look like in this coming week? Where and when will be a good time to look for the moon?

I am very excited to hear what each of you observed.

## **Pre-service Teacher Participants**

The participants in this study were 45 pre-service elementary teachers ranging in age from 19 to 23 and enrolled in their second or third year of a teacher preparation program at a large Mid-western university. Participants were selected for this study based on their enrollment in sections of an Elementary Science Methods course taught during the Spring 2004 semester. Non-randomness is a limitation of this study because students self-selected by registering in a particular section. To insure anonymity, participants used the same identification number on all of the instruments they submitted. Of the participants in the experimental group, sixteen had completed the prerequisite general physics course; four had taken an introductory Astronomy course instead of the Physics course; and four had taken neither Physics nor Astronomy.

The catalog descriptions for the Physics and Astronomy courses do not mention the moon or its phases as topics to be covered, but that is something that either instructor could have chosen to include. The course descriptions are listed below because they both introduce an uncontrolled variable into the study.

PHYCS 101 Physical Science Concepts for Teachers. (1-3) Principles and concepts of the laws of nature involving mechanical, heat, light, electrical, nuclear, and chemical energy and the conservation laws associated with these forms of energy. Emphasizes applications appropriate to the classroom. Designed primarily for students in elementary education programs.

ASTRO 100 Introductory Astronomy: A Study of the Solar System and Beyond. (3) Study of the physical nature of objects in the universe and methods used by astronomers to understand them. Topics selected from basic laws of nature, the solar system, stars, nebulae, galaxies, and cosmology.

The control group in the study was a second section of the same science methods class, but taught by a different instructor. It is unknown if the control group received any course-related instruction about the moon, but the group did not participate in The MOON Project, itself. The control group included 21 students similar in demographics to the experimental group in terms of age and educational experience. While this group would have had the same prerequisite science course requirement as the experimental group, it is not known which course they took or what grade they received.

Demographics for both the experimental and the control group participants are shown in Table 3.2.

Table 3.2: Participant Demographics

Group	Gei	nder	Physics Gra					•		No Course	
	M	F	A	В	C	D	A	В	C	D	Taken
Experimental (n=24) Control		19 18									4 O U R S E S
(n=21)											

# **Research Questions:**

The study's research questions have been restated here as null hypotheses.

- 1. There is no statistically significant difference in content knowledge gain between pre-service elementary teachers who took part in The MOON Project and preservice elementary teachers who did not take part.
- There is no statistically significant difference in pre-service teachers' perception
  of pedagogical content knowledge prior to and following their participation in
  The MOON Project.
- 3. There is no significant difference in pre-service teachers' perceptions of their ability to use the Internet as an effective teaching tool prior to and following their participation in The MOON Project.
- There is no significant difference in the number of pre-service teachers'
  misconceptions about the moon prior to and following their participation in The
  MOON Project.

The MOON Project is a unique and original approach to teaching in a science methods class, so a search of traditional sources and related literature failed to provide a suitable instrument for gathering information from the participants. Consequently, this study combined quantitative and qualitative analyses of instructor-created instruments to explore the research questions. The four instruments used to collect data are listed and described below. A discussion of the design of the study follows instrument descriptions.

- 1. Instrument #1 is a 15-item Instructor-created Questionnaire administered at the beginning and the end of the project. This is the only instrument of the four given to both the experimental and the control groups.
- 2. Instrument #2 consists of 4 Basic Moon Phase Knowledge Questions, administered at the beginning and the end of the project. This instrument was developed by Trundle, Atwood and Christopher in 2002 as part of an earlier version of The MOON Project.
- 3. Instrument #3 is a set of 2 reflective essays administered at the beginning and the end of the project.
- 4. Instrument #4 is the Moon Knowledge Application Test, a web-tutorial for use by children taken from the Crayola website (Crayola, 2001). The pre-service teachers critiqued the tutorial for misconceptions that had been previously identified by the course instructor. This task was completed following the Observation Phase, but prior to the Internet Phase of the project.

## **Description of the Instruments**

# 1. 15-Item Instructor-created questionnaire: 01

The 15-item Instructor-created Questionnaire (Appendix C) consisted of 15 questions written by the course instructor to assess participants' conceptions of the Moon and Moon phases, as well as their ability to use this knowledge to predict motion and phases of the Moon as observed from different locations on the earth. This instrument was administered to both the experimental and the control groups. Both groups repeated the instrument at the conclusion of their respective courses. The 15 questions on the instrument were grouped into 5 categories:

- Items 1-5: General knowledge of the Moon's movement about the Earth based on observations and predictions in both hemispheres; use of terms "revolve" and "rotate."
- Items 6-7: Observation or approximation of moon's appearance expressed as a phase; understanding of the progression of phases from Full Moon to Full Moon.
- Items 8-9: Questions answered either from observational experience or reasoning based on previous observations and knowledge.
- Items 10-11: Predictions about the appearance of the moon on the other side of the world in the same hemisphere and in the opposite hemisphere.
- Items 12-13: Application of reasoning to explain the movements of the moon from observations.
- Items 14-15: observations or reasoning used to explain motions of the moon around the Earth.

Open-ended questions (Items 8-15) were included to approximate the level of understanding an elementary/middle school teacher would be expected to possess in

order to explain the concepts to students in grades K-4 and 5-8. Instrument #1 provided data to address the first hypothesis.

Participants were directed to write "I Don't Know" in the answer space to any question if they did not know the answer. The choice of writing "I Don't Know" permitted later exploration of any misconceptions constructed by participants and participants' perceptions of their own understanding. (Hypotheses 2 & 3)

# 2. 4 Basic Moon Phase Knowledge Questions O<sub>2</sub>

Elementary science teachers need certain basic knowledge and skills to help children understand the phases of the moon and the causes of those phases (Brunsell & Marcks, 2005). For the purposes of this study, seven skills that would allow participants to demonstrate this basic knowledge were identified and are listed below.

- 1. Draw correct shapes and orientations for basic moon phases.
- 2. State that the shapes would occur in a certain order.
- Draw the moon phase shapes at the correct angle as viewed in the Mid-western United States.
- 4. Include the eight basic moon phases.
- 5. Draw the moon phases in the correct order.
- 6. Label each phase with the correct name.
- 7. Correctly describe the cause of the moon changing shape.

Instrument #1 did not provide the opportunity to evaluate these skills, so 4 Basic Moon Phase Knowledge Questions (Appendix D) were chosen from interview questions previously developed by Trundle et al. Trundle developed the set of interview questions to determine pre-service elementary teachers' conceptions of moon phases before and after completing a month-long inquiry activity. The activity was similar to The MOON Project in that the pre-service teachers observed the moon daily and recorded their observations. They did not receive additional instruction, nor did they use Blackboard™ to communicate with elementary students. Trundle used the interviews to identify alternative conceptions held by pre-service teachers before and after the moon phase inquiry activity. The 4 Basic Moon Knowledge Questions were adapted with permission from Trundle's interview questions because they ask basic knowledge questions not asked in Instrument #1 about the moon phases.

These 4 basic questions were included in the study to examine the impact, if any, of observational inquiry on participants' construction of the correct pattern of moon phases. Correct answers to all four questions required participants to be able to demonstrate knowledge of all moon phases. Answers to the 4 Basic Moon Phase Knowledge Questions were read together for evidence of the 7 moon phase competency skills to determine initial misconceptions before the project began and again for changes in misconceptions after the project was over. The participants' scores on Instrument #1 were compared with their responses to the 4 Basic Moon Knowledge Questions to determine the gain in basic knowledge about and causes of the moon's phases and to verify the correct use of phases and terms in responses on Instrument #1. Participants'

responses to the 4 Basic Moon Knowledge Questions were examined qualitatively for alternative conceptions about the phases of the moon. (Hypotheses 1 & 2)

# 3. Reflective Essays: O<sub>3</sub>

The participants were given the following two prompts from which they wrote Reflective Essays. The first set of reflective essays were written just after being introduced to the MOON Project but prior to beginning any Phase I observations or study of the moon. Responses were emailed to the instructor. Participant names were replaced with identification codes and forwarded to the researcher. The prompts for the reflective essays were as follows:

- 1. When I think about teaching students in the MOON Project via the Internet, I.....
- 2. When I teach about why the Moon changes shape, I.....

The participants responded to the same 2 prompts via email again at the conclusion of Phase II by emailing their essay to the instructor.

Question 1 probed the participants' perception of teaching over the Internet as a possible uncontrolled variable influencing content knowledge gains. Question 2 examined participants' perceptions of their own Pedagogical Content Knowledge before and after participating in the MOON Project. Individual Reflective Essay responses helped to explore patterns of alternative conceptions and the reasons for them in greater depth. (Hypotheses 3 & 4)

## 4. Moon Knowledge Application Test: O<sub>4</sub>

The Moon Knowledge Application Test was administered prior to the Internet Phase of the project to determine whether the participants could recognize misconceptions students might share in their Blackboard™ discussion groups. The test (Appendix E) consisted of a tutorial intended for use by children, taken by the course instructor from the Crayola website (Crayola, 2001). The tutorial contained the following six major errors prioritized by the course instructor:

- 1. States the moon "rotates around the Earth."
- Describes and displays a diagram of moon phases caused by the Earth's shadow.
- 3. States the moon "becomes larger" and "becomes smaller."
- 4. Displays the moon moving in a clockwise direction around the Earth.
- 5. Portrays the moon as moving back and forth like a pendulum.
- 6. Does not show light rays from the Sun striking the moon.

The participants were asked to describe two of the six problems depicted in the document regarding how the moon changes shape. Content analysis of the participants' responses documented and described the misconceptions held by the participants prior to beginning the online phase of the project with elementary students. (Hypotheses 1 & 2)

# Reliability and Validity of the Instruments

## Test-Retest Reliability

Pearson's r values (correlation coefficients), commonly used to show test-retest reliability (Gliner & Morgan, 2000), were established for Instrument #1 by using archived data from five pilot semesters of The MOON Project. An r value of at least 0.7 must be achieved to show a strong positive correlation (Pyrczak, 1996), thus indicating that scores on the two tests are significantly close. As seen in Table 3.3, however, r values for the 5 sets of archived scores were no stronger than 0.2, indicating weak to very weak correlations or, in one case (r=-0.05), no correlation at all.

Table 3.3:
Test-Retest Reliability for Instrument #1, 15 Item Instructor-Created Questionnaire X = Mean Number of Correct Answers

	Pretest X	Posttest X			
Group	(SD)	(SD)	n	r	df
Pilot #1 Spring 2002	6.706 (3.642)	13.412 (3.549)	17	0.096	15
Pilot #2 Fall 2002	5.080 (2.606)	14.840 (2.752)	25	0.37	23
Pilot #3 Spring 2003	7.000 (3.699)	15.158 (2.943)	29	0.14	17
Pilot #4 Fall 2003	6.429 (2.993)	11.000 (1.927)	14	-0.05	12
Pilot #5 Fall 2004	6.792 (3.055)	11.208 (3.109)	24	0.215	22

Variation in r values among the pilot groups may have resulted from changes made by the instructor in teaching the class from semester to semester. Variation could also reflect preliminary scoring by the researcher only (before multiple raters were employed). In each case, the lack of positive correlation for The MOON Project classes indicates participation in The MOON Project may have greatly increased posttest scores.

## **Inter-Rater Reliability**

Inter-rater reliability for Instrument #1 was established by having 2 practicing secondary science teachers, both with undergraduate concentrations in Earth and Space Science, and 1 high school English teacher score the pre-tests and corresponding posttests from the experimental group. The high school English teacher was chosen because she had only a fundamental background in Earth Science and might be expected to make fewer inferences about the pre-service teachers' responses. They were given a list of code categories and no other explanation. Because the sample size was small, even a few areas of disagreement among raters would have a potentially large impact on the outcome. On Instrument #1, there were no differences among the "I Don't Know" responses because either the words were written or the answer space was left blank. There were 21 answers on the 15-Item Instructor Created Questionnaire. After the pilot scoring of 3 pretests and 3 posttests by all 3 raters, disagreement occurred only on items 14 and 15, and only as regards the coding of answers as "Observational" or "Rational." It was eventually agreed that "Observational" responses would be those that were actually seen, based either on the participant's observation of the actual phenomena or one similar to it. "Rational" responses would be those that were not based on actual observations.

Although observations might be cited in a response coded as "Rational," the participant's reasoning about the observation was emergent. After clarification, three more post-tests were scored with no difference among the raters. The remaining post-tests were scored with only 2 responses for Item 15 being scored differently by one of the three raters.

Instrument #4 was coded initially by the researcher, then three sets of responses were coded by the same three teachers who scored Instrument #1. The three sets of tests whose codings were verified were chosen randomly, one each from the top, middle, and low scorers on Instrument #1. With one exception, all coded responses were in agreement among the raters.

## Face Validity

Face validity for Instrument #1 was established by the course instructor and then the investigator independently by comparing the instrument items to the National Science Education Standards and to commonly accepted descriptions of the moon's motion.

T-tests were used to determine the difference between the means in gain scores for within-group pretests and posttests to examine Hypothesis #1.

#### The Experimental Design

A mixed methods design was used in this study. Both quantitative and qualitative data collection and analysis tools were used. Instruments #1, #2, and #3 were administered simultaneously at the beginning of the study, or parallel phase. Instrument #4 was administered following Phase 1 but prior to Phase 2, adding a sequential, or time dependent variable (Tashakkori & Teddlie, 2003). The participants were in an

educational setting offering diverse ways to collect as much information as possible with a goal of not interrupting the participants' learning.

Educational settings provide unique limitations with respect to assigning students to either the experimental group or the control group. Course section enrollment is determined by external factors and the researcher must use the sections as registration sets them up. It is also not usually possible to simply withhold instruction from a control group. In the case of the sections in this study, two different instructors opted for different instructional approaches. Lack of random assignment made a quasi-experimental repeated measures control group pretest-posttest design appropriate for the quantitative portion of the study (Gliner & Morgan, 2000, p. p. 95).

The participants' gains in learning about the moon were determined quantitatively by numerical scores assigned to responses in Instruments 1, 2, and 4. Test-retest gain scores were used to examine statistical significance among the data. Uncovering and documenting the participants' alternative conceptions was accomplished by content analysis of the open-ended responses on Instruments 1, 2, and 4. Deeper understandings of the participants' alternative conceptions and their perceptions of their learning about the moon and inquiry learning over the Internet were gained using a grounded theory approach integrating open-ended responses on Instruments 1, 2, and 4 with the reflective essays from Instrument #3.

The design of the study is represented by the following model:

The instruments and treatments represented here were described previously in detail.

- O<sub>1</sub> 15-item instructor-created Questionnaire (Pre-test and Post-test)
- O<sub>2</sub> 4 Basic Moon Phase Knowledge Questions (Pre-test and Post-test)
- O<sub>3</sub> Reflective Essays 1 and 2
- O<sub>4</sub> MOON Knowledge Application Test
- X<sub>1</sub> Moon Observation (Phase 1) begins
- X<sub>2</sub> Class discussion; work with MOON Project Teacher Handbook
- X<sub>3</sub> Internet Phase (Phase 2) begins; Phase 1 complete
- X<sub>4</sub> Internet Phase (Phase 2) complete

### **Data Analysis**

The data collected were analyzed first quantitatively and then qualitatively in this mixed-methods study. Statistical tests used were chosen with two considerations in mind. The first consideration was to find an inferential statistical test that would allow quantitative acceptance or rejection of the null hypotheses. The second consideration was the need to describe the data collected in terms of possible alternative conceptions held by the participants and almost certainly communicated to their elementary students. Qualitative analysis provided a means to gain insight into the origins of these alternative conceptions and how the pre-service elementary teachers constructed scientific knowledge during inquiry learning and teaching.

Scores from pre and post administrations of Instrument #1 taken by the experimental group were compared to scores from pre and post administrations of Instrument #1 taken by the control group. Responses to the pre and posttest items were first scored for correctness. Student responses to the 15 items on the instrument were then coded as "Correct," "Misconception," or "I Don't Know" (See Appendix F for the Scoring

Guide). These three categories were used for comparing means using paired t-tests. After scoring, the responses coded as "Misconceptions" were re-coded by type of misconception.

Correct responses were determined prior to scoring. To be scored as correct, a response must have included at least one statement communicating an understanding of the concept assessed by the item and must not have included a misconception.

Misconceptions were tallied during the scoring process and placed into the categories that simultaneously emerged. The categories differed from item to item depending on the content assessed. The categories were initially used to insure consistency among all the scorers.

The study used both quantitative and qualitative analysis to gain insight into preservice teachers' learning and teaching by inquiry, knowledge gained by their own inquiry, and perceptions about their knowledge after the study was over.

#### Quantitative Analysis Methods

Correlation coefficients were calculated for pre and posttest gains to show the strength of the relationship between within-group test scores (Pyrczak, 1996). The score samples in this study represented the entire population involved, but were close to or smaller than n=20 so the null hypothesis was also tested by comparing means using a paired t-test. The t-test is commonly used in the analysis of simple cases of pre-test/post-test designs (Games, 1990; Gliner & Morgan, 2000; Laird, 1983; Singer & Andrade, 1997; Staneck, 1988).

Scoring the pre-service teachers' responses and then using statistical analysis to quantify learning about both content and inquiry pedagogy builds the quantitative foundation for the study. T-tests compared pre-test scores to post-test scores to establish patterns of change attributed to participation in The MOON Project.

## Qualitative Analysis Methods

Quantitative relationships established among data may describe a problem, but they do not necessarily provide a deep understanding of what is needed to solve the problem (Smith, 2006). Exploratory data from the five earlier MOON Project pilot studies (providing reliability statistics for Instrument #1) indicated that participants' knowledge of the moon increased significantly as a result of their participation. Documentation of this increase in knowledge is useful in determining the effectiveness of The MOON Project, but still more useful is accounting for all of the variables impacting the participants (Campbell, 1978; Corbin & Strauss, 2008). In this study, the likely variables impacting the participants' newly-constructed knowledge were the preconceptions held by the participants at the beginning of the study as well as the conceptions constructed during their participation in the project. Deeper content analysis of the participants' responses to the items presented on the instruments revealed information about their misconceptions and conceptual changes about the moon, about inquiry learning and teaching, and about teaching over the Internet. This emergent knowledge scaffolded upon the initial statistics and led to new insights about misconceptions resulting from knowledge newly constructed by the participants.

The grounded theory approach used to uncover such insights is inductive in nature and uses a combination of coding procedures. Open coding refers to a first examination of the data leading to categorization and labeling of phenomena that are derived. Axial coding is the process of coding data around a single category. Data are connected in new ways between a category and subcategories. In selective coding, the core category contains the central phenomenon that arises from the data. The other categories integrate around the core category. Relationships among categories are validated. Other categories can be refined and developed as needed (Charmaz, 2006).

Based on the prompts for the reflective essays (Instrument #3), four categories were expected to emerge. As shown in Table 3.4, these categories were used to inform Hypothesis 3 and 4 about participant perceptions of their own learning about the moon, about inquiry, and about teaching over the Internet.

Table 3.4 Examples of Expected Categories for Instrument #3

Meaning of Codes	Code
Content Knowledge (participant)	ConKno
Teaching Methods and Strategies - PCK	PCK
Inquiry Learning and Teaching	InqLT
Teaching over the Internet	TchInt

Once the initial categories were confirmed, subcategories describing specific perceptions of participants were noted and comparisons between participant comments before and after The MOON Project were made. These data contributed to the understanding of the participants' perceptions of best practices in teaching about the moon, teaching by inquiry, and teaching over the Internet.

#### **CHAPTER 4**

### **RESULTS**

The purpose of this chapter is to present the results of the study and to connect these results to the research questions described in Chapter One. The first question concerned the construction of content knowledge by the participants while learning and teaching about phases of the moon by inquiry and over the Internet. The second and third questions focused on the participants' perception of their constructed pedagogical content knowledge and their perception of their ability to use the Internet as an effective teaching tool. The fourth question looked at alternative conceptions, both constructed by participants during The MOON Project and in place but unchanged as a result of their participation. Results were based on a) the statistical analysis of participant gain scores from Instruments #1 and #2 (the 15-item Instructor Created Questionnaire and the 4 Basic Moon Phase Knowledge Questions); b) statistical analysis of both participant misconceptions (incorrect responses) and participant perceptions ("I don't know" responses) from Instrument #1; c) qualitative discussion of trends and patterns found in open-ended responses to Instrument #3 (the two reflective essays); and d) statistical analysis of misconceptions as described by the participants on Instrument #4 (the on-line Moon Knowledge Application Test).

Constructed knowledge data from Instrument #1 and #2 were analyzed to answer Research Question One. Perception data from Instrument #1 and trends and patterns from Instrument #3 were examined to answer Research Question Two. Trends and patterns from Instrument #3 were also used to examine Research Question Three.

Responses from Instrument #4 as well as misconception data from Instrument #1 were used to look more closely at Research Question Four. The Research Questions and instruments used to examine them are listed below in Table 4.1.

Table 4.1 Research Questions and Instruments

Research Questions and Instruments  Research Question	Instrument
Research Question 1:  Does pre service teachers' content knowledge increase as a result of participation in The MOON Project?	Instrument #1: 15-Item Instructor Created Questionnaire Instrument #2: 4 Basic Moon Phase Knowledge Questions
Research Question #2:  Does pre-service teachers' perception of pedagogical content knowledge increase as a result of participation in The MOON Project?	Instrument #1: 15-Item Instructor Created Questionnaire Instrument #3: Reflective Essays
Research Question #3:  Does pre-service teachers' perception of their ability to use the Internet as an effective teaching tool increase as a result of their participation in The MOON Project?	Instrument #3: Reflective Essays
Research Question #4:  Does the number of pre-service teachers' misconceptions about the moon decrease as a result of their participation in The MOON Project?	Instrument #1:  15-Item Instructor Created Questionnaire Instrument #2:  4 Basic Moon Phase Knowledge Questions Instrument #4:  Moon Knowledge Application Test

Research Question 1: Does pre service teachers' content knowledge increase as a result of participation in The MOON Project?

## A Statistical Analysis of Constructed Knowledge

Instrument #1: 15-Item Instructor Created Questionnaire

Responses on Instrument #1 (Appendix C) provided the statistical answer to Research Question One. Gain score means from experimental and control group pre and posttests were compared using t tests. The results are shown in Tables 4.2 and 4.3. Table 4.2 indicates that only the experimental group showed a significant gain in constructed knowledge about the moon during the semester. Table 4.3 shows that initial knowledge about the moon was not statistically different between the two groups at the time of the pretest. This provides evidence for the assertion that participation in The MOON Project was responsible for the difference. On the basis of these findings, the answer to Research Question One is yes, and its null hypothesis is rejected. Note: this was the only instrument taken by both the experimental and control groups.

Table 4.2: Within Group Pre and Posttest Gain Scores for Instrument #1 X = Mean Number of Correct Scores

Group	X	SD	t	p	
Experimental (n=24) Pre Post	3.79 11.17	2.45 3.15	-8.60	0.00*	
Control (n=21) Pre Post	3.43 3.95	1.97 2.28	0.44	0.16	

 $p \le 0.05$ 

Table 4.3:
Between Group Pre and Posttest Gain Scores for Instrument #1
X = Mean Number of Correct Scores

Test	Experi X	mental SD	<u>Contr</u> X	<u>ol</u> SD	t	р
Pre	3.79	2.45	3.43	2.01	0.55	0.59
Post	11.17	3.14	3.95	2.33	8.81	0.00*

 $p \le 0.05$ 

One component of the data from Instrument #1 remains problematic. While there was a significant increase in constructed knowledge among the experimental group, the mean posttest score of 11.17 out of 21 possible is only 53%. This would indicate that at the end of the semester, The MOON Project participants could still only answer a little more than half of the questions deemed by the instructor as necessary for teaching the same information to students.

#### Instrument #2: 4 Basic Moon Phase Knowledge Questions

Elementary science teachers need basic knowledge and skills to help children understand the phases of the moon and the causes of those phases. For the purpose of this study, seven skills that would allow participants to demonstrate this basic knowledge were identified and are listed in Table 4.4.

Table 4.4: Seven Moon Phase Competency Skills

- 1. Draw correct shapes and orientations for basic moon phases.
- 2. State that the shapes would occur in a certain order.
- 3. Draw the moon phase shapes at the correct angle as viewed in the Midwestern United States.
- 4. Include the eight basic moon phases.
- 5. Draw the moon phases in the correct order.
- 6. Label each phase with the correct name.
- 7. Correctly describe the cause of the moon changing shape.

As participant responses to the 4 questions on Instrument #2 (Appendix D) were read, they were searched for references to any of the seven Moon Phase Competency Skills. Each time that a new skill was mentioned in a response, the participant's overall score was increased by one. The highest score possible on the instrument was 7.

Table 4.5 below compares the pre and posttest skill scores on Instrument #2 for the experimental group. It shows that the difference between the means was statistically significant. Like the 15-item Instructor Created Questionnaire, the 4 Basic Moon Phase Knowledge Questions indicate that an increase in constructed knowledge took place during The MOON Project. On this basis, the null hypothesis for Research Question One is again rejected.

Unfortunately, as with Instrument #1, the increase in constructed knowledge on Instrument #2 does not necessarily translate into adequate pedagogical skills. A mean post score on Instrument #2 of 4.42 out of 7 possible is 64%. While this is a slight improvement from Instrument #1, it still calls into question whether the pre-service teachers were adequately prepared to teach about the moon.

Table 4.5:
Pre and Posttest Skill Scores for Instrument #2
X = Mean Number of Correct Scores

Test	X	SD	t	p
Pre	2.13	1.30	-5.65	0.00*
Post	4.42	1.98		

<sup>\*</sup>p≤ 0.05

Research Question #2: Does pre-service teachers' perception of pedagogical content knowledge increase as a result of participation in The MOON Project?

A Statistical Analysis of Perceptions; A Descriptive Analysis of Trends and Patterns

Instrument #1: 15-Item Instructor Created Questionnaire

Because Instrument #1 included instructions to use the response "I Don't Know" rather than leaving an answer blank, it presented an opportunity to assess a participant's perceptions of his/her own knowledge (or lack thereof). Presumably, large numbers of "I Don't Know" responses meant that participants perceived their knowledge to be low. Conversely, small numbers of "I Don't Know" responses meant that participants perceived their knowledge to be high. Table 4.6 represents the difference between pre and posttest "I Don't Know" responses for both the experimental and the control groups. Results show that only the experimental group had a statistically significant change in the number of these responses between the two test administrations.

Table 4.6:
Within Group Pre and Post Perceptions ("I Don't Know" Responses) for Instrument #1
X = Mean Number of "I Don't Know" Responses

Group	X	SD	t	p	
Experimental (n=24)					
Pre	9.75	3.89	10.49	0.00*	
Post	0.92	1.35			
Control (n=21)					
Pre	9.76	4.79	1.37	0.19	
Post	8.71	4.14			

 $p \le 0.05$ 

Table 4.7 confirms that while there were no significant differences in the number of "I Don't Know" responses between the two groups at the pretest, by the end of the semester, the change in the number of these responses between the groups was large.

Table 4.7:
Between Group Pre and Post Perceptions ("I Don't Know Responses) for Instrument #1
X = Mean Number of "I Don't Know" Responses

Test	Experi X	mental SD	<u>Contr</u> X	<u>ol</u> SD	t	p
Pre	9.75	3.89	9.76	4.79	-0.01	0.99
Post	0.92	1.35	8.71	4.14	-8.26	0.00*

 $p \le 0.05$ 

While the data tell us that the experimental group's perceptions of their knowledge changed significantly as a result of their participation in The MOON Project, the research question asks if that change was an increase or a decrease. By looking at the frequency of "I Don't Know" Responses from both groups on each of the two tests, that answer is

revealed. The 24 experimental group participants chose the "I Don't Know" response 234 times on the pretest but only 22 times on the posttest; while the 21 participants in the control group chose "I Don't Know" 205 times on the pretest and 183 times on the posttest. Clearly, the experimental group perceived their knowledge to have dramatically increased over the course of the semester. While the control did show some increase in perceived knowledge, the t tests tell us that the increase was not significant. Based on these findings, the answer to Research Question Two is yes, and its null hypothesis is rejected.

## Instrument #3: Reflective Essays

Statements taken from the Reflective Essays provided an indication of the participants' perceptions of their own Pedagogical Content Knowledge. In their pretest responses to the second of the two prompts, "When I think about why the moon changes shape, I...," only 2 of the 24 pre-service teachers directly stated that they were confident of their knowledge of the moon while another 17 stated that they did not know enough facts to teach them to others. While most participants admitted their own content knowledge limitations at the beginning of the Project and described themselves as nervous or anxious about the limitation, 16 were also able to describe in some detail the teaching strategies they would use to help students learn. Unfortunately, most of those strategies began with the words "I will explain," "I will tell," and "I will show." Such strategies do not reflect the student-centered, hands-on/minds-on approach that defines inquiry. One participant described an inquiry approach that included observations, hypotheses testing and conclusions drawn from evidence, while another 5 were moving

in this direction with references to the elicitation of student prior knowledge and the focus on shared observations.

On the posttest responses to the same prompt, 6 participants stated confidence in their PCK and 11 more implied confidence by either describing student misconceptions they had corrected via the Internet discussions or by detailing inquiry-style teaching methods they would choose to teach about moon phases and their causes in their own future classrooms. This time there were only 2 students out of 24 who continued to describe themselves as nervous or anxious.

Twenty pre-service teachers admitted that they did not know much about the moon at the start of The MOON Project. Seventeen participants then wrote confidently at the end about the pedagogy they planned to use in teaching about the moon, implying they perceived they had the knowledge needed to teach about the moon to elementary students. Unfortunately, some of those 17 perceived a gain in knowledge even when the actual gain in knowledge was quite minimal as shown by scores on Instrument #1 or when the descriptions of teaching methods they would use contained misconceptions.

Excerpts from the responses to the second prompt on Instrument #3, along with the participants' corresponding Instrument #1 pre and posttest scores, are shown in Table 4.8.

Table 4.8:
Comparisons of Reflective Essay Responses and Scores on Instrument #1

Participant #	Pretest	Pretest Posttest		Posttest score	
1	I have some knowledge about the moon and why it has different shapes throughout the month from a physics class taken here.	Even I did not know many of the basic facts about the moon until last semester in my Physics class. It was not that I had many misconceptions I just did not have a reason to believe the way that I did (most of which were wrong.)	2	16	
2	I hope that through observations and activities in and out of class, I will be able to answer questions and explain.	I would have goals to help me be more organized, in asking questions and responding. Overall, I think I did pretty well.	8	13	
3	It is very important as a teacher to know the information. I have never really understood that (why the moon changes shape).	I feel I have learned a great deal this semester alone. I know I have so much more to learn about the moon but I feel I have come a long way and feel that I knew enough to be teaching students over the Internet.	7	10	
4	I would explain how the moon revolves around the Earth Although this is not something I feel confident about explaining at this time, I hope I will better understand it. I have a lot more to learn before I can begin to teach the content.	I would use pictures and diagrams because I feel that the terms are better explained visually. It (teaching over the Internet) gave me the opportunity to spread my knowledge farther.	4	9	
5	I do not know my science, computer, or teaching abilities.	I am now confident in my knowledge of the moon, and thus I have become more confident in my teaching abilities concerning this subject area.	5	6	

Participant #1 (who showed the greatest gain from pretest to posttest for Instrument #1) did not feel that his content knowledge was lacking at the beginning of The MOON Project, but did realize he had learned at the end. Still, his posttest score reflected that he corrected only two thirds of his previously incorrect or answers he did not know.

Participant #2 hoped class would help him learn to "answer questions and explain."

Despite only a 5-point gain on the post-test, he perceived that he "did pretty well." He planned to use 'goals' for both himself and his students next time, but did not hint at what the goals might be. Participant #3 (who showed only a 3 point gain between the pretest and posttest) believed that he had "come a long way." Participant #4 stated confidence in his knowledge of the moon, yet wrote that statement immediately after writing 3 major misconceptions as ideas to use in teaching about the moon. Participant #5 initially stated a lack of confidence in teaching about the moon and then enthusiastically described the benefits of using diagrams to teach content and "spread his knowledge farther."

While most participants' perceptions about their PCK generally increased over the semester, these five cases show that this was not always true in reality. Nevertheless, based on the responses to the Reflective Essay Questions, the answer to Research Question #2 is yes, and the null hypothesis is again rejected.

**Research Question #3:** 

Does pre-service teachers' perception of their ability to use the Internet as an effective teaching tool increase as a result of their participation in The MOON Project?

A Descriptive Analysis of Trends and Patterns

The first of the two prompts from the Reflective Essays, "When I think about teaching students in The MOON Project via the Internet, I......" provided the answer to Research Question Three. On the pretest to this prompt, all 24 participants anticipated a positive experience in learning to teach over the Internet. Twenty participants wrote that they were excited for the opportunity to increase their computer skills, to interact with students around the world, or to learn a teaching method that they could take into their own future classrooms. Twelve participants admitted to feeling nervous at the beginning and 10 participants stated they were both nervous and excited.

While most participants were sure that the Project would result in their increased computer skills, only 8 expressed the belief that the Internet would be an effective teaching tool. Another 8 expressed skepticism about the value of the Internet, fearing that it would restrict their ability to implement "hands-on" learning and reduce their opportunity for "face-to-face" contact with students. Of the 8 participants who believed the Internet would be an effective teaching tool, 2 thought it was a great way to avoid having to get up in front of students and actually "do" something.

Posttest responses to this prompt showed that more participants were frustrated with the Internet than were still excited by its use. Eleven of the 17 who admitted to frustration cited the lack of focus in message board posts by the students in their groups. Four blamed classroom teachers whom they believed had not held students to the requirement that they make daily moon observations. Despite the obstacles they incurred, 7 participants said they would try teaching over the Internet again if given the

opportunity. Five stated that they would not use the Internet to teach, and 12 expressed no feelings about online teaching one way or the other.

On the essay pretest, only one pre-service teacher (the only one who had a technology concentration) expressed confidence in his ability to teach via the Internet. On the posttest this number increased by one, indicating that the experience, itself, had done little to improve this credential overall. Interestingly, while no one admitted to having low computer skills at the beginning of the Project, by the end, 7 participants were more than ready to do so. While 8 participants had been skeptical of the Internet as an effective teaching tool on the pretest, that number actually rose to 12 on the posttest, with 7 of the 12 frankly stating that their teaching experience with The MOON Project had not been successful.

Clearly, on the basis of these responses, the answer to Research Question #3 is no and its null hypothesis is accepted.

Research Question #4: Does the number of pre-service teachers' misconceptions about the moon decrease as a result of their participation in The MOON Project?

## A Statistical and Qualitative Analysis of Misconceptions

Instruments #1 and #2 each supported a significant increase in the content knowledge constructed by participants in The MOON Project. Under most circumstances, a statistically significant gain in such knowledge might be considered sufficient to support the use of the inquiry method of teaching and learning in an elementary science methods course. However, the analysis of data from only correct responses was not, in this study, a complete picture of the learning that took place. Of concern were the misconceptions

still in place or newly constructed by the participants as a result of their experience. Such misconceptions could negatively influence the students they will later teach.

## Instrument #1: 15-Item Instructor Created Questionnaire

Because constructed knowledge about moon phases (as measured by increases in the number of correct responses between pre and posttests) on Instrument #1 was not the only variable of interest, incorrect responses (representing misconceptions on the part of the participants) were also tracked. Table 4.9 shows the within group differences between pre and posttest misconceptions for both the experimental and the control groups.

Table 4.9: Within Group Pre and Posttest Misconceptions (Incorrect Responses) for Instrument #1 X = Mean Number of Incorrect Responses

Group	X	SD	t	p	
Experimental (n=24) Pre Post	7.46 8.96	2.52 2.61	-1.83	0.08	
Control (n=21) Pre Post	7.81 8.33	3.66 3.21	-0.85	0.41	

 $p \le 0.05$ 

These data show that neither the experimental nor the control group significantly changed the number of incorrect responses (i.e., the number of their misconceptions) between the two test administrations. Between group differences in incorrect responses are shown in

Table 4.10. Again, there is no statistically significant difference between the experimental and control group at either the pre or the posttest, indicating that the two groups began and ended the semester with the about the same number of misconceptions.

Table 4.10: Between Group Pre and Posttest Misconceptions (Incorrect Responses) for Instrument #1 X = Mean Number of Incorrect Responses

Test	Experi X	mental SD	<u>Contr</u> X	<u>ol</u> SD	t	p
Pre	7.46	2.52	7.81	3.66	-0.37	0.71
Post	8.96	2.61	8.33	3.29	0.70	0.49

 $p \le 0.05$ 

At the individual student level, these data are of even more interest. Of the 21 preservice teachers in the control group, 11 (or 52%) had more misconceptions at the end of the semester than they did at the beginning. Since this group had no specific moon-related instruction of any kind during the semester, this result is not particularly surprising. The experimental group, however, had 15 out of 24 pre-service teachers (or 63%) who ended the semester with more misconceptions than they had at the beginning. This is the group who studied the moon via inquiry activities under the direction of their course instructor and then facilitated the same study among a group of children over the Internet. This result is not only surprising, but alarming. Table 4.11 shows the number of participants who changed their misconceptions between the pre and posttest by group.

The direction of the change (whether it was an increase, a decrease, or no change) is also noted. No participant in either group ended the semester with zero misconceptions.

Table 4.11: Number of Participants Who Changed Misconceptions Between Test Administrations

Group	Increased #	Decreased #	No Change in #	
Experimental (n-24)	15	7	2	
Control (n-21)	11	7	3	

On the basis of these data, the answer to Research Question #4 is no, and its null hypothesis is accepted.

Instrument #2: 4 Basic Moon Phase Knowledge Questions

As already noted in the discussion of Research Question One, the 4 Basic Moon Phase Knowledge Questions were scored on the basis of participant reference to one or more of the 7 Moon Phase Competency Skills listed in Table 4.4. Each of these skills was taken from a description in the National Science Education Standards of something children in grades 4 should be able to do. While numerical scores on Instrument #2 showed a significant increase in constructed knowledge about moon phases from pre to posttest, qualitative analysis of item #4 from that instrument revealed evidence of existing misconceptions concerning the cause of those phases (i.e., Competency Skill #7).

Pre-test responses to item #4 showed that all participants knew the phases of the moon would change in some way, but only one participant correctly explained the cause:

"The relationship between the Earth, moon, and the sun. The moon revolves around the Earth and the sun reflects off of the moon on the same side, so as the moon goes around the Earth, we see different parts of the moon."

Posttest responses to item #4 showed that 3 participants correctly attributed the moon's apparent change in shape to the rotation or revolution of the Earth, Sun, and moon and could do so without including any misconceptions in their explanations. But while these explanations did not contain any misconceptions, they were considered incomplete in that specific details or descriptions were missing. The remaining 21 participants cited a variety of reasons for the moon's apparent change in shape, each of them revealing one or more misconceptions. Inductive data analysis was performed on the item to identify potential patterns and themes among the responses. The coding categories for the misconceptions that emerged from this process are shown in Table 4.12.

Table 4.12
Emergent Coding Categories for Incorrect Responses/Misconceptions

Code	Meaning of code
R <>R	Terms rotation and revolution confused
R-I	Rotation/revolution incorrectly described (Earth rotates around moon)
MSL	Amount of sunlight striking Moon causes phases
$M\Delta S$	Moon literally changes shape
ESh	Earth's shadow on moon causes phases
ParSee	We see only the illuminated part of the moon
MOV/LOC	Movement or location of EMS but no description (incomplete)

The number of times each of these coded responses was given by participants on both the pre and posttests is shown in Table 4.13.

Table 4.13 Frequencies of Incorrect Responses/Misconceptions

Code	Pretest	Posttest	Both*
R <>R	3	0	
R-I	1	3	
MSL	3	13	2
MΔS	7	7	4
MSh	4	6	2
ParSee	3	7	2
MOV/LOC	4	5	3
Nonsense		5	
Totals	25	46	13

<sup>\*</sup> Also reported in Pretest and Posttest columns

In 13 cases, the same misconception was found in the explanation given by an individual participant both before and after participating in The MOON Project. These responses are accounted for in the last column, titled "Both."

A total of 25 misconceptions all together were reported on the pretest. The misconception that the moon literally changes shape may have been inadvertently "planted" in the minds of the participants by the wording of the question, itself, which asked "why the moon changes shape." For this reason it was not counted as an incorrect response for scoring purposes, but was coded as a misconception for this analysis.

A total of 46 misconceptions were reported on the posttest, an increase of 21. Five of these are listed in the frequency table as 'nonsense' as they did not match any other response type and simply appeared as gibberish to the researcher. This means that 21 more misconceptions were reported by participants after they had received instruction about the moon and after they had led small groups of elementary children through an

inquiry exercise about the moon over the Internet. The most common misconception on the post-test described the cause of moon phases as the amount of light the moon receives from the sun. This is a misconception because the moon always receives the same amount of light from the sun except during an eclipse. Eclipses, however, were not mentioned by any of the participants.

In one instance 3 participants' misconceptions were corrected by the end of The MOON Project. On the pretest, these 3 people confused the terms 'rotation' and "revolution," but by the end of the experience, they used the terms correctly in their explanations. Unfortunately, each of them also included a new misconception in those explanations.

While the mean posttest scores on Instrument #2 showed a gain in knowledge constructed by the participants, this increase does not account for the three participants whose only apparent knowledge at the conclusion of The MOON Project was that the moon's shapes would appear in a certain order in the sky. Neither did the increase show that only three participants could correctly demonstrate all seven moon phase skills even after completing both a physics class and the Science Methods Class. Were these preservice teacher participants to use the responses they gave on the posttest with a class of elementary students, not one student would receive a clear, complete explanation of the moon's phases.

These data support the findings from Instrument #1. The answer to Research Question #4 is no, and the null hypothesis is accepted.

# Instrument #4: Moon Knowledge Application Test

Instrument #4 asked the participants to describe at least two of six distinctly different errors depicting moon phases and their causes found by the instructor on a commerciallyproduced web tutorial (Crayola, 2001). (It should be noted that this tutorial has since been removed from the Crayola webiste.) This instrument was given to the participants only once during the study, just before the start of the Internet Phase. It was hoped that after participants found the errors on the tutorial, they would be more likely to identify and correctly explain any such misconception errors constructed by the elementary students during Blackboard discussions. Table 4.14 shows the number of times each of the six major errors on the tutorial was identified by the participants. Sixteen participants described at least two errors, seven participants described only one error, and one participant did not attempt to describe any errors at all. Unexpectedly, 12 of the 'errors' mentioned by participants described an aspect of the drawing that was not, in fact, an error at all or was not important to a child's interpretation of the drawing. For this reason those 12 responses are not included in the table. For example, one participant wrote that the diagram lacked a reference to hemispheres. While it is true that the drawing did not reference hemispheres, this information would not cause a child to misinterpret the diagram. As shown, participants did identify errors in the diagram 35 times instead of the at least 48 expected if each of 24 participants identified 2 errors each.

Table 4.14: Frequency of Identified Misconceptions by Order of Importance

Misconception	# times mentioned
Diagram shows moon rotating around Earth (used by the	2
instructor in class as an example)	
Diagram shows moon phases caused by Earth's shadow	11
Diagram shows moon "becomes larger" or "becomes smaller"	6
Diagram shows moon moving clockwise around Earth	2
Diagram portrays moon moving back & forth (like a pendulum)	3
Diagram does not show light rays from sun striking moon	11

The instructor listed the most important misconception as an example. The misconception listed as second most important was identified by only eleven of the twenty-four participants, or 45.8%. Two participants identified the misconception listed third by the instructor. Seven participants would not have realized that this commercial document would potentially perpetuate at least two and as many as six major misconceptions about the moon to children if used as a learning tool, in or out of the classroom. The inability of 7 participants to identify at least 2 of the 6 errors and the confusion of errors with non-errors on the diagram do not support a decrease in preservice teacher misconceptions. Based on the data from this instrument, the answer to Research Question #4 is no and the null hypothesis is again accepted.

#### **CHAPTER 5**

## CONCLUSIONS AND RECOMMENDATIONS

#### **BACKGROUND AND RATIONALE**

The lack of scientific literacy in the general public lies in the preparation of elementary teachers to teach science. Inquiry teaching and learning are critical to establishing science literacy (Bianchini & Colburn, 2000; Colburn, 2000; Dewey, 1956; Metz, 2004; National Research Council, 1996; Tamir, 1983). Knowledge constructed through meaningful scientific inquiry is a powerful part of science literacy for several reasons. The learner experiences a concept firsthand by manipulating and/or observing physical objects. Thinking and reasoning skills are involved in making meaning of the observations during data analysis. New information is integrated into the learner's current cognitive schema and the new idea is conceptualized as 'truth.' Once a concept, correct or not, is integrated into a learner's schema, the conceptualization is very difficult to change (Brownlee et al., 2001; Marion, Hewsen, Tabachnick, & Blomker, 1999; Vosniadou, 2007; Vosniadou et al., 2004). Inquiry learning can result in the construction of either conceptually accurate knowledge or in the construction of misconceptions, depending on the teacher's understanding and Pedagogical Content Knowledge, or skill in guiding the students' thinking during the investigation.

Teaching by inquiry is not easy. Recording observations, as the participants and their elementary school children did in this study, is a simple process. Designing a valid investigation is difficult. Interpreting observations into meaningful knowledge is still more difficult. Observation is often the only part of the inquiry process that takes place in elementary classrooms. Such was the case in this study, as expressed by many participants in their reflective essays. Elementary students belonging to Blackboard discussion groups were free to interpret the observations and discussions in any way that made sense to them, correct or not. Pre-service teachers in the study, it appears, were free to do the same. While class demonstrations and discussions of those demonstrations were included or implied by several participants in their Reflective Essays, there was no evidence that the children's moon phase data was ever actually analyzed.

Commonly, elementary teachers often do not receive adequate preparation in inquiry. In addition, they often have insufficient content knowledge, fraught with misconceptions, that are passed on to their students. A cycle perpetuating misconceptions between teachers and students begins as young children accept the misconceptions of their elementary teachers and retain those faulty conceptions throughout their own teaching careers.

Elementary teachers are responsible for teaching reading, mathematics, writing, social studies, health, physical education, art, and music. Thus, their preparation programs must include both content and methods coursework in multiple disciplines. Reading, writing skills, and arithmetic are often emphasized above all other subjects due to the importance placed on them by standardized testing. Subjects not directly tested or whose scores are not used in determining Adequate Yearly Progress, such as science, are pushed aside

instead of being used to engage students in applications of other skills. Pre-service teachers, overwhelmed by the number of subjects they must learn to teach, sometimes also believe that they only need to know more about science than do their young students (Westerback, 1982). As practicing teachers, they hold this view and remain more concerned with professional development in literacy or mathematics.

It is a given that to teach reading one must be able to read, and to teach arithmetic, one must be able to add and subtract. To teach inquiry, then, shouldn't one have some quality experience actually doing scientific inquiry? The MOON Project was intended to provide pre-service elementary teachers with such an experience.

## **PURPOSE, DESIGN, AND METHODS**

This study was an attempt to evaluate the effectiveness of an inquiry-learning module called The MOON Project. This 14-week module was inserted into one section of a university elementary science methods course. The pre-service teachers in that section became the study's experimental group while a second section that did not participate in The MOON Project acted as the study's control. Elementary and middle school students from around the world were connected with the experimental group in an investigation of the Moon. Pre-service teachers and students shared their observations of the moon and its phases with one another via the Internet using asynchronous messaging on Blackboard<sup>TM</sup>. The MOON Project 's objectives were to:

 prepare teachers to use the power of the Internet to teach science through inquiry for a culturally diverse mix of children in Grades 3-8 and 2. immerse pre-service teachers and children in Grades 3-8 in a long-term (14-week) investigation of a natural phenomenon so that they simultaneously would learn about nature and, more importantly, would strengthen their skills and dispositions as inquirers (Smith et al., 2003).

# **Purpose of the Study**

This study had four premises that helped to define its purpose. The first premise was that observing the Moon and its patterns in the sky over time would help pre-service teachers increase their knowledge of and correct misconceptions related to the moon's phases and changing location in the sky. The second premise was that teaching about the moon by inquiry to elementary students around the world via asynchronous message boards would help pre-service teachers, themselves, learn inquiry skills and the pedagogy needed to teach about the moon by inquiry over the Internet. The third premise was that pre-service teachers would correctly perceive a gain in their knowledge of the Moon and in their ability to teach inquiry to students over the Internet. The fourth premise, by implication, was that teachers would have the technological proficiency needed to deliver the instruction to students in a technologically appropriate manner.

## The Research Questions

This study was an attempt to answer the following research questions:

1. Does pre service teachers' content knowledge increase as a result of participation in The MOON Project?

- 2. Does pre-service teachers' perception of Pedagogical Content Knowledge increase as a result of participation in The MOON Project?
- 3. Does pre-service teachers' perception of their ability to use the Internet as an effective teaching tool increase as a result of their participation in The MOON Project?
- 4. Does the number of pre-service teachers' misconceptions about the moon decrease as a result of their participation in The MOON Project?

# **Data Collection and Analysis**

Four types of data were collected. Pre-service teachers in both the experimental and the control groups were given a 15-Item Instructor-Created Questionnaire over their knowledge of the moon during the first week of their science methods course. At the same time, the experimental group also completed 4 Basic Moon Phase Knowledge Questions. After a brief introduction to The MOON Project, the experimental group responded to the following two reflective essay prompts:

- When I think about teaching students in the MOON Project via the Internet,
   I.....
- 2. When I teach about why the moon changes shape, I.....

Midway through the course, the experimental group was given the Moon Knowledge Application Test. This test was an on-line tutorial meant to explain the phases of the moon as represented by drawings. As an application of their learning, the pre-service teachers were asked to describe two of six conceptual errors found on this website that supposedly explained moon phases for children. At the end of The MOON Project, the

elementary pre-service teachers were again given the 15-Item Instructor Created Questionnaire, the 4 Basic Moon Phase Knowledge Questions and the 2 Reflective Essay prompts.

Pre-service teachers' understandings of the motion of the moon were examined as follows:

- Responses to the 15-Item Instructor Created Questionnaire from both the
  experimental and the control classes were scored and compared statistically to
  determine if there was a gain in participants' general content knowledge about
  the moon.
- 2. Free response answers on the pre and posttests of the 4 Basic Moon Phase Knowledge Questions were compared using content analysis for patterns of misconceptions and conceptual change and for basic knowledge constructed about the phases of the moon and the causes of those phases.
- 3. Participants' responses to 2 Reflective Essay questions before and after participation in The MOON Project were examined qualitatively to determine the participants' perceptions of teaching by inquiry and teaching over the Internet, and of their own ability to do so (PCK).
- 4. Participants' actual learning as determined from the analysis of the pre-tests and post-tests were contrasted with their reflective essays to determine agreement between what the pre-service teachers thought they learned and what they actually did learn.

5. Applications of the pre-service teachers' learning, as determined from the analysis of a commercial student handout, were examined for correct conceptual understanding and the presence of misconceptions.

## FINDINGS AND DISCUSSION

Participation in the inquiry learning and teaching experience offered by The MOON Project resulted in significant construction of content knowledge about the moon in preservice elementary teachers. These findings agree with a study by Trundle et al (Trundle et al., 2002) which showed that participants receiving inquiry-based instruction were less likely to hold alternative conceptions about the Moon. There is, however, much more to the story.

# **Research Question One: Content Knowledge**

Gains on Instruments #1 and #2 suggested statistically that significant learning took place, resulting in knowledge constructed by the participants. The mean raw score on the Instrument #1 posttest for the experimental group nearly tripled from the pretest and doubled on Instrument #2. This statistic does not, however, tell us that the mean posttest scores on these two instruments were only 53% and 63%, respectively, or that the posttest scores ranged from 28% to 76% on Instrument #1 and from 30% to 64% on Instrument #2. The question then becomes, is it acceptable for a teacher to know only half of the content material presented in a course if they are expected to someday teach it themselves? Likewise, are study results that show a statistically significant increase sufficient to tell a much more complicated story?

The youngest of the participants in this study, based on the ages reported, would have been in or exiting grade six when the National Science Education Standards were published. It is unlikely that their teachers in grades 1-6 included instruction about the moon as the NSES suggested, unless this concept was already included in district-mandated curriculum. Some school districts include an earth/space science course in grades 7-8 which may include a unit on astronomy. The astronomy unit may or may not have included the cause of moon phases. Once students reach high school, they may receive some instruction about the moon in a ninth grade earth/space science course, but astronomy courses in high school move past the behavior of objects in the solar system, assuming that students have previously met such standards in grades K-8. The point is, the participants in this study were unlikely to have been exposed to formal K-12 instruction about moon phases and their cause. They were highly likely to have brought many personally constructed misconceptions about these phenomena with them to their science methods class.

Three additional research questions explore and clarify the findings about the learning and possible reasons for why learning did or did not take place.

## Research Question Two: Perceptions of Pedagogical Content Knowledge

The large number of "I don't know" responses on Instrument #1 support the assumptions made about content knowledge, above. About half the responses on the pretest were "I don't know." Presumably, participants were being honest, thinking that they wouldn't be expected to have much knowledge about the moon, as the course had just begun. Very few participants wrote in their reflective essays about having previous

instruction about the moon. When previous knowledge was mentioned, the prerequisite university physics course was mentioned as the source. The posttests had many fewer "I don't know" responses. The increased number of both correct and incorrect responses suggested that the participants either perceived their knowledge to be sufficient and answered questions knowledgeably, or they were guessing in hopes of getting a better exam score. In either case, participants could only write what they knew.

All participants perceived a gain in knowledge regardless of their actual score gain. One participant with a score of 9 out of 21 on both the pretest and the posttest did not state a perceived increase in PCK. The participant only listed a few moon phases on the pre-project Reflective Essay. His post-project Reflective Essay described having had to do "lots of research" to get three message board questions each week and described posting the websites used to obtain the questions so that the children could look up the answers.

It was expected that participants might describe beliefs about their abilities that were inconsistent with the knowledge shown on the assessments (Instruments #1, #2, and #3). This may have been due to confusion emerging from their pre-existing beliefs and the new information they constructed about their beliefs during the semester. This discrepancy would indicate that The MOON Project experience helped them to begin the process of changing their epistemological belief system, in this case their belief system regarding their future learning of PCK.

Fewer than half of the participants mentioned the use of inquiry or inquiry methods on either the pre- or the post-project Reflective Essay, although inquiry teaching and learning was a major focus of The MOON Project.

About 45%, or 11 of the participants, intended to use their learning from The MOON Project in their own classrooms later. About 30%, or 7 participants, also described the use of teaching methods that they personally found most helpful in learning about the cause of moon phases. Both instances demonstrate that teachers teach as they are taught and in ways they, themselves, learn best.

A teacher having PCK, by various descriptions in the literature, knows how best to teach a particular topic to students. An accomplished teacher by National Board standards, knows his/her students and can make appropriate instructional decisions about what is best for those students at a given time and in a given setting. The responses to the Reflective Essays showed only 7 of the participants advocating any instructional method based on finding out what the elementary students already knew.

The participants' responses on Instrument #3, the Reflective Essays, implied that they still viewed themselves as deliverers of content rather than facilitators of learning by inquiry. The inquiry experienced by the participants was guided inquiry, modeled as such by the methods class instructor so that they could teach in the same way with the elementary children. The inquiry actually done by the elementary children was, according to pre-service teacher final reflections, limited to observations and never progressed to the analysis stage.

# Research Question Three: Perceptions of Ability to use the Internet as an Effective Teaching Tool

Reflective Essays asking about teaching over the Internet changed focus from beginning to end. At first the participants were nervous about not being able to use a new "program" (Blackboard™), about not being able to explain, show images or films, and do demonstrations with students in a face-to-face situation. Participants were still uncertain about how their teaching over the Internet would be "interactive." By the end of the project, most participants still described these concerns but a new concern had emerged: the elementary students.

More than half of the participants stated that the children sent messages that were mostly or completely off topic, did not actually observe the moon as they had been instructed, or simply did not participate at all. Some schools had connectivity issues or Blackboard was blocked from their computers. Others had trouble scheduling computer time. The participants found this frustrating. It was the most common response cited for not wanting to teach over the Internet. Some participants suggested that the participating classroom teachers should have been more mindful of what their students were actually doing during their computer time. Several participants suggested better teacher supervision of students during this time would be not only helpful but necessary for the project to be worthwhile.

Another frustration with the project was also communication-related. Participants found it difficult to communicate using only words and a few recommended websites.

Several mentioned wanting to find a way to share images and videos, apparently unaware

that these could have been linked or embedded on a web page in their own universityprovided server space.

# Research Question Four: Misconceptions about the Moon

Semantics found in pre-service teacher descriptions are not a part of conceptual science understanding but are critically important in expressing that understanding. A child asking why the moon has the same shape but different orientation when viewed in Muncie or Australia expects a more thorough explanation than "We are in different places." What is meant by "different?" Do all places labeled as "different" see a "different" orientation of the moon?

The phrase "moon changes shape" was included in item # four of the 4 Basic Moon Phase Questions. That phrase was used in seven participants' Reflective Essays prior to participation in The MOON Project and in seven post-project Reflective Essays. Four participants who used this phrase did so on both the pre- and post-project essays.

Instruments #1 and #2 indicate that there was significant gain in knowledge constructed by pre-service teachers participating in The MOON Project. Along with the correct factual knowledge constructed, the broader understanding needed to correctly conceptualize these facts is lacking as supported by the statistically significant gain in misconceptions about the causes of moon phases. Fifteen of the 24 experimental group participants ended the semester with more misconceptions than they had at the beginning. Along with the construction of knowledge about the moon, the participants also failed to correct an alarming number of misconceptions. Of still more concern is the number of

new misconceptions they constructed. These misconceptions will almost certainly surface when teaching about the moon in their own classrooms.

Teachers commonly use materials found on the Internet to enhance instruction. These materials may be images, animations, handouts, the work of other teachers, or an activity such as the one used in Instrument #3, the Moon Knowledge Application Test. The Moon Knowledge Application Test responses additionally suggest that the pre-service teachers did not have the skills to critically analyze instructional materials for children or to select materials that would not contribute to student misconceptions.

Unfortunately, the context under which the reflective essays were written was one of pre-service teachers wanting to get a good grade in their methods course. The pre-service teachers may have written what they thought would get them a good grade, not necessarily what they would have written if a grade were not at stake. One participant submitted nearly the same essay both at the beginning and at the end, changing mostly only the tense. Again, there is no clear, convincing, or consistent evidence to show that this group of pre-service teachers is prepared to lead elementary children in an investigation about the moon and its phases.

#### CONCLUSIONS

- 1. Participants in The MOON Project increased their learning about the moon and moon phases in varying degrees, however, they took away understandings of why the moon changes shape that were basic at best and fraught with misconceptions.
- 2. Participants' misconceptions about the cause of moon phases and about the moon in general also showed a statistically significant increase as a result of

- participation in The MOON Project. Some misconceptions resulted from terminology apparently learned during instruction about The MOON Project. Other misconceptions resulted from the analysis (or lack of analysis) of observational data collected by the participants and their virtual students.
- 3. Participants perceived a significant gain in knowledge about the moon, the cause of moon phases, teaching by inquiry, and their own PCK in a physical classroom. This perceived gain was not supported by any instrument used in this study.
- 4. Participants had mixed perceptions about teaching over the Internet, mostly due to the degree to which their elementary student groups responded with focus to questions and discussions or, in some cases, participated at all.
- 5. The misconceptions harbored by pre-service elementary teachers as participants were likely constructed or reinforced in the classrooms of teachers who, themselves, had little knowledge and PCK about the moon and the cause of moon phases. There is obviously much opportunity for the implementation of conceptual change models in rigorous teacher education programs.

#### IMPLICATIONS FOR STAKEHOLDERS

## For elementary/middle school students

The elementary and middle school students were extremely important stakeholders in The MOON Project, but were not the subject of this study. Data describing their learning were not available; all that is known is whatever the participants reported. According to the participant responses, many students either posted off-topic responses on Blackboard<sup>TM</sup>, or they did not respond at all. Several participants questioned the teacher

supervision during computer time or the lack of emphasis put on message board posts by the classroom teachers. Perhaps more teacher supervision would have helped, or perhaps this is just normal behavior in elementary or middle school students who have not participated in this type of nontraditional assessment experience. Even accomplished teachers with a tool bag of best practice strategies cannot guarantee that students will change their behavior. Elementary school is the first place students receive instruction leading to the formal construction of their knowledge base about the natural world and the nature of the science. Inquiry instruction appropriate for each student's ability and readiness is a critical tool for fostering the construction of such knowledge. Clearly, there is a need to examine what the children participating in The MOON Project actually gained from their work.

## For pre-service elementary teachers

Pre-service elementary teachers often do not accurately perceive their own ability to teach science. More often, they may believe they know effective methods for teaching about the moon, but do not see that their own understandings of the moon and its phases contain many misconceptions. It is the purpose of science methods courses to build preservice teachers' confidence in their own PCK. Pre-service elementary teachers harboring the paradigm that writing, reading, and mathematics skills can effectively be taught in isolation from science would benefit from instruction facilitating their science PCK as a means to reaching their instructional goals in those basic skills.

## For elementary teachers

Inquiry in the elementary classroom does not end with observation, nor does it end with discussion allowing students to reach invalid conclusions through random guesses about their data. Teachers must know their content and, themselves. be skilled at learning by inquiry, possess at least adequate Pedagogical Content Knowledge to teach inquiry methods, be skillful discussion leaders, and know their students well enough to help guide their analysis of observational data. A recent attempt to help elementary teachers face their own known misconceptions and build their PCK is a series of resource books titled "Stop Faking it!" that currently includes titles on Chemistry, Weather, Force and Motion, Math, Energy, Sound, Light, and Electricity and Magnetism (Robertson, 2004). Unfortunately, there is no book yet in the series dealing with Astronomy or the moon.

#### For teacher educators

Teacher educators must be mindful that the terminology used in all courses is the terminology they wish elementary teachers to use in their classrooms. Pre-service teachers will quickly adopt the terms used by an instructor. The participants in this study began to use the phrase "changing shape" when referring to moon phases rather than distinguishing between literal and apparent shape change. To the instructor, the word "apparent" was implied; to the pre-service teachers it was ignored and then forgotten.

Each pre-test instrument afforded the opportunity to intervene in the participants' individual misconceptions prior to beginning the observation phase. Specific interventions could be designed to target each misconception category observed as the

pre-tests were scored. Such an awareness of their own misconceptions early on could increase participants' awareness of how easily they and their future students construct misconceptions.

There were many missed opportunities for reinforcing the knowledge constructed by the pre-service teachers. Reflective practice (different from the Reflective Essays used as a data collection instrument in the study) is an important component of National Board Certification and is a skill used formally and informally by accomplished teachers. It must be learned and practiced deliberately to have positive impact on improving teacher quality. Incorporation of reflective practice could have been incorporated into The MOON Project in a number of ways. While the elementary students had a venue for discussing their observations among themselves, the pre-service teachers did not. Reflective writing is a vehicle for powerful formative analysis. Pre-service teachers could have been asked to do, at the very least, a critical analysis of their own explanations, selfassessed according to a rubric. More meaningful opportunities could have included a blog for each pre-service teacher for the purpose of posting and sharing possible questions for their student message boards, for sharing their own learning as it was constructed, for discussing proper use of terms describing the motion of the Earth, Sun, and moon and moon phases, and for metacognitive analyses of their own learning and misconceptions. Blogs are especially powerful when students read and comment on one another's work in an informal peer review process. A Blackboard ™ space could also have provided this opportunity. Time in class or asking students to form groups and meet outside of class to peer-review one another's written explanations of why the moon appears to change shape would have offered another chance to catch and correct

misconceptions. Pre-service teachers will teach as they are taught, particularly if they perceive the method effectively increases their own learning. As a bonus, peer review and collaboration could have been additional important pedagogical skills learned in The MOON Project.

## For Use of Technology in Instruction

Technology has progressed a great deal since this study took place. Many improvements to the instructional use of the Internet are now possible. With such improvements come the likelihood of increases in the effectiveness of The MOON Project or for any attempt to use this type of technology-dependent inquiry. Skype, Flash animations, and significantly more sophisticated websites showing planetary motion are now common. One participant mentioned a videoconference with the elementary children at one school, but that participant was unable to attend the videoconference. The proceedings of the conference are not known. With newer videoconferencing tools such as Skype or even Facetime on iPhones, participants could meet with their students once a week for sharing of models, discussion of results, and questions and answer sessions. Scans of diagrams could easily be shared. Participants could make and share videos of the models they describe using Youtube or Vimeo. Prezi or Animoto could be used to create lively and somewhat interactive presentations.

Another alternative to Blackboard or other asynchronous message board is student blogs. Platforms such as Edublog.com can provide each elementary student with his own blogging space. Blogs can be configured in a far more visually appealing manner than can message boards. Posting scanned drawings, photos, videos, and links is easy.

Blogging might also provide writing practice, which most elementary classroom teachers would be more inclined to use. The participating pre-service teachers, classroom teachers, and even parents could read and comment. Elementary students, their teachers, and the pre-service teachers could read one another's group work and comment as well, making an even more collaborative community. Blogging could also offer the opportunity for more frequent reflection for both pre-service teachers and elementary students.

Wikis such as wikispaces.com or pbworks.com are options for either pre-service teachers or elementary students to share content. Videos can also be posted, so children and pre-service teachers can demonstrate and share models. A wiki offers a more website-like feel for easily posting links, photos, scanned drawings, data, and student-produced content. Wikis can be edited by more than one person, making them a great resource for students at any level to build a knowledge base for a community of learners.

Google docs might be of use as a collaborative tool for the pre-service teachers to share possible ideas for message board posts. Pre-service teachers could list their questions, building and synergizing from one another's ideas. The use of any of these newer technologies would have eliminated many pre-service teacher complaints about the Internet not allowing for face-to-face contact with students and for not being able to make their Blackboard interactions more "hands-on."

## For policy makers

High-stakes testing is directed toward literacy, writing, and mathematics. All of these skills are necessary for learning science, but science also provides a context and practice for learning these skills. Science educators must have a working knowledge of literacy, writing, and mathematics to teach science. Courses in those content areas are already part of most science teacher education programs. Science teachers must also have the PCK to guide student learning in those content areas as well as in science. Unfortunately, a disjointed reality finds that science education is often poorly delivered or neglected in grades K-6 due to pressure from administrators to spend time on "tested" areas when science could be used to teach all the skills those same tests assess. This pressure leads to less emphasis on science in both pre-service elementary teacher programs and in professional development emphasis for practicing teachers. The science *il*literacy cycle is, thereby, further promoted.

The irony is that science, technology, engineering and mathematics (STEM) is currently being loudly touted by America's political and business leaders. All educators would benefit from financial and genuine pedagogical support for programs facilitating the inclusion of more authentic science inquiry in education at all levels. Teachers need the resources of time and funding to seek out and employ strategies resulting in solid understanding of science concepts and the nature of science among their own students. This, however, cannot happen when State and National testing emphasizes only literacy and math.

#### RECOMMENDATIONS FOR FUTURE RESEARCH

Missing from this study's available data were control group responses for Instruments 2, 3, and 4. The impacts of a science methods course on pre-service teachers' perceptions of their own abilities to teach about the moon by inquiry over the Internet might change

as they gained confidence in their general PCK, whether or not they actually had experience with a particular teaching method. With no control group data, this impact remains unknown. Also missing from this study were potential interviews with the participants before, during, and after their work with The MOON Project. Such interviews would have offered the opportunity to probe their actual understanding of moon-related content and their perceived instructional skills much more thoroughly.

One concern with the validity and reliability of the study's data involved the participants' grades in their science methods course. Would they have done things differently in their interactions with the students had they not perceived their work as being constantly evaluated by the instructor? What decisions did they make (or not make) because they felt their class grade depended on the outcome? Had The MOON Project activities not been part of the graded assignments for the course, would results have been different? On the other hand, had The MOON Project activities not been part of the graded assignments for the course, would participants have completed them at all? This is an unfortunate reality in many college classes.

Also informative would have been an instrument, either an interview or written survey/reflective essay, asking pre-service teachers about their attitudes toward teaching science as compared to other subjects. Because elementary teachers are often overwhelmed with non-instructional tasks to perform and with preparing students to take standardized tests, science is often not given the class time or attention that is needed. Pre-service teachers doing field experiences in these classrooms see this inattention to science and sense this prioritizing of test-related practice and often come away believing that such behavior will be expected of them as well.

Another problem with the study was that only sample message board posts (gleaned from the pre-service teachers' Reflective Essays) were available to the researcher.

Analysis of the actual message board posts made by the pre-service teachers and the elementary students' responses to them might have helped explain the participants' perceived lack of participation from the elementary students. What types of questions were posted by the participants? What prompts were provided to the students? Would a choice of multiple prompts to questions have been helpful? What direction and support was provided to the students by their classroom teachers?

#### THE MOON PROJECT AS A VIABLE TOOL

It appears from the statistical analysis of the instruments used in the study that the preservice teacher participants showed significant gains in the content knowledge they constructed. However, considering the low pre-test score mean, the gain scores in factual knowledge do not show the increase expected of one who will eventually teach the same information to children. The Pedagogical Content Knowledge that participants may have gained with respect to learning and teaching by inquiry and over the Internet was also not as significant as the participants perceived. There was little evidence of inquiry learning among the participants and their Blackboard™ student groups. Most participants did not describe inquiry activities done with their students, other than to comment that moon observations had been performed. Many of the participants did not have a positive experience in teaching over the Internet due primarily to lack of student participation.

Some participants voiced their willingness to give teaching over the Internet a second

chance, but many remained skeptical of its value as a teaching tool because it did not provide them with a face-to-face experience with students.

Clearly, The MOON Project (in this iteration) did not perform as well as was expected on any of its intended goals. The four premises that helped define the purpose of the study were, quite simply, not upheld. Observing the Moon and its patterns in the sky over time did not substantially help pre-service teachers increase their knowledge of or correct their misconceptions related to the moon's phases and changing location in the sky.

Teaching about the moon by inquiry to elementary students around the world via asynchronous message boards did not help pre-service teachers learn inquiry skills and the pedagogy needed to teach about the moon by inquiry over the Internet. Pre-service teachers did not correctly perceive a gain in their knowledge of the Moon and in their ability to teach inquiry to students over the Internet. And while pre-service teachers may have gained in their technological proficiency during the Project, it appears that they were not able to use those technological skills to adequately deliver appropriate instruction to students.

## APPENDIX A

### MOON PROJECT STUDENT HANDBOOK

# **MOON PROJECT**

# Student Handbook January – April 2004

Name

January 2004

Welcome to the MOON Project. For the next few months, students in several countries along with college students at Ball State University in Muncie, Indiana, will be studying the Moon together.

At first you and other students in your class will observe the Moon every day and record those observations. We hope that about once each week you and the other students in your class will report and compare the observations you have made. Are you making the same observations? Or are there significant differences in what you are seeing?

After you have been looking at the Moon for awhile, we hope you will look for patterns in your observations.

- Does the Moon stay the same shape from day to day?
- Can it always be found in the same place?
- Is it visible only at night?

When you enter the Internet discussion about the Moon, we hope you will compare and contrast what you and your classmates have observed in your home town with what others from around the world have observed.

While you are making those observations, comparing your observations with others in your class, and finding patterns in your observations, we hope you also will talk with adults about the Moon. We hope they will join you in making observations. We hope you and they will talk about how the Moon is portrayed in everyday conversation, music, poetry, movies, and literature. Do they have any special memories about the Moon? Are there any stories or songs or movies they know about the Moon?

In March you will start to use the Internet to share what you have learned about the Moon with other students around the world. Then you can compare and contrast what you have learned. Does the Moon appear the same everywhere or are there differences? Do people have the same ideas, songs, and stories about the Moon around the world or are there differences?

When you join other students on the Internet, you will need to agree to these conditions.

- I will only write about the Moon.
   (This is not a time to chat about television shows, your friends, popular singers and so forth.)
- 2. I will limit my messages to answering the questions asked by the Ball State University student to start the discussion each week.
- 3. I will take notes about what the other students are saying on the Internet about the Moon, and I will share these notes with the other students in my class.
- 4. I will not share personal information on the Internet. I will not write anything that will allow others to identify who I am or contact me outside the MOON Project.
- 5. I will use proper language and I will not threaten anyone.
- 6. If I see bad or threatening language or think an argument is starting, I will log off and inform my teacher of the problem.
- 7. If I read a message that makes me feel uncomfortable, I will tell my teacher immediately. I have a responsibility to help make sure the MOON Project Internet messages are appropriate and that this is a safe place for students to communicate with each other.

You have an important responsibility to collect and share accurate information so we can learn together.

Welcome. We're glad you are part of the MOON Project.

Walter S. Smith Director, MOON Project Ball State University

On the next pages when you are reporting the shape of the Moon each day, in the circle please **blacken** the part of the **Moon** you see (for example, is a full Moon and is a crescent).

# MOON Project Observations Fill out this chart every day for 14 weeks.

Fill out this chart every day for 14 weeks.						
Monday	Tuesday	Wednesday	Thursday	Friday		
Time Direction Angle	Time Direction Angle	Time Direction Angle	Time Direction Angle	Time Direction Angle		
Saturday	Sunday	Question of the v				
		Question of the	vecie.			
Time	Time					
Direction	Direction					
Angle	Angle					
Monday	Tuesday	Wednesday	Thursday	Friday		
Monday	Tuesday	Wednesday	Thursday	Friday		
Monday  Time	Tuesday  Time	Wednesday		Friday		
			Thursday  Time  Direction	TimeDirection		
Time	Time	Time	Time	Time		
Time	Time	Time Direction Angle	Time Direction Angle	TimeDirection		
Time Direction Angle	Time Direction Angle	Time	Time Direction Angle	TimeDirection		
Time Direction Angle	Time Direction Angle	Time Direction Angle	Time Direction Angle	TimeDirection		
Time Direction Angle  Saturday	Time Direction Angle	Time Direction Angle	Time Direction Angle	TimeDirection		

## **Questions of the Week**

Answer the Question of the Week each week after making your observations.

#### Week 1

What has the Moon's shape been this week? When and where have you seen it?

#### Week 2 and Week 3

Have you been able to see the Moon this week?

#### Week 4

What has the Moon's shape been this week? When and where have you seen it?

#### Week 5

How would you describe the shape of the Moon over the last two weeks?

#### Week 6

Even if you have not seen the Moon this past week, can you figure out what shape it is and when would be a good time to look for it?

#### Week 7

Where and when will be a good time to look for the Moon next week?

#### Week 8

How does the Moon's shape and location this past week compare with what you observed four weeks ago?

Follow your teacher's directions to write your observations in these two tables.

## Table One

Shape of the Moon	Date 1	Date 2	Days Between

## Table Two

Shape of the Moon	Date 1	Date 2	Days Between

## **MOON Project Observations**

#### Week 9

How did the shape of the Moon you saw this week compare with the shapes reported by students in other parts of the world?

Draw sketches and write notes about what your research partners from other parts of the world have reported between

November 3-9 about the Moon's shape and location.

#### Week 10

How did the shape of the Moon you saw this week compare with the shapes reported by students in other parts of the world?

Draw sketches and write notes about what your research partners from other parts of the world have reported from November 10-16 about the Moon's shape and location

#### Week 11

How did the location of the Moon you saw this week compare with the locations reported by students in other parts of the world?

Draw sketches and write notes about what your research partners from other parts of the world have reported from November 17-23 about the Moon's shape and location.

#### Week 12

When you've looked at the Moon this week, which side of the Moon was illuminated? How do these observations that you have made compare with those of students in other parts of the world?

Draw sketches and write notes about what your research partners from other parts of the world have reported from November 24-30 about the Moon's shape and location.

#### Week 13

Where has the Moon been located when you have looked at it over the past two weeks in the evening at about 7-8 PM? How do these observations that you have made compare with those of students in other parts of the world?

Draw sketches and write notes about what your research partners from other parts of the world have reported from December 1-7 about the Moon's shape and location.

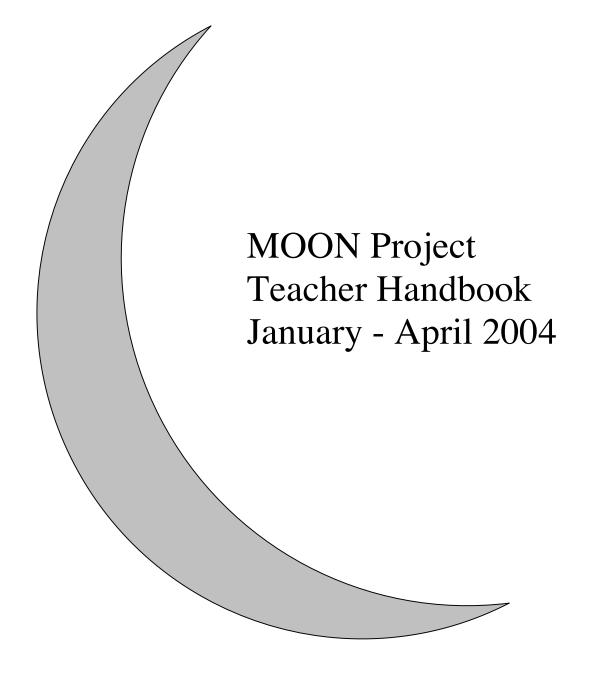
#### Week 14

Are there any similarities or differences in how the Moon changes shape and location around the world?

Draw sketches and write notes about what your research partners from other parts of the world have reported from December 8-14 about the Moon's shape and location.

## APPENDIX B

## MOON PROJECT TEACHER HANDBOOK



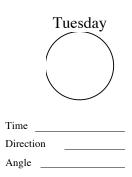
. January 2004

#### Dear MOON Project Teacher:

Thank you very much for agreeing to be a part of the MOON Project this semester. We hope it will be a good experience for you and your students.

#### Student Handbook:

Please give each of your students a copy of the student handbook which will guide their data collection and thoughts about the Moon. We hope your students can begin daily lunar observations by or before September 8; but if not, please start as soon as possible.



Each day the student should darken in a part of the circle to represent the shape of the Moon observed that day and note the time of observation. You will need to decide how you want them to note the direction of the Moon (e.g., Southwest or 225° from North) and its angle above the horizon. Younger students may write "halfway" to mean halfway between the horizon and straight up. Other students may say that the Moon is at a 45° angle above the horizon. If they do not see the Moon on a particular day, they could write "too cloudy" or similar words across the Moon and note the time of observation.

Starting on page 3 of the Student Handbook, there is a row for five days of observations and then two days, the weekend, on the next

line. Then there is a "question of the week." We have tried to logically sequence those questions, but you may want to substitute other questions. Also, you may want to encourage students to ask the same questions more than one time.

#### Class Discussion:

We envision your students starting each week with a lunar discussion. On January 26, or whatever your first day is, you can explain the process. One week later, possibly February 2, the students can share their observations for the preceding week and discuss the Question of the Week. You may want to have students draw on the board a consensus set of observations for the preceding week. You could have students add pages to their handbook to keep track of this consensus data. Later, during the Internet phase, we hope students from around the world will share these observations, so ask your students to keep careful notes.

This same pattern of daily observations and weekly discussions should continue until April 30.

As you lead these weekly discussions, please emphasize reporting of observations by your students. Then, based on these observations, have your students figure out patterns in their observations. Finally, students should come up with explanations for their observations; but these explanations come after the students have spent a great deal of time with observations and patterns.

At about the eighty week of those observations and discussions – after the Moon has completed two cycles – please have a discussion that strongly focuses on patterns.

Ask students individually to look over their (approximately) eight weeks of observations and pick out a distinctive shape that seems to be repeated more than once. Have them draw that distinctive shape in the first box in the left column titled "Shape of the Moon" in Table One. Under "Date 1" they should write the date they observed that distinctive shape; and then under "Date 2" they should write the next time they saw that exact same shape. Then in the right column, "Days Between," they should calculate the number of days between "Date 1" and "Date 2." They then should repeat the same process for four more distinctive shapes. (These tables appear in the Student Handbook after November 2.)

#### Table One

Shape of the Moon	Date 1	Date 2	Days Between

They then should draw a second table, but this time the shapes from the first table should be inserted in chronological order, according to the dates in the Date 1 column.

Table Two

Shape of the Moon	Date 1	Date 2	Days Between

Based on Table Two, conduct a discussion about patterns in the shape of the Moon. They should be able to figure out that the Moon's shape changes in a regular pattern; and they should be able to use that information to predict the Moon's shape in the future.

This information will be very helpful to students when they engage in the Internet discussions with students from around the world.

#### Lunar Ideas:

Attached to this handbook is an appendix titled "Moon Observations: What can you see? What patterns can you find?" But I lovingly call it a "cheat sheet," a list of ideas that **your students should discover themselves** about the Moon as a result of these activities. Please don't give the cheat sheet to your students. My students will use the "cheat sheet" in the Internet phase as they try to draw the ideas on the sheet out of the students. You might do the same in your classroom discussions.

#### WITH YOUR GUIDANCE,

YOUR STUDENTS SHOULD DISCOVER FOR THEMSELVES THESE IDEAS ABOUT THE MOON.

#### Community Conceptions of the Moon:

During the first two months, we hope students will talk about the Moon with their parents and other adults. Based on those conversations, we would like your students to write a couple paragraphs about ideas people in their community have about the Moon. Later in the Internet phase of the MOON Project, the students will share what they have written.

#### Parental Assistance:

The MOON Project provides an excellent opportunity to involve your students' entire families. Encourage your students' parents and other adults and family members to watch the Moon together. A sample letter to parents appears at the end of this handbook. Please feel free to use the letter as is or adapt it in any way you see fit.

We have found if students and other family members observe the Moon for a semester, they develop habits that continue long into the future.

#### Astrolabe:

Attached are directions for making an astrolabe from rather simple materials and information about the astrolabe's history. With an astrolabe, your students can be more precise in their estimation of the Moon's angle above the horizon. It's your choice whether you have your students make and use the astrolabe.

#### Internet Phase:

Once I receive your students' first names, we will place all of the students into discussion groups, each of which will be headed by one Ball State University pre-service teacher. To the best of our ability, each group will have no more than one student from any one classroom, so they will be discussing their lunar observations with students from many different locations. Depending on how many students are involved this semester, there will be 6-10 students per discussion group.

Each discussion group will carry out a six weeks long Internet discussion of their lunar observations and patterns they have figured out. By Monday of each week, starting the week of March 22, my students will start a new discussion thread. Your students should respond at least once each week to the thread. It is very important that your students respond at least once per week so that the discussion will continue. We have found that if students begin to drop out of the Internet message sharing, the others become discouraged and communication suffers.

IT IS VERY IMPORTANT THAT YOUR STUDENTS RESPOND AT LEAST ONCE PER WEEK.

IF THEY DO LESS, OTHER STUDENTS BECOME DISCOURAGED AND COMMUNICATIONS SUFFERS.

In class you and your students will have collected and discussed lunar observations. On the Internet they will compare their findings with those of others. If everyone participates as expected, the students will find out that there are many similarities around the world. For example, the Moon's shape doesn't change quickly enough for differences to be noted in a 24 hour period. Thus, if students in Los Angeles see a full Moon, then all students around the world will see a full Moon that day (assuming no cloud cover). On the other hand, there are some differences due to the point of view of the observer. For example, since students in the northern and southern hemisphere are standing upside down relative to each other, the waxing crescent Moon is seen on the right side in the northern hemisphere and on the left in the southern.

During the Internet phase, the students also will share what they have written about what people think about the Moon in different parts of the world. Some amazing cultural exchanges can take place. For example, in late 2002 Muslim students shared with the other (predominantly) Christian students how the Muslim calendar is based on the lunar cycle; and since these cycles do not precisely correlate with the Western calendar, the start of each Muslim month moves relative to the Western calendar. For example, Ramadan, a significant month in the Muslim calendar, began on November 6 in 2002 and October 27 in 2003, but will start on October 15 in 2004, and October 4 in 2005.

Directions for how your students can log into the MOON Project Internet will be sent separately to you.

#### Weekly Discussion Topics:

The question of the week starting March 22 will guide my students in what they ask to begin each week's discussion thread. We hope, for example, that sufficient data will be reported during the weeks of November 3 and 10 from around the world so that during those two weeks you and your students will be able to compare and contrast what you've seen in your hometown with what other students have seen elsewhere.

Since some of the MOON Project classes are east of us in Indiana and therefore are several hours later than us, my students are asked to start each week's discussion thread by Saturday. Thus, the discussion thread for the week of March 22 will be started by Saturday, March 20 (Muncie time).

The discussion threads will focus on lunar observations; but in late April my student will also ask your students to share what have learned about what adults in their community think about the Moon in conversation, literature, music and so forth. At that time your students will share the couple paragraphs they have researched and written on that topic.

#### 3x3 Student Responses:

Since we've previously had trouble getting students to write more than a couple sentences of response, at the suggestion of an Australian MOON Project teacher, we're implementing a 3x3 plan this semester. Each week my college student will ask three questions of the children in her/his discussion group and ask the children to reply with at least three sentences of response for each of the three questions.

PLEASE REINFORCE TO YOUR STUDENTS THAT EACH WEEK THEY SHOULD WRITE AT LEAST THREE SENTENCES OF RESPONSE TO EACH OF THE THREE QUESTIONS ASKED OF THEM.

#### **Internet Rules:**

The Student Handbook contains rules of etiquette for your students' use of the Internet in the MOON Project. It is very important that you stress that your students follow these rules.

Rarely, but occasionally a student in the past has made an inappropriate comment. My students are asked to read messages in their discussion group at least every other day, so they can respond to any new messages. If they see an inappropriate message, they are to report it to me immediately. I will delete the message, if it is inappropriate, electronically remove the author of the inappropriate message from the MOON Project, and inform you of what happened for any action you may want to take. Usually the teacher has not allowed that student to rejoin the MOON Project; but sometimes they have asked me to add the student back into a discussion group. If you feel the student should return, I can do that.

A bigger problem we've had is students chit-chatting; and with the mushrooming use of chat groups, buddy chats, and other forms of instant messaging (IM), the problem seems to be getting worse. Students use shorthand and slang, and they send frequent messages that have nothing to do with the Moon.

PLEASE EMPAHSIZE THAT STUDENTS SHOULD FOCUS ON THE MOON IN THEIR INTERNET MESSAGES AND NOT ON IDLE CHIT-CHAT.

Thus, we ask that you have your students give you a copy of each of their messages, either before or after the messages have been sent --- your choice. What you do with the messages is up to you; but we want the students to understand that their communication needs to be on target; it needs to respond to the discussion threads started by the Ball State University student each week regarding the Moon.

The students should be told that every teacher, including their own, and university professors and other collaborators in the MOON Project, as well as the rest of their discussion group has access to all of their messages, so they should be polite and respectful in all that they write. We don't want to hide the fact that we can monitor what they are writing.

#### Teaching to Standards:

At the end of this handbook is a list of Indiana standards --- we call them proficiencies --- which the MOON Project has been designed to address. Most MOON Project teachers are located outside Indiana; but the Indiana standards (proficiencies) are roughly modeled after Project 2061's Benchmarks, which are one form of national guidelines in the U. S. Thus, the Indiana standards (proficiencies) are fairly representative of what teachers in other states and countries are asked to teach. It is our hope that there is sufficient flexibility in the MOON Project for you to focus on standards that particularly apply to you. Yes, the MOON Project is about the Moon; but much more importantly it focuses on students observing, finding patterns, and coming up with explanations. We're focusing on a global inquiry.

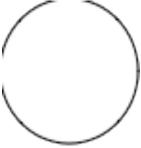
THE MOON PROJECT IS ABOUT THE MOON; BUT MORE IMPORTANTLY IT'S ABOUT ENGAGING STUDENTS IN LONG TERM INQUIRY.

#### Feedback:

We have learned a great deal from the teachers who have been part of the MOON Project in the past, and we hope we can learn from you. Please give us your feedback at any time.

Finally, thanks, thanks, thanks. We couldn't do this without you.

P.S. If you are a member of the National Science Teachers Association, at nsta.org you can access an article about the MOON Project that appeared in the May 2003 Science Scope.



http://dir.coolclips.com/Technology/Space/Astronomy/Planets/Moon/moon2.html; Viewed 1.13.03

# Moon Observations What Can You See? . . . . What Patterns Can You Find?

As you watch the Moon, these are some things you might observe. (Unless otherwise noted, directions are from the perspective of someone in the continental U. S. Some ideas (e.g., point 1) are true all around the Earth; but some ideas (e.g., point 5) need to be modified a little or a lot, depending on the location of the observer.

These ideas emphasize observation and patterns in observations. Interpretations of why the Moon does what it does are de-emphasized.

- 1. The Moon is not visible at all times, even when the sky is clear.
- 2. Sometimes the Moon can be seen during daylight hours; sometimes it can be seen when it's dark.
- 3. The Moon changes shape from day to day. When you look at the Moon for two days in a row, you may not be able to see this change; but when you compare the Moon's shape for, say, 3-5 days, you can see that its shape changes.

The various Moon shapes are called phases. You can learn more about Moon phases at <a href="http://www.EnchantedLearning.com/subjects/astronomy/moon/Phases.shtml">http://www.EnchantedLearning.com/subjects/astronomy/moon/Phases.shtml</a>

4. The Moon has many shapes often called "phases."

The idea of "phases" is something <u>invented by people</u> to name a few of these basic shapes. For example, we refer to a "crescent Moon;" but sometimes the crescent is quite skinny and sometimes it's sort of fat and sometimes it's in between. The Moon has all of these shapes, but we tend to use one word, "crescent," to name this basic shape.

5. When the Moon is illuminated on the right side, as in these drawings, it is growing larger in size.

When referring to a side of the Moon (e.g., "right side"), I'm referring to the side relative to the observer on Earth.

If the drawings to the right are how the Moon appeared to you, you'd say it was illuminated on the right side.

6.



When the Moon is illuminated on the left side, as in the drawings to the left, it is growing smaller in size.

Points 5 and 6 are true in the Northern hemisphere, but the reverse is true in the southern hemisphere.

- 7. A Moon that is illuminated on the right side, which is growing in size from day to day (see point 5), is called a *waxing* Moon. (Think about how candles are made. A wick is dipped into melted wax; and then the wax is allowed to dry. The candle is re-dipped into the melted wax and the new layer is allowed to dry. This process is repeated several times until the candle "grows" [waxes] to the desired size. In other words, this growing candle is waxing. And that's why we call the growing Moon a *waxing* Moon.)
- 8. A waxing crescent Moon (i.e., a crescent Moon that is illuminated on the right side) can best be seen in the southwest to western<sup>1</sup> sky at dusk or shortly thereafter.
- 9. A waxing half Moon, which is sometimes called a quarter Moon, that is illuminated on the right side can be seen around dusk in the southern sky. Later --- after sunset --- it can be seen in the southwest and then western sky.



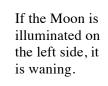
Two weeks after the new, skinny waxing crescent Moon appears<sup>2</sup> in the western sky it has grown (waxed) to a full Moon.

- 10. The full Moon appears in the eastern sky at dusk; and as the night goes on, the full Moon moves to the southern sky and then to the western sky.<sup>3</sup>
- 11. The full Moon, which rose (appeared) in the eastern sky, sets the next morning in the western sky.
- 12. After the Moon is full it starts to shrink in size over the next few days.
- 13. The part of the shrinking Moon that is missing is on the right side of the Moon. (Thus, the part you can see is on the left, as in this drawing.<sup>4</sup>)



- 14. The Moon that is growing smaller (see point 6) is called a waning Moon.
- 15. You can tell right away by looking at the Moon whether it is waxing or waning.

If the Moon is illuminated on the right side, it is waxing.





<sup>&</sup>lt;sup>1</sup> Northwest to western sky in the southern hemisphere.

<sup>&</sup>lt;sup>2</sup> Be careful about the word appears. A new, skinny, waxing crescent Moon is up most of the daylight, but it's hard to see this skinny Moon before the Sun goes down, because the Sun is so bright.

<sup>&</sup>lt;sup>3</sup> In the southern hemisphere the full Moon will be seen to move from east to west, but instead of moving from east to south to west, it will move from east to north to west.

<sup>&</sup>lt;sup>4</sup> In the southern hemisphere the left side is missing and the right side of the waning Moon is visible.

(These statements are true in the northern hemisphere; but the reverse is true in the southern hemisphere.)

- 16. The waning Moon rises later and later each night.
- 17. Both the Sun and Moon always rise in the east.
- 18. Both the Sun and Moon always set in the west.
- 19. It's easier to see the Moon rise in the east in the evening when the Moon is full or starts to wane.
- 20. It's easier to see the Moon set in the west in the evening when the Moon is a new waxing Moon or in the morning when it is a full Moon or close to a full Moon.
- 21. The side of the Moon that is illuminated is on the side facing the Sun.

This fact is easiest to see when there is a new waxing crescent Moon in the early evening.

The waning crescent Moon is another easy time to see that the side of the Moon that is illuminated is toward the Sun; but it's best to see this in the early morning just before sunrise --- so you have to get up early to make this observation!

22. Even though it's easiest to see the illuminated side of the Moon is toward the Sun when the Moon is a crescent; the illuminated side is always toward the Sun.

It's good to make this observation when the Moon is full. When the Moon is full, in the evening the full Moon is in the east and the Sun is in the west; and when the full Moon is setting in the west, the Sun is rising in the eastern sky.

- 23. The Moon doesn't stay in the same place.
- 24. From hour to hour the Moon moves toward the west.

This fact is easiest to observe when looking at a full Moon or close to a full Moon. The full Moon rises in the east and sets in the west. If you observe the Moon between these two extremes, you'll see the Moon move from the east around to the south<sup>5</sup> and then to the southwest and then finally to the west.

25. From minute to minute the Moon moves toward the west.

This fact is easiest to observe when looking at the Moon over a 30-minute period when the Moon can be seen relative to a fixed object like a tree, flagpole or edge of a building.

26. This minute to minute movement (point 25) follows the same path as the hour to hour observations (point 24).

<sup>&</sup>lt;sup>5</sup> To the north in the southern hemisphere.

27. From day to day the Moon moves toward the east.

This fact is easiest to observe when watching the waxing Moon shortly after sundown. A waxing crescent shortly after sundown is seen in the west. A week later the waxing half Moon is seen shortly after sundown in the south.<sup>6</sup> And a week after that the full Moon is seen shortly after sundown in the east.

- 28. The waning Moon continues day to day to move toward the east and, thus, rises later and later each day; but it's more difficult to make these observations, since we tend to have gone to bed by the time the waning Moon rises. (However, night owls or those who wake up before sunrise can help verify these observations.)
- 29. If you could poke a hole in the middle of the Moon, you would see that the Moon rotates in a clockwise direction as it moves across the sky.

This can be seen with a waxing half Moon. When first seen in the late afternoon or evening, the straight edge of the waxing half Moon is on the left or bottom left of the Moon. Later on, as it moves toward the west, that straight edge moves (rotates) in a clockwise direction; and when this half Moon is close to setting, the straight edge is on the top left or top of the Moon.

Note that this is a tricky idea. Here we're talking about how the Moon <u>appears</u> to us and NOT about whether the Moon is actually rotating.

The Moon's orientation rotates clockwise in the northern hemisphere





<sup>&</sup>lt;sup>6</sup> In the north in the southern hemisphere.

## WHERE IS THE MOON? CONSTRUCTING AN ASTROLABE

National and state standards in various ways call for students to learn that people have invented instruments (sometimes referred to as tools) that have helped humans learn more about the natural world. The standards also call for students to learn how to use simple instruments/tools such as magnifying glass, compass, and microscope.

So far this semester you have been using your eyeball and possibly your fist to measure the Moon's angle above the horizon. We are about to make a tool/instrument called an astrolabe to help us make those measurements more precise. You should continue to use this astrolabe as you make your Moon measurements.



(Photo courtesy Adler Planetarium and Astronomy Museum. The Mariner's Astrolabe was used to determine the latitude of a ship at sea by measuring the noon altitude of the Sun or the meridian altitude of a star of known declination.).

It was not possible to determine longitude at sea in the early days of European transoceanic navigation, but it was quite easy to determine latitude. To go to a place of known latitude, the ship sailed to that latitude and then sailed east or west along the latitude line until the place was

reached. To find the latitude of the ship at sea, the noon altitude of the Sun was measured during the day or the altitude of a star of known declination was measured when it was on the meridian (due north or south) at night. The Sun's or star's declination for the date was looked up in an almanac. The latitude is then 90° - measured altitude + declination.

A number of devices were used to measure the Sun's noon altitude. Among them were the quadrant, cross staff and, later, the back staff and the mariner's astrolabe. All these devices had a single use; to measure the altitude of a celestial body above the horizon. The Mariner's Astrolabe, which was popular in the late 15th and early 16th centuries, was a simple brass ring, graduated in degrees with a rotating alidade for sighting the Sun or a star. The ring was cast brass, quite heavy and cut away to keep it from blowing around in the wind. It was not a very good instrument and errors of four or five degrees were common.

It should be noted that any instrument used to measure altitudes above the horizon can be called an *astrolabe*. The term astrolabe is often used in a context that is not the same as the classic planispheric astrolabe.

http://www.astrolabes.org/MARINER.HTM viewed on 2.28.01

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#### Materials needed to make a simple astrolabe:

- 1. A piece of cardboard (approximately 8.5" x 11" [i.e., approximately 22 x 28 cm]).
- 2. A drinking straw.
- 3. A piece of string (about a foot [30 cm] long).
- 4. A weight (such as a nut or washer) to which you can tie the string.
- 5. The reverse protractor see drawing on the next page.
- 6. Glue.
- 7. Sharp object to punch a hole in the cardboard.
- 8. Scissors to cut the cardboard.
- 9. Scotch tape.

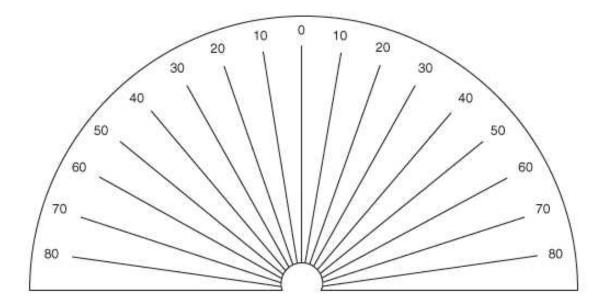
#### Directions for making the astrolabe:

- 1. Using a photocopier, make a copy of the reverse protractor on the next page such that the straight edge of the protractor is the same length as the longer straight edge of the cardboard (i.e., about 28 cm or 11 inches).
- 2. Use a few dabs of paste to paste the protractor to the cardboard with the straight edge of the protractor lining up with the longer straight edge of the cardboard.
- 3. Cut out the cardboard around the protractor.
- 4. Poke a hole in the cardboard about ¼ inch (.5 cm) from the straight edge of the cardboard, directly above the 0° mark. It may be helpful to start the hole with a straight pin and then widen the hole with scissors. Make the hole as close to the straight edge as possible.
- 5. Tie the weight to one end of the string. (Once tied to the string, the weight should not extend beyond the curved edge of the protractor.)
- 6. Thread the other end of the string through the hole and tie it in place.
- 7. Tape the straw to the straight edge of the cardboard.
- 8. Trim the two ends of the straw so that the ends do not extend quite to the end of the straight edge.

#### Directions for using the astrolabe to measure the angle of the object above the horizon:

- 1. Hold the astrolabe with the straight edge of the cardboard on top, parallel to the ground, with the string hanging down. (If the straight edge is parallel to the ground, then the string should cross the 0° mark on the protractor.)
- 2. Use one eye to look through the straw at the Moon (or whatever celestial body you're trying to position), allowing the string to hang free.
- 3. With the cardboard astrolabe still in place and the straw pointing toward the Moon, when the string stops swinging, use your index finger and thumb to pinch the string against the cardboard. Your thumb should be on the back side of the cardboard opposite your index finger so that the string will be held in place against the cardboard.
- 4. Use the lines radiating from the point toward the curved edge to estimate the angle between the object you're observing and the horizon. (For example, if the string is positioned half way between the 40° and 50° lines, the object you're observing is about 45° above the horizon.)

Because of the crudeness of this tool, you probably cannot measure any more accurately than within 5-10° of the object's actual position, but your estimate is probably better than "eyeballing" the object's position or using your fist to make the estimate.



### Indiana Science Standards Addressed by the MOON Project

Although written for use in Indiana, these standards were based on the Project 2061 Benchmarks, so they are applicable around the country and, we think, the world. The first number in, for example, 4.2.7, refers to the grade level. The second to the standard and the third to the sub-standard, which we call indicators in Indiana.

(The Scientific View of the World) 4.1.1 Observe and describe that scientific investigations generally work the same way in different places.

(Critical Response Skills) 4.2.7 Identify better reasons for believing something than "Everybody knows that..." or "I just know" and discount such reasons when given by others.

(The Universe) 4.3.1 Observe and report that the moon can be seen sometimes at night and sometimes during the day.

(The Earth and the Processes that Shape It) 4.3.8 Explain that the rotation of the Earth on its axis every 24 hours produces the night-and-day cycle.

(The Earth and the Processes that Shape It) 4.3.9 Draw or correctly select drawings of shadows and their direction and length at different times of day.

(Model and Scale) 4.6.3 Recognize that and describe how changes made to a model can help predict how the real thing can be altered.

(Scientific Inquiry) 5.1.2 Begin to evaluate the validity of claims based on the amount and quality of the evidence cited.

(Manipulation and Observation) 5.2.4 Keep a notebook to record observations and be able to distinguish inferences\* from actual observations.

(Communication Skills) 5.2.7 Read and follow step-by-step instructions when learning new procedures.

(Reasoning and Uncertainty) 5.5.7 Explain that predictions can be based on what is known about the past, assuming that conditions are similar.

(Reasoning and Uncertainty) 5.5.8 Realize and explain that predictions may be more accurate if they are based on large collections of objects or events.

(Constancy and Change) 5.6.4 Investigate, observe, and describe that things change in steady, repetitive, or irregular ways, such as toy cars continuing in the same direction and air temperature reaching a high or low value. Note that the best way to tell which kinds of change are happening is to make a table or a graph of measurements.

(The Universe) 6.3.3 Explain that the Earth is one of several planets that orbit the sun, and that the moon, as well as many artificial satellites and debris, orbit around the Earth.

(Physical Setting) 6.3.6 Use models or drawings to explain that the phases of the moon are caused by the moon's orbit around the Earth, once in about 28 days, changing what part of the moon is lighted by the sun and how much of that part can be seen from the Earth, both during the day and night.

(Common Themes) 6.7.2 Use models to illustrate processes that happen too slowly, too quickly, or on too small a scale to observe directly, or are too vast to be changed deliberately, or are potentially dangerous.

### APPENDIX C

INSTRUMENT #1: 15-ITEM INSTRUCTOR-CREATED QUESTIONNAIRE

### Moon Test

1.	As viewed from a spot standing on the Earth in Muncie, toward which direction does the Earth rotate? In the box to the right, write the direction or "I don't know."	
2	As viewed from a spot standing on Earth in Sydney,	
	As viewed from a spot standing on Earth in Sydney, Australia, to which direction does the Earth rotate? In the box to the right, write the direction or "I don't know."	
3.	As viewed from a spot in space above the North Pole, in which direction does the Earth rotate? In the box to the right, write the direction or "I don't know."	
	· ·	
4.	As viewed from a spot in space above the South Pole, in which direction does the Earth rotate? In the box to the right, write the direction or "I don't know."	
5.	As viewed from Muncie, in which direction does the	
	does the Moon revolve around the Earth? In the box to the right, write the direction or "I Don't Know.	
6.	How much of the Moon is illuminiated today? In the box to the right, write your answer or "I don't' know."	
7.	If we look into the sky in Muncie some evening and see this thin crescent Moon shown, what will its shape be seven days from now? In the box to the right, draw the shape you'll see in seven days or write "I don't know."	

Circle your answ	er: Yes		No	I don't kn	ow.
If yes, where is i	t? If no, v	why can it not	t be seen then	?	
9. Is it ever possible to s Muncie? Here's a pic			hat is nearly a	a half Moon at	noon in
Circle your answer:	Yes	No	I do	on't know.	
If yes, where is it? If I	no, why ca	nn it not be se	een then?		
10. Would you see the sa	ame shape	Moon in Ro	me, Italy and	Indianapolis o	on the same day?
Circle your answ	er: Ye	es	No	I don't kn	ow.
Explain the ratio	nale for yo	our answer.			

8. Is it ever possible to see a full Moon at noon in Muncie?

11. If you saw this moon one day in Indianapolis would you see exactly this same shape in Sydney, Australia on the same day?								
	Circle your answer:	Yes	No	I don't' know				
	Explain the rationale for your answer.							
12	. Why does the Moon rise	e in the East a	and set in the <b>W</b>	Vest as seen in Mund	rie?			
12.	willy does the Wooli fisc	m the Last t	and set in the v	vest, as seen in ividic				
13.	What can be obsered th	at supports th	ne idea that the	Moon revolves arou	nd the Earth?			

Would students in both Muncie and Sydney both correctly say that the Moon is orbiting the Earth I the same direction?						
Circle your answer:	Yes	No	I don't know			
Explain the rationale for your answer.						
Is the Moon visible for the	same amount of	time each day in	all places on Earth?			
Circle your answer:	Yes	No	I don't know			
Explain the rationale for your answer.						
	Earth I the same direction Circle your answer:  Explain the rationale for y  Is the Moon visible for the Circle your answer:	Earth I the same direction?  Circle your answer: Yes  Explain the rationale for your answer.  Is the Moon visible for the same amount of  Circle your answer: Yes	Earth I the same direction?  Circle your answer: Yes No  Explain the rationale for your answer.  Is the Moon visible for the same amount of time each day in Circle your answer: Yes No			

### APPENDIX D

**INSTRUMENT #2: 4 BASIC MOON PHASE KNOWLEDGE QUESTIONS** 

#### **Instrument #2 Four Basic Moon Phase Knowledge Questions**

1. You've probably noticed that the Moon doesn't always look the same. Sometimes we have a full Moon and other times the Mon is not full. Over the next few monthsyou are going to be observing the Moon. Draw pictures of the shapes of the Moon you think you will be observing over the course of a month.

Please color the part of the **Moon** you will see (for example, is a full Moon and is a crescent.

- Do you predict the shapes of the Moon will occur in a certain order? Circle your answer. Yes No
- 3. If you answered yes, draw the shapes in the order you think you will see them. Again, color in what you will see.
- 4. Explain what causes the Moon to change shape.

### APPENDIX E

## INSTRUMENT #4: MOON KNOWLEDGE APPLICATION TEST

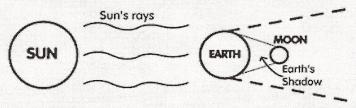
4. On the next page, describe two distinctly different problems with what Crayola.com has presented (reproduced below from their web site) regarding how the Moon changes shape. For each problem, state what the problem is and also state what the correct information should be. For example, this site says that the Moon rotates around the Earth, but in fact the Moon revolves around the Earth. Now describe at least two other distinctly different problems. (This rotate/revolve problem is almost minor compared to others that exist at this site.) Your answers almost inevitably will be longer than the example. Remember that sometimes a drawing is helpful to explain a point you want to make. Assume this web site is drawn from the northern hemisphere perspective.

Viewed at Crayola.com (http://www.crayola.com/activitybook/print.cfm?id=926&delete\_session=1) on 11.27.01. To their credit, this page now finally seems to have been pulled.

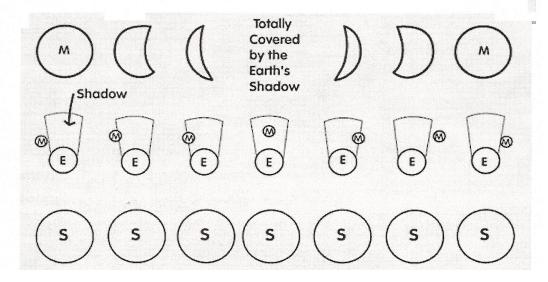
## Crayola.com

## MONTHLY MOON STAGES

The moon has no light of its own. It reflects the light from the sun. The moon rotates around the earth once every 29 days. When the moon orbits behind the earth, the earth blocks any sun from hitting the moon. As the moon moves from out of the shadow we see different sections of it.



We don't see the moon at the beginning of the cycle, but it gradually becomes larger until it is a Full Moon. Then it continues to rotate around the earth and appear smaller until we can't see it at all. Here is a diagram of how the moon seems to disappear or change shapes because it gradually becomes hidden by the earth's shadow.



# APPENDIX F

# **INSTRUMENT #1 SCORING GUIDE**

Instrument #1 Scoring Guide
\*Responses in bold are the most correct response.

TOTAL C	GODDEGE DEGRONAGES	NIGODDEGE DEGE STITE
<u>ITEM</u>	- <del>-</del>	INCORRECT RESPONSES
1	Toward East or East	Toward West or West
	Counterclockwise	Clockwise
	Right, if facing North	Other wrong answer
	Left if facing South.	Left or Right, no qualifier
2	<b>Toward East or East</b>	Toward West or West
	Clockwise	Counterclockwise
	Right, if facing North	Left or Right, no qualifier
	Left if facing South	
3	Toward East or East	Toward West or West
	Clockwise	Counterclockwise
	Right, if facing North	Left or Right, no qualifier
	Left if facing South	
4	Clockwise	Toward West or West
	Toward East or East	Counterclockwise
	Right	Left
5	<b>Toward West or West</b>	Toward East or East
	Clockwise	Counterclockwise or left
	Right	
6	One half	All other responses
	A phase (e.g. crescent)	-
7	Half (or slightly > )	All other responses
7 8	Half (or slightly > ) No	All other responses Yes
8	No	Yes
	No Full moon rises at dusk (Minimal)	Yes State a location
8	No Full moon rises at dusk (Minimal) Full moon rises at dusk plus correct	Yes State a location Eclipse
8	No Full moon rises at dusk (Minimal) Full moon rises at dusk plus correct elaboration	Yes State a location Eclipse Clouds
8	No Full moon rises at dusk (Minimal) Full moon rises at dusk plus correct	Yes State a location Eclipse Clouds Time Zones
8	No Full moon rises at dusk (Minimal) Full moon rises at dusk plus correct elaboration	Yes State a location Eclipse Clouds
8	No Full moon rises at dusk (Minimal) Full moon rises at dusk plus correct elaboration Opposite sides of Earth	Yes State a location Eclipse Clouds Time Zones
8 8A 9	Full moon rises at dusk (Minimal) Full moon rises at dusk plus correct elaboration Opposite sides of Earth Sun too bright to see moon Yes	Yes  State a location Eclipse Clouds Time Zones Latitude No
8 8A	No Full moon rises at dusk (Minimal) Full moon rises at dusk plus correct elaboration Opposite sides of Earth Sun too bright to see moon  Yes Southeast (SE to South) only	Yes  State a location Eclipse Clouds Time Zones Latitude  No Sun too bright to see moon
8 8A 9	Full moon rises at dusk (Minimal) Full moon rises at dusk plus correct elaboration Opposite sides of Earth Sun too bright to see moon Yes	Yes  State a location Eclipse Clouds Time Zones Latitude No

# 10 CORRECT RESPONSES\* Yes or no, depending on explanation 10A Moon stays relatively same shape each day (no further explanation)

each day (no further explanation)

Moon appears the same because
the two cities are in the same
hemisphere.

The moon is seen in the same phase everywhere.

See same shape; south of Equator, opposite side is illuminated.

Opposite shape; faces opposite direction when viewed from opposite side of Earth.

Same shape, opposite side illuminated.

11 Yes or no, depending on explanation

# 11A Yes, moon stays same shape each day

No, moon same shape but reversed, backward, opposite side illuminated

Yes, moon same shape but reversed, backward, opposite side illuminated

Yes, same shape, different hemisphere so shape is opposite

# 12 Earth rotates toward East; moon "rises" at Eastern horizon, moves toward West.

Moon actually moves toward the west each day Revolution of the moon

Rotation of the Earth, no explanation

# **INCORRECT RESPONSES**

Yes or no, depending on explanation

Rome and Indianapolis are in different locations; people have different views.

Rome and Indianapolis at different latitude and longitude; different shapes seen.

Night in Indianapolis is day in Rome. Earth rotates.

Shadow of Earth is different in different parts of the world.
Sun would reflect differently on moon (ambiguous language).

Yes or no, depending on explanation

Different parts of world/location; no reference to hemisphere. Ambiguous language; partly correct but cannot with certainty be taken as correct

Because the sun moves this direction Sun is on same side as the moon Rises in east & sets in west Earth rotates toward West Rotation of the moon Rotation/revolution used incorrectly Ambiguous language (it, different)

ITEM 13	Moon is seen in different location each successive day at the same time.  Same as 1 but also says that moon is	INCORRECT RESPONSES Foucoult's Pendulum Sun is on same side as the moon Because the sun moves this
	moving (revolving) toward the east	direction
	Progression of phases	Tides
	Phases of moon	Ambiguous language (it, different) Always see same side of moon from Earth
14	Yes or no, depending on explanation	Yes or no, depending on explanation
14A	Correct response with supporting observation	Wording too arbitrary to code as correct
	Correct response with added correct supporting rationale	Observation is incorrect Rationale is incorrect
15	Yes or no, depending on explanation	Yes or no, depending on explanation
15A	Correct response with supporting observation	Wording too arbitrary to code as correct
	Correct response with added correct	Observation is incorrect
	supporting rationale	Weather interferes with observation
		Rationale is incorrect
		Daylight, sunrise, sunset
		Location on Earth, latitude,
		longitude

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