THE DEVELOPMENT AND VALIDATION
OF A TWO-TIERED MULTIPLE-CHOICE INSTRUMENT TO IDENTIFY
ALTERNATIVE CONCEPTIONS IN EARTH SCIENCE
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ALTERNATIVE CONCEPTIONS IN EARTH SCIENCE

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy in Curriculum and Instruction

By

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Abstract

This study was to determine reliability and validity for a two-tiered, multiple-choice instrument designed to identify alternative conceptions in earth science. Additionally, this study sought to identify alternative conceptions in earth science held by preservice teachers, to investigate relationships between self-reported confidence scores and understanding of earth science concepts, and to describe relationships between content knowledge and alternative conceptions and planning instruction in the science classroom.

Eighty-seven preservice teachers enrolled in the MAT program participated in this study. Sixty-eight participants were female, twelve were male, and seven chose not to answer. Forty-seven participants were in the elementary certification program, five were in the middle school certification program, and twenty-nine were pursuing secondary certification.

Results indicate that the two-tiered, multiple-choice format can be a reliable and valid method for identifying alternative conceptions. Preservice teachers in all certification areas who participated in this study may possess common alternative conceptions previously identified in the literature. Alternative conceptions included: all rivers flow north to south, the shadow of the Earth covers the Moon causing lunar phases, the Sun is always directly overhead at noon, weather can be predicted by animal coverings, and seasons are caused by the Earth’s proximity to the Sun.

Statistical analyses indicated differences, however not all of them significant, among all subgroups according to gender and certification area. Generally males outperformed females and preservice teachers pursuing middle school certification had
higher scores on the questionnaire followed by those obtaining secondary certification. Elementary preservice teachers scored the lowest. Additionally, self-reported scores of confidence in one’s answers and understanding of the earth science concept in question were analyzed. There was a slight positive correlation between overall score and both confidence and understanding. Responses on the questionnaire were investigated with respect to pedagogical choices. Evidence suggests that content knowledge and having alternative conceptions or science fragments may impact a teacher’s pedagogical choices.

Through careful development of instruments like ACES-Q II-R and other two-tiered, multiple-choice instruments, educators and researchers can not only identify possible alternative conceptions, they can raise an awareness of alternative conceptions held by children and adults.
This dissertation is approved for
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Dedication

This dissertation is dedicated in memory of my father,

Michael Angelo Mangione

1931 – 1995

for showing me the stars and encouraging me to reach for them;

And to my son,

Orion Teague Leslie

named in honor of those starry nights.
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Chapter 1:

Introduction

Humans orbit the Sun on a spaceship known as planet Earth. Despite our implicitly close relationship with Earth, many of us are unaware of the workings of life, the phenomena behind night and day, the seasons, formation of rock, and many other processes on our planet. While some may argue that understanding the causes of the seasons or whether the greenhouse effect is a ‘good thing’ or not is of no great importance, scientists and science educators are gravely aware of the significance of these and other earth science topics. How is a scientifically literate society judged? It is by the informed decisions its citizens make on scientific matters.

Content knowledge is a primary focus in teacher education programs. Not only are preservice teachers subjected to the rigors of several standardized exams before being eligible for teacher programs, graduation, and certification (e.g., Praxis I, II, & III), preservice teachers are mandated by state requirements to complete a specific number of content area courses based on their certification areas. Despite the course work and standardized testing, years of research indicate that preservice and in-service teachers possess a wealth of alternative conceptions (e.g., Atwood & Atwood, 1995 & 1996; Schoon, 1989, 1992, & 1995). Alternative conceptions are ideas or beliefs that do not match scientific understandings (Hewson & Hewson, 1993; Lipson, 1986).

Teacher educators understand that content knowledge is key to success as a teacher. Hashweh (1987), Leinhardt and Smith (1985), Osborne and Simon (1996), and
Smith and Neal (1989) found that in planning instruction, teachers tend to delete details that they do not understand. One study (Stofflett, 1993) found that the topic of volcanoes is one of the most popular to be taught in elementary science courses; however, plate tectonics, an integral concept related to volcanoes, is rarely covered. When teachers omit topics and concepts that they themselves do not understand, are they unwittingly passing on their own alternative conceptions to their students?

Science educators have been expressing concerns about alternative conceptions for several decades (Abimbola, 1988; Doran, 1972; Driver & Easley, 1978; Novak, 1977; Schwab, 1963). Alternative conceptions in science may indicate a lack of content knowledge in both teachers and students. Research from the past three decades has shown strides being made in connecting content knowledge to instruction (Aubrey, 1996; Kallery & Psillos, 2001; Wilson, Shulman, & Richart, 1987). This is in part due to Shulman’s (1986, 1987) theoretical development of the concept of pedagogical content knowledge (PCK). Pedagogical content knowledge is the marriage of content knowledge and the understanding of how best to teach the content. Findings in a project conducted by the National Research Council (NRC) (1996) encouraged science education faculty to structure the content, pedagogy, and assessment strategies in science courses, especially in the lower division, to optimize student learning, thereby providing future teachers with the knowledge, understanding, and skills necessary to teach in accordance with the standards (p.6).

With this in mind, teacher educators should “reexamine our assumption that subject matter knowledge required for teaching can be acquired solely through courses taken in the appropriate university department” (Grossman, Wilson, & Shulman, 1989, p. 23). Science teacher educators need to be conscious of preservice teachers’ needs to develop
their own understanding about scientific concepts and possible misconceptions that they may bring to the learning environment.

Rice (2005) cited the Glenn Commission’s (US Department of Education, 2000) report *Before It’s Too Late* stating that the math and science preparation that students in the United States receive is unacceptable. Rice speculated that if the Glenn Commission is correct then it is possible that

a significant part of the science achievement problem in the U.S. lies with teachers who are ill-prepared to teach science, especially at the elementary level where students have their first experiences with school science. (p. 1060)

We cannot ignore the research and assume that preservice teachers ‘get’ the science content knowledge needed to be effective science teachers in the college content courses. By assessing what preservice teachers know, we can better meet their needs via more effective content courses and better developed methods courses. An awareness of the alternative conceptions that we and our preservice teachers possess is the first step in preparing preservice teachers to be better science educators and in creating a scientifically literate society.

**Theoretical Issues**

Epistemology, the study of how people create their understandings of the world around them, has been of interest to educators and psychologists alike. The importance of prior knowledge plays a fundamental role in learning models formulated by science educators and psychologists around the concept that knowledge is a human construction (Piaget & Inhelder, 1969; von Glasersfeld, 1988). A tenet of constructivism (Gunstone, 1990; Piaget & Inhelder, 1969) is that for meaningful learning to take place, it is of
utmost importance for the teacher to consider what knowledge the learner already possesses. This includes alternative conceptions the child may already have. Constructivism goes beyond the identification of prior knowledge to encompass how knowledge is generated, stored, and integrated with new information (Vosniadou, 1991). Research on alternative conceptions has generated a great deal of information on how prior knowledge affects the learning and assimilation of new concepts (e.g., Driver, 1981; Gilbert, Osborne, & Fensham, 1982; Gunstone, 1990; Hashweh, 1986; Vosniadou, 1991).

Common terms used to describe the phenomenon of nonscientific conceptions in the learning environment include misconceptions, naïve beliefs, persistent pitfalls, or science fragments (Wandersee, Mintzes, & Novak, 1994). The phrase “alternative conceptions”, defined as scientific ideas of an individual that are at odds with or do not match current scientific understandings (Fisher & Lipson, 1986; Hewson & Hewson, 1993), will be used throughout this dissertation. This definition was chosen because it recognizes the learner as an individual trying to make sense of the world with understandings that they have constructed and that work for them (Leslie, Dockers, & Wavering, 2005).

Evidence indicates that preservice and inservice teachers hold many of the same science alternative conceptions as their students (Harlen, Holroyd, & Byrne, 1995; Parker & Heywood, 2000; Smith & Neale, 1989; Wandersee, Mintzes, & Novak, 1994). Alternative conceptions are both pervasive and persistent (Franklin, 1992; Schoon 1992, 1995). Coupling the ideas that alternative conceptions are common and resistant to change with the evidence that teachers possess many of the same alternative conceptions as their students— as well as viewing learning as a passive endeavor may promote the
development of or pass on currently identified alternative conceptions in the science classroom.

Data on various alternative conceptions have been generated over the past several decades (Doran, 1972; Fisher & Lipson, 1986; Jones, Lynch, & Reesink, 1987; Lucas & Cohen, 1999; Trumper, 2000a & 200b; Trundle, Atwood, & Christopher, 2003, 2006, & 2007); however, there has not been a push to create a teacher-friendly instrument that specifically identifies earth and space science alternative conceptions. One goal of this study was to create a questionnaire that will enable professors of preservice teachers of all grade levels to assess their students’ alternative conceptions in earth and space science. Another aspect of this study was to identify alternative conceptions of earth science held by preservice teachers and the possible impact these alternative conceptions may have on pedagogical choices.

Justification for this Study

Alternative conceptions can have a negative impact on teaching and learning processes (Driver, 1981; Gilbert, Osborne, & Fensham, 1982; Gunstone, 1990; Northfield & Gunstone, 1983). Identifying what alternative conceptions teachers hold is the first step toward changing the way university classes are taught and preventing the transfer of alternative conceptions in the classroom. Understanding what alternative conceptions we have and that our students might have can reduce the probability for drawing mistaken conclusions about why students fail to perform as expected (Hesse, 1989; Lightman & Sadler, 1993).
Studies show that teachers feel they lack specific content knowledge (Kallery & Psillos, 2001; Parker & Heywood, 2000; Smith & Neale, 1989). In one study, nearly seventy-five percent of math and science teachers recognized a need to increase their content knowledge in the area of science (Weiss, Banilower, McMahon, & Smith, 2001). Does this lack of knowledge indicate that teachers hold alternative conceptions in science? By assessing alternative conceptions held by preservice teachers we can facilitate conceptual change and ultimately impact their classroom practices when they become teachers.

Traditional teachers often perceive the learning process as passive on the part of the student. However, in science what teachers try to achieve is to “modify the beliefs of the students” (Franklin, 1992, p. 6). Teachers often do not consider prior knowledge, prior beliefs, or the possibility that students may have alternative conceptions before executing a lesson.

It is imperative to address not only alternative conceptions in earth science, but also to create an instrument to help identify and raise awareness of common alternative conceptions in earth science. Earth science is required to be taught at every grade level according to the Arkansas Frameworks (Arkansas Department of Education [ADE], 2005). However, preservice teachers in Arkansas are not required to take earth science as a content area course for certification. Without formal courses in earth science, teacher candidates lack content knowledge and may bring alternative conceptions to their students. A teacher’s level of content knowledge impacts how, and often times if, he or she teaches a topic (Parker & Heywood, 2000; Smith & Neale, 1989). Even armed with awareness and research, alternative conceptions are difficult to “teach away.”
Purpose of the Study

Research on various misconceptions has been generated over the past several decades (Atwood & Atwood, 1995 & 1996; Daikidoy, Vosniadou, & Hawks, 1997; Doran, 1972; Schoon 1992, 1995; Schwab, 1963; Vosniadou, 1991; Wandersee, 1983) but there has not been a push to create an instrument that identifies earth and space science misconceptions. This study focuses on the understanding of preservice elementary, middle, and secondary school interns on common earth science concepts taken directly from the Arkansas State Frameworks (ADE, 2005) and National Science Education Standards (NSES) (NRC, 1996) for kindergarten through 12th grade. Earth science is the one area of science that is covered at all levels of the Arkansas State Frameworks (ADE, 2005) and is therefore required to be taught at all grade levels. Ultimately it is the teacher, and eventually the preservice teacher, that is instrumental in shaping the scientific understandings of children in their classrooms. By examining the earth science content knowledge of preservice teachers we can assess the effectiveness of university science courses and science pedagogy classes as well as help preservice teachers become aware of alternative conceptions that they may bring to the classroom.

One objective of this study is to create a questionnaire that will enable professors of preservice teachers of all grade levels to assess their students’ alternative conceptions in earth and space sciences. A review of literature revealed several ways to assess misconceptions:

- Questionnaires and other pen and paper instruments (Franklin, 1992; Schoon, 1992 & 1995; Trumper, 2001a & 2001b)
- Analyses of national standardized tests (Wandersee, Mintzes, & Novak, 1994)
- Interviews (Osborne & Freyburg, 1985; Osborne & Gilbert, 1980)
• Interviews combined with pen and paper (Atwood & Atwood, 1995 & 1996; Franklin, 1992; Trundle, 1999)
• Two-dimensional drawings (Callison, 1993; Callison & Wright, 1993; Trundle, 1999; Trundle, Atwood, & Christopher, 2002 & 2003)
• Or other combinations of the above.

While the interview method has been the most fruitful of the above techniques, it is not likely to be used in a classroom of 30 or more students (Franklin, 1992). Therefore, instrumentation is needed to help teachers recognize their own alternative conceptions and to identify their students’ alternative conceptions.

The Alternative Conceptions in Earth Science – A Questionnaire Revised (ACES-Q II-R) was developed based on a two-tier, multiple-choice format (Franklin, 1992; Leslie, Dockers, & Wavering, 2005, 2006; Peterson, Treagust, & Garnett, 1989; Tobin & Capie, 1980; Treagust, 1988). Each item was developed based on the Arkansas Science Frameworks (ADE, 2005) and the National Science Education Standards (NSES) (NRC, 1996). Distractors were based on alternate conceptions, held by both children and adults, reported in the literature from the past several decades. Earth and space concepts covered by the instrument included: solar system, Earth’s history, Earth’s systems, and climate. One aspect of this study was to identify alternative concepts of earth science held by pre-service teachers. The information gathered in this study benefits not only the preservice teachers in their understanding of alternative conceptions, but will aid professors in both the education and science departments with restructuring classes to address alternative conceptions via classes designed for conceptual change.
Research Questions

The questions motivating this study were:

1. What evidence of reliability and validity exist for the ACES-Q II-R, a two-tiered, multiple-choice instrument used to give insights into what alternative conceptions preservice teachers may hold in the areas of earth science?
2. What alternative conceptions do preservice teachers hold regarding specific earth science concepts based on National Science Education Standards (NRC, 1996) and Arkansas State Frameworks (ADE, 2005)?
3. How confident are preservice teachers regarding their earth science understandings and or the alternative conceptions they may hold?
4. Does having alternative conceptions impact preservice teachers’ pedagogical choices?

Definitions

**Scientific Conceptions** are current theories accepted by experts and scientists. An example of a scientific conception is that the sun is the center of our solar system (heliocentrism).

**Misconceptions** are ideas that differ from the understandings accepted by scientists and experts (Fisher, 1983). An example of a misconception is that the Earth is the center of our solar system (geocentrism).

**Alternative Conceptions** are beliefs that differ from the ideas and understandings held by scientists and experts. This neutral term is preferred by researchers in science education instead of the term misconceptions (Lipson, 1986; Hewson & Hewson, 1993). It “confers intellectual respect on the learner who holds those ideas…” (Wandersee, Mintzes, & Novak, 1994, p. 178). Other neutral terms for misconceptions include naïve beliefs (Caramazza, McCloskey, & Green; 1981), preconceptions (Hashweh, 1999), and personal models of reality (Champagne, Gunstone, & Klopfer, 1983 &1985).
**Primary Alternative Conceptions** are alternative conceptions that are more prevalent than scientifically acceptable conceptions (Schoon, 1992 & 1995). An example from Schoon (1995) is that the sun is always directly overhead at noon.

**Secondary Alternative Conceptions** are common alternative conceptions; however they are less common than scientifically acceptable conceptions (Schoon, 1992 & 1995). An example from Schoon (1995) is that severity of winters can be predicted by observing animal or insect coverings.

**Functional Alternative Conceptions** are alternative conceptions that may interfere with one’s ability to function in society (Schoon, 1992). An example from Schoon (1992) is that ‘north is up.’

**Organization of the Chapters**

This dissertation is divided into five chapters. The first offers a brief introduction to the topic and an explanation of the pertinence of the study. Chapter Two provides a review of the literature and focuses on identified alternative conceptions in earth and space science as well as modes of identifying alternative conceptions. The third chapter details the methodology; this includes a discussion of the design, the development of the instrument, the subjects, and the procedures. The fourth chapter serves to present and to analyze the results of the study. The fifth chapter contains a summary of the results, conclusions, implications, and recommendations of this researcher for further research.
Chapter 2:

Literature Review

The purpose of this study was to find evidence of reliability and validity for a two-tiered, multiple-choice instrument designed to identify alternative conceptions in earth science. Additionally, this study sought to identify possible alternative conceptions in earth science held by preservice teachers, to investigate the relationships between self-reported confidence scores and understanding of earth science concepts, and to describe the relationship between content knowledge, alternative conceptions and planning instruction in the science classroom.

This chapter begins with a discussion of alternative conceptions, followed by a brief review of assessment practices in identifying them. As many preservice and inservice teachers hold the same scientific alternative conceptions as their students (Berg & Brouwer, 1991; Harlan, Holroyd, & Byrne, 1995; Parker & Heywood, 2000; Schoon, 1992 & 1995; Smith & Neale, 1989), a discussion of both children’s alternative conceptions and teacher’s alternative conceptions follows. Studies on alternative conceptions for both children and preservice teachers are divided into three broad categories: astronomy and solar system, Earth’s history and Earth’s systems, and climate and meteorology. General earth science studies follow. Studies in each subsection are presented in chronological order. The chapter concludes with a discussion of developing two-tiered, multiple choice items to identify alternative conceptions and a summary.
Alternative Conceptions

“It is now well established that during their experiences in everyday life children develop their own ‘naïve theories’ which they use to explain the natural phenomena which they observe in the world around them” (Palmer, 1998, p. 65). This quote brings to light the ubiquity and fundamentality of scientific misconceptions. The past several decades (Doran, 1972; Franklin, 1992; Schwab, 1963; Wandersee; Mintzes, & Novak; 1994) have seen a wealth of research in the area of alternative conceptions: defining them, naming them, and identifying them.

Scientific misconceptions (Doran, 1972; McClelland, 1985) refer to ideas that are at odds from the definitions accepted by experts and scientists (Fisher, 1983). Several terms have been used to describe these ideas: naïve beliefs (Caramazza, McCloskey, & Green, 1981), children’s science (Osborne & Freyburg, 1985), alternative frameworks (Driver & Easley, 1978), and world knowledge (Gunstone, Champagne, & Klopfer, 1981 & 1983). However, alternative conceptions, a more neutral term preferred by many researchers in science education instead of the term misconceptions (Fisher & Lipson, 1986; Hewson & Hewson, 1993), has quickly taken hold. Wandersee, Mintzes, and Novak (1994) posit that the term alternative conceptions “confers intellectual respect on the learner who holds those ideas…” (p. 178).

Schoon (1992 & 1995) has not only identified alternative conceptions held by children and teachers alike, he has categorized these alternative conceptions according to their prevalence. Primary alternative conceptions are alternative conceptions that are more prevalent than scientifically acceptable conceptions (Schoon, 1992, 1995). An example from Schoon (1995) is that the sun is always directly overhead at noon.
Secondary alternative conceptions are common alternative conceptions; however they are less common than scientifically acceptable conceptions (Schoon, 1992, 1995). An example from Schoon (1995) is that severity of winters can be predicted by observing animal or insect coverings. Functional alternative conceptions are alternative conceptions that may interfere with one’s ability to function in society (Schoon, 1992). An example from Schoon (1992) is that ‘north is up.’

Alternative conceptions are more than mistakes made by children or adults. “Mistakes are usually not strongly held by the student” (Abimbola, 1988, p. 180), when a particular conception or belief is “held strongly and persistently by the students they are no longer mistakes” (p. 180). Their persistence coupled with their impact on the learning of new information cause these beliefs to be categorized as alternative conceptions.

Alternative conceptions may stem from a variety of experiences. Champagne, Gunstone, and Klopfer (1981 & 1983) suggest that language or everyday use of science vocabulary may promote alternative conceptions (e.g., speed, acceleration, and velocity are used interchangeably by most people). “Many words in science are used in an alternative way in everyday language” (Gilbert, Osborne, & Fensham, 1982, p. 625). Teachers may also wrongly assume that students understand a concept based on the words the student uses. Another opportunity for alternative conceptions to arise can be found in textbooks. Pictures, diagrams, and two-dimensional models may be difficult to interpret as they represent abstract scientific ideas and may lead to alternative conceptions (Beatty, 2004). Preservice teachers participating in Schoon’s (1995) study cited several reasons for alternative conceptions. The most often reported was that participants were directly taught an alternative conception. This researcher recalls her
own sixth grade experiences when her teacher announced in Social Studies that "all rivers flow north to south." Media, reasoning a situation out, and folklore were also identified as causes for alternative conceptions (Schoon, 1995).

Whether or not one chooses to use the term personal models of reality (Gunstone, Champagne, & Klopfer, 1981) or children's science (Osborne & Freyburg, 1985) or whether the alternative conceptions identified are primary, secondary, or functional (Schoon, 1992 & 1995), alternative conceptions are both pervasive and resilient (Wandersee, Mintzes, & Novak, 1994) and serve as barriers to learning new concepts (Klymkowsky, Taylor, Spindler, & Garvin-Doxas, 2006). It is imperative for educators to identify alternative conceptions before planning or beginning instruction (Champagne, Gunstone, & Klopfer, 1981 & 1983; Driver, 1981; Driver & Easley, 1978; Hashweh, 1986; Wandersee, Mintzes, & Novak, 1994).

**Detecting Alternative Conceptions**

The literature describes several methods for the identification of alternative conceptions. The most popular being questionnaires and other pen and paper instruments due to their ease in administration (Franklin, 1992; Peterson, Treagust, & Garnett, 1986; Schoon, 1992 & 1995; Tamir 1971 & 1972, 1990; Trumper, 2001a & 2001b; Wandersee, 1983). National standardized tests may also be analyzed to identify areas where students may hold alternative conceptions. Two-dimensional drawings (Callison, 1993; Callison & Wright, 1993; Trundle, 1999; Trundle, Atwood, & Christopher, 2002, 2003, & 2006) and concept mapping (Hoz, Bowman, & Kozminski, 2001; Novak, 1983; Wandersee, 1990) have also been used to elucidate alternative conceptions. Interviews (Osborne &
Freyburg, 1985; Osborne & Gilbert, 1980), while time consuming and difficult to transcribe and analyze, still provide some of the deepest understandings we have of alternative conceptions.

Interviews have been found to be the best approaches for uncovering children’s ideas and possible alternative conceptions (Osborne & Gilbert, 1980). Osborne and Gilbert (1980) and later Osborne and Freyberg (1985) followed on “from the approach to probing children’s thinking developed by Piaget” (Osborne & Gilbert, 1980, p. 159) by identifying two categories of interviews: interview about instance and interview about events. In the interview about instance method provides the interviewee with an illustration of an instance (e.g., man pushing against a wall). The interviewee is then asked to further explain the situation. Questions are developed about examples and non-examples pertaining to a particular scientific concept. These situations presented in an interview about instances are usually represented by line drawings and other illustrations. The interview about events approach (Osborne & Freyburg, 1985; Osborne & Gilbert, 1980) asks the interviewee to observe or participate in a demonstration of a particular scientific concept or phenomenon. Then, via a series of questions, the interviewer would try to elicit the interviewee’s understanding of the concept.

Interviews, while rich with insights into children’s thinking, have serious drawbacks. Much of the data can be lost in the translation if the interviewer has not been trained in qualitative research methodology. Additionally, the potential for generalizing the findings to a larger group may also be limited. These factors combined with the fact that interviews are time consuming and require special training make them unlikely to be
used by teachers or science educators (Amir, Frankl, & Tamir, 1978; Franklin, 1992; Sadler 1998).

Wandersee and Mintzes (1987) found that multiple-choice tests were the second most common research method (after interviews) used in studies of alternative conceptions in life sciences. Klymkowsky et al. (2006) suggest that multiple-choice concept inventories be used as pre- and post-tests to evaluate learning gain and to identify possible alternative conceptions before instruction takes place. Several researchers have found success in using multiple-choice questionnaires to identify alternative conceptions in a variety of science content areas (Atwood, 2005; Doran, 1972; Franklin, 1992; Halloun & Hestenes, 1985; Helm, 1980; Linke & Venz, 1978 & 1979; Schwab, 1963; Tamir, 1971 & 1989; Treagust, 1988; Trembath, 1984).

A less common approach for identifying alternative conceptions involves the use of drawings (Callison, 1983; Callison & Wright, 1983; Trundle, 1999; Trundle, Christopher, & Atwood, 2000) or concept mapping (Hoz, Bowman, & Kozinsky, 2001; Novak, 1983; Wandersee, 1990). Concept maps may be indicative of alternative conceptions in a variety of ways. Alternative conceptions may appear regarding basic facts in the existence of forbidden connections or mistaken explanations for these connections. They may also become evident in the way concepts are organized. There may also be over linking or under linking to these various concepts.

Paper and pencil questionnaires are growing in their popularity due to their ease in administration. Questions for these instruments may range from open-ended, constructed response to multiple-choice or true/false items. In 1983 Wandersee suggested a requirement for additional explanations on some items on the Photosynthesis
Concept Test. Analysis of justification data provided a depth of information previously unavailable to the traditional multiple-choice test format. In 1981 Tobin and Capie modeled a two-tiered, multiple-choice design that Treagust and Haslam (1986), Peterson, Treagust, and Garnett (1989), Franklin (1992), and Leslie, Dockers, and Wavering (2005, 2006, & 2009) have used explicitly to identify alternative conceptions. Amir, Frankl, and Tamir (1978) posit that the contributions of justifications or reasons are twofold: first, alternative conceptions can be identified; secondly, the researcher or instructor has better insight into the understanding of the notions held by students. Additionally, instruments requiring justifications provide teachers a starting place for identifying and addressing known alternative conceptions. A two-tiered, multiple-choice instrument can be used as a diagnostic tool both before and after instruction (Franklin, 1992; Haslam & Treagust, 1987; Klymkowsky et al., 2006).

Children’s Understandings of Earth Science

Children’s thinking, particularly in science has been an interest of educators and researchers alike for nearly 80 years. It is argued that Piaget’s interviews into children’s thinking are some of the first studies to share children’s scientific ideas (Driver, 1981). Sixty years ago Matteson and Kambly (1940) created a 199 item, free-response instrument from a survey of elementary science textbooks. Five hundred and seventy-three pupils entering the seventh grade across four Midwestern schools participated in the study. Despite the broad nature of the instrument, several alternative conceptions in earth science were identified. A few of these included confusion between the terms cyclone
and tornado and confusion between the terms rotation and revolution with respect to Earth’s movements.

A decade later Haupt (1950) shares findings from a first grade class discussion prompted by the question “let’s talk about the Moon” (p. 224). Haupt identified several alternative conceptions that are still present among today’s school children: the Moon has a face; the Moon does not move; phases of the Moon are caused by clouds or weather; and the night hides the Moon.

Keuthe (1963) using responses provided on a 50 question, general science content area exam identified several “sophisticated errors” (p. 361) or alternative conceptions present in 100 young men who had completed their last year of high school and were college bound. Keuthe found that 70% of these students were unable to explain the causes of an eclipse. Over a quarter of the subjects identified oxygen as the most abundant gas in our atmosphere. Nearly one-fifth (19%) indicated that the Moon does not rotate and over half of them failed to list the sun as our nearest star. Three students were unable to identify east as the direction the Sun rises. A full third of the sample was unable to explain why the Sun appears to rise in the east, “that is they were unable to give the correct direction of the Earth’s rotation (p. 364). While it can be argued that the focus of these three studies is science content knowledge, several alternative conceptions were identified and these studies have set the foundation for research on the identification of misconceptions.

Astronomy and Solar System

Nussbaum (1979) modified open-ended interview questions from Nussbaum and Novak (1976) and created a multiple-choice instrument administered to 240 children
spanning fourth through eighth grades. Results from both studies indicated that both American children (Nussbaum & Novak, 1976) and Israeli children (Nussbaum, 1979) share similar alternative conceptions. These include 1) the Earth is flat, 2) the Earth is a sphere, but the ground is flat, 3) items on the bottom of the Earth will fall off the Earth, and 4) people only live on the upper half of the Earth (lest we fall off!). Several years later in a study evaluating the effectiveness of planning instruction for conceptual change, Nussbaum and Sharoni-Dagan (1983) revealed the same alternative conceptions illuminated in Nussbaum's previous research endeavors.

Jones, Lynch, and Reesink (1987), using a clinical interview technique and stimulus materials (models), asked third and sixth graders (nine year olds and 12 year olds) questions about the shape, size, and motion of the Earth, Moon, and Sun. Third graders were twice as likely to use an Earth-centered model as sixth graders. There were no differences noted between genders. When describing the shape of the Earth, Moon, and Sun, third graders were more likely to choose incorrect shapes to represent these bodies. Again, there were no differences noted between genders. With relation to cosmic body size over 70% of both third and sixth graders were unable to correctly compare the sizes. Females were much more likely to hold incorrect notions about size than males.

Baxter (1989) interviewed 20 nine to 16 year olds in the United Kingdom. Based on these interviews he developed an instrument that he administered to 100 students from the same age group. His investigations showed that students held a great number of alternative conceptions regarding the Earth and its gravity, day and night, phases of the Moon, and the seasons. Some of these alternative conceptions included:
• The Earth is shaped like a saucer; the Earth is shaped like a sphere, however the ideas of up and down still persist.
• Night is caused by the Moon covering the sun; night is caused by the Sun going behind a hill, or clouds covering the Sun.
• Phases of the Moon are caused by clouds; planets cast shadows over the Moon; the shadow of the Sun falls on the Moon; and the shadow of the Earth causes lunar phases.
• Seasons are caused by heavy winter clouds, distance from the Sun, and changes in plants.

Daikidoy, Vosniadou & Hawks (1997) used a 45 item questionnaire developed by Vosniadou and Brewer (1994) to guide the interviews of 26 Lakota children in first, third, and fifth grades. Concepts studied included shape of the Earth and the cause of night and day. Nearly 60% of the Lakota children indicated the Earth to be a flattened sphere, a hollow sphere, or a disc (flattened like a pancake). Only 5% of the students explained day and night using scientifically accepted descriptions. Two of the students indicated that both the Sun and Moon orbit the Earth. Interestingly, nearly a quarter of the students attributed night and day to animistic or cultural reasons. These data match findings from Vosniadou and Brewer (1994), with the exception that Lakota children were more likely than their European and American peers to have both a scientific understanding of the concepts or to express cultural or animistic explanations.

Schoon (1992) used an 18 item, multiple-choice questionnaire to investigate the ideas of 1,213 students in both inner-city and suburban schools. Like many other studies focused on alternative conceptions, Schoon found that males were generally less likely to possess alternative conceptions than females, however, black males were more likely to have alternative conceptions than black females. Additionally, inner-city students were more likely to have alternative conceptions than students in the suburbs. Schoon identified many alternative conceptions via his study:
• The Sun is directly overhead at noon.
• Summer is hotter because we are closer to the Sun.
• A full Moon visible from the United States means that Australia is experiencing a different lunar phase.
• Lunar phases are caused by the Earth’s shadow covering all or part of the moon.
• Dinosaurs and cavemen coexisted.

An interesting finding indicated that students with an earth science class were more likely to place cavemen next to dinosaurs!

Bar, Sneider, and Martimbeau (1997) researched the ideas of nearly 50 sixth grade students. These students were asked to share their understandings of gravity on Earth and in space both before and after instruction. Nearly 80% of these students “expressed the idea that gravity must have air to act” before instruction began on a Solar System unit. Lessons were planned with conceptual change in mind. Despite careful attention to children’s thinking, fewer than half of the students had a scientific understanding that gravity needed no medium to “work.” This study reminds us that alternative conceptions are a serious barrier to learning new material and that they are persistent and resistant to change.

Third Grade Students’ Ideas about Lunar Phases published in the Journal of Research in Science Teaching (Stahly, Krockover, & Shepardson, 1999) involved four, third grade students. Alternative conceptions regarding lunar phases were probed via qualitative interviews and observations. Despite the small sample size, several alternative conceptions were revealed:

• Clouds cause the lunar phases.
• Two different places on Earth can experience different lunar phases.
• It is possible to see different phases of the Moon on the same evening.
• There are no patterns to lunar phases; they are caused by unpredictable weather.
Trumper (2001a) investigated 378 Israeli high school students’ alternative conceptions of astronomy concepts via a questionnaire. While fewer of the subjects in Trumper’s study tended to hold alternative conceptions than in research by Lightman and Sadler (1993) or Trumper (2000), several alternative conceptions were evident. Approximately 30% of the subjects identified the Earth orbiting the Sun as the reason for night and day. Nearly 30% believe that the Earth’s shadow causes lunar phases. Alternative conceptions regarding seasons included: the Earth is closer to the Sun during summer, and the Earth’s rotational axis flipping back and forth as the Earth orbits the Sun.

Trumper (2001c) used the questionnaire mentioned above on a sample of 2,087 junior high school through university students. Trumper’s findings support his earlier study and show that students from junior high school up to university continue to hold alternative conceptions on several basic astronomy concepts.

Dove (2002) explored the understandings of 98 12 year old girls attending a selective secondary school in the United Kingdom. Dove analyzed responses to nine questions about astronomical events included in an end-of-year science test. Ninety-one percent of the pupils were able to correctly explain the causes of night and day with three-quarters of them correctly including that the spin occurred around the Earth’s axis. Nearly half correctly identified that observers on Earth only see one side of the moon! It is important to note that these findings are not common in either children’s or preservice teachers’ alternative conception research.

Lunar Concepts identified several alternative conceptions held by students regarding lunar phases. Several of these alternative conceptions appear earlier in the literature: phases of the Moon are caused by the Earth’s shadow on the Moon and clouds get in the way and cover the Moon causing lunar phases. However a couple of the alternative conceptions reported have not appeared in previous literature: the Moon is a star; the Moon has no gravity; it is a burning gas object thousands of miles away; and the Moon is different shapes at different times of the year (Rider, 2002).

Brunsell and Marcks (2007) used a survey to investigate the beliefs of 52 sixth graders, 83 eighth graders, and 47 tenth and eleventh graders. The short survey consisted of three questions covering the phases of the Moon and relative size and scale of the Earth and Moon. Ninety-six percent of sixth graders held alternative conceptions regarding lunar phases with the most popular explanation suggesting the Earth casts shadows on the Moon causing the changing shapes. One-fifth of the six-graders suggested that clouds and weather were responsible for lunar phases. Ten percent expressed a science fragment that different amounts of the Moon were lit by the sun (Note: One-half of the Moon is always lit by the sun.). These findings, although not to the same extent, were mirrored in the responses of both the eighth graders and the tenth and eleventh graders participating in the study.

Earth’s History & Earth’s Systems

Ault (1982 & 1984) investigated children’s understandings of geological time, fossilization, and rock formation. “Children have many unfinished and nonstandard conceptions of how rocks form and change” (p. 90). Some of the alternative conceptions and science fragments Ault shared include:
• Rocks are brought to us from rivers and oceans.
• Rocks are blown out of volcanoes.
• The Earth is one big boulder and rocks break off from it.

Giese (1987) surveyed thirteen gifted eighth grade students, both boys and girls, via a 20 question pretest on water pressure. An alternative conception identified by this study that was mirrored in the literature was the conclusion that pressure related to liquid only pushes downward (instead of all directions) (Engle, Clough, and Driver, 1984). Another alternative conception identified by Giese (1987) included “horizontal pressure at a point on an object is directly proportional to the horizontal distance from that point to the nearest boundary of the water” (p. 146).

Ford (2003) in Sixth Graders’ Conceptions of Rocks and Their Local Environments used a survey to explore students’ ideas of rock formation, rock identification, and Earth’s history. Ford concludes that students rely heavily on everyday experiences and language when creating definitions about rocks. Ford’s assertion that the term “rock” itself poses a problem as it is used interchangeably by both children and college students to describe minerals, rocks, and manmade materials is mirrored in the research (Dove, 1996; Happs, 1982 & 1985). Alternative conceptions identified in this study include: “a rock is a mineral that came from a volcano that erupted” and “a rock is hard matter that is oddly shaped” (p. 375).

Viiri (2004) probed the scientific understandings regarding tide held by approximately 30 eighth grade students. An open-ended questionnaire was used both before and after instruction to assess prior knowledge, alternative conceptions, and any change in understanding. An alternative conception relative to tide exposed by this study was ‘the tide is only a coastal phenomena and the tide is caused by wind’. Science
Climate and Meteorology

Bar (1989) and Bar and Travis (1987) in two studies involving over 300 Israeli children spanning ages five to 15 discovered several alternative conceptions regarding the water cycle and cloud formation via Piagetian style clinical interviews. Bar and Travis discovered that children often rationalize the disappearance of water, say from a puddle after the rain, in a variety of ways. Some of these children’s explanations include: water simply disappears; water evaporates into some unknown or unseen container; and that when water evaporates it is scattered into the air. Common misconceptions regarding cloud formation and weather identified via this study are:

- God sends clouds.
- Clouds collect water from the sea.
- Clouds are vapor from a kettle.
- Sun boils the sea.
- Rain comes from colliding clouds.
- Rain falls when clouds become too heavy.

Similarly, Ben-zvi-Assarf and Orion (2005) explored Israeli junior high students’ understandings of ground water and the water cycle. They employed both quantitative (e.g., Likert scale questionnaires) and qualitative (e.g., open questions, drawings, and interviews) measures. Their study revealed that nearly 70% of these junior high students did not recognize groundwater as part of the water cycle. Of the few students that identified groundwater as part of the water cycle, nearly two-thirds of them viewed groundwater as a static, underground body of water. Results also indicated that these students held alternative conceptions regarding basic physical and chemical processes
associated with the water cycle. Interesting to note was these students’ belief that evaporation was strongly associated with heat temperature.

As evidenced in the review of research investing children’s ideas in earth science, there have been a great deal more studies conducted that probe understanding in astronomy. There are a scant few studies involving Earth’s history, Earth’s systems, and weather. It is important to note that regardless of gender, ethnicity, or geographical location children of all ages possess similar alternative conceptions regarding common earth science concepts. As previous research indicates (Berg & Brouwer, 1991; Schoon, 1992 & 1995) and as the following section will reveal, preservice and inservice teachers share many of the same alternative conceptions as their students.

**Teachers’ Understandings of Earth Science**

**Astronomy and Solar System**

Callison (1993) and Callison and Wright (1993) investigated preservice teachers’ conceptions of Earth, Sun, and Moon relationships. Interviews using models and drawings were used to elucidate participant’s understandings before and after instruction. Two striking alternative conceptions were identified via these studies: 1) the phases of the Moon are a result of the Earth’s shadow falling on the Moon, and 2) the amount of Moon we see depends on how much the shadow covers the moon’s surface.

Atwood and Atwood (1995) used both a paper and pencil instrument followed by interviews using models to ascertain preservice elementary teachers’ ideas of what causes night and day. Of the 50 subjects only 12 (or 24%) provided scientific explanations for both procedures. Alternative conceptions regarding night and day included 1) the Earth
revolves around the Sun in one day, 2) the Sun revolves around the Earth, and 3) tilt of the Earth causes night and day.

Atwood and Atwood (1996), building on their previous study (1995) continued employing both paper and pencil instrument followed by interviews using models to discover preservice teachers’ understandings of the causes of the seasons. Of the 49 preservice teachers investigated, only one provided a scientific concept on the written procedure and one provided a scientific concept during the interviews. It is important to note that these scientific conceptions were provided by the same student. The most common alternative conceptions about the causes of the seasons revealed by this study included 1) distance of the Earth from the sun, 2) direction of the Earth’s tilt ‘flip flops’ as the Earth revolves around the sun, and 3) rotation of the Earth on its axis.

Trumper (2001b) used the same instrument developed for his study of children’s alternative conceptions in astronomy (Trumper, 2001a & 2001c). Four hundred and thirty-three preservice teachers participated in the study. Popular held conceptions included one-third of the participants believing the Earth revolves around the Sun to cause night and day and nearly 10% indicated the Sun revolves around the Earth to cause night and day. With respect to lunar phases nearly one-half of the Israeli preservice teachers (48%) indicated the Earth’s shadow obscured portions of the Moon or the Moon moved into the Earth’s shadow to cause phase changes. Forty-seven percent indicated the Moon did not rotate on its axis over three-fourths of the group failed to correctly identify that the moon always has the same side turned toward Earth. Additionally these teachers identified that the Sun would be directly overhead at noon despite their geographical location north of the Tropic of Cancer.
Trundle, Atwood, and Christopher (2002) focused on the conceptual understandings of lunar phases held by 78 preservice elementary teachers. Understanding was measured via interviews and drawings. Before instruction less than 10% of these preservice teachers held scientific understandings of lunar phases. After instruction, over 80% retained scientific understandings of lunar phases. Instruction on lunar phases occurred over a semester long physics class. These findings were mirrored in a later study (Trundle, Atwood, Christopher, 2003).

Trundle, Atwood and Christopher (2003) investigated the understandings of 52 preservice elementary teachers’ understandings of lunar phases. Based on National Science Education Standards (NSES) (NRC, 1996) standards for K-4 students Trundle asked preservice teachers to describe changes in the lunar phases. More than half of the subjects were unable to accurately represent the lunar phases in their drawings. Instruction designed for conceptual change occurred throughout a semester long course in astronomy. When these subjects were tested again, nearly all of them were able to represent scientific understandings of lunar phases.

Kalkan & Kiroglu (2007) used a 14 item questionnaire called the Astronomy Diagnostic Test (ADT). They modeled this instrument after previous sources: Trumper (2001a, 2001b, & 2001c) and Zeilik, Schau, & Mattern (1998). This instrument was used to assess understanding before and after participating in an astronomy course that reported an attendance rate of 70%. The study indicated that regardless of whether these Turkish preservice or inservice teachers were science majors or non science majors, alternative conceptions in astronomy were both present and persistent. Persistence was measured by low percentage correct combined with a low gain index. Alternative
conceptions identified via this study included: 1) the Sun is directly overhead at noon; 2) the Sun is the center of the universe; 3) relative sizes of and distances between the Sun, Earth, and Moon; 4) confusion regarding rotation and revolution of the Moon, thus impacting the understanding of lunar phases and percentage of the lunar surface we see from Earth; and 5) Earth’s distance from the Sun causes our seasons. The questions with the least overall gain, implying that the participants may still hold alternative conceptions in these areas, included sun’s angle (the sun is directly overhead at noon), causes of lunar phases, and causes of the seasons. Interestingly, science majors were more likely to indicate that the sun would be directly overhead at noon than non science majors both before and after instruction.

Earth’s History and Earth’s Systems

Stofflett (1993) tested 111 preservice elementary teachers using a pencil and paper test about their knowledge of rocks and rock formation. Stofflett (1993) discovered that the “teacher candidates exhibited very limited and low-level understandings” (p. 226) of rocks and rock formation. Seventy-five percent were unable to identify rocks as metamorphic, sedimentary, or igneous. Interestingly, there were no statistical differences between those preservice teachers that had taken geology courses and those who had not taken geology courses.

Ucar, Trundle, & Krissek (2006) used a questionnaire based on science standards to investigate 63 early childhood preservice teachers’ conceptions regarding earth science, specifically rocks and soil. The data indicated that these preservice teachers possess very little content knowledge about properties of rocks and soil. An alternative conception revealed may have its roots in confusion surrounding science vocabulary and
science words appearing in everyday language (e.g., work). These preservice teachers, like students in a similar study (Ault, 1984; Ford, 2003) were unable to differentiate between minerals and rocks. The term stone was used solely to identify manmade materials.

Climate and Meteorology

Lambert (2006) used both qualitative and quantitative measures to assess earth science alternative conceptions held by 105 preservice teachers enrolled in their elementary science methods course. Many students attributed global warming to the hole in the ozone layer as well as distance from the Sun as the cause for Earth’s seasons. An alternative conception regarding pedagogy was also revealed via this study; inquiry learning was identified as simply incorporating hands-on activities into the science curriculum.

General Earth Science

Several studies conducted had a broader scope and covered concepts from across several earth science content areas. The studies that follow include alternative conceptions identified in astronomy, Earth’s history and systems, and climate and weather.

Schoon (1995) created a questionnaire to identify the origin and extent of alternative conceptions in Earth and space science held by 122 preservice elementary teachers. His results indicated that many of the preservice elementary teachers he studied hold many of the same alternative conceptions as students. He divided his findings into primary alternative conceptions and secondary alternative conceptions. Some of the alternative conceptions Schoon identified were summer is caused because the Earth is
closer to the Sun in the summer; lunar phases are caused by the Earth’s shadow; when the United States experiences a full Moon Australia experiences another phase; it takes one day for the Moon to orbit the Earth; if a crystal can scratch glass it must be a diamond; the Moon shines like a star (instead of simply reflecting light from the Sun and Earth); and cold winters can be predicted by thickness of fur and tree bark. In addition to identifying alternative conceptions, Schoon (1995) was interested in ascertaining the origins of alternative conceptions. Preservice teachers attributed their alternative conceptions to several factors: they were “taught it” in school or by a parent, media (TV or movies), logical reasoning, and folklore.

Schoon and Boone (1998) identified several alternative conceptions over the course of a study investigating preservice teachers’ self-efficacy. Ten campuses and 619 preservice teachers in Rhode Island, Pennsylvania, Florida, Kentucky, and Arkansas participated in a survey exploring the relationship between having alternative conceptions and self-efficacy. The findings indicated that preservice teachers with the greatest number correct answers, indicating possession of fewer alternative conceptions, had higher self-efficacy measures. Conversely, lower scoring participants had lower self-efficacy measures. A broad variety of alternative conceptions in earth and physical science were identified:

- Planets can only be seen with a telescope.
- Dinosaurs lived at the same time as cavemen.
- Rusty metal weights less than the iron it came from.
- Electricity is used up in appliances.

Rice (2005) spent 10 years formally and informally polling 414 preservice and 67 in-service teachers alike with a few simple questions she created: 1) Which of the
following is closest to oxygen’s boiling point? 2) Of the following organisms identify all that are animals, and 3) During which season of the year are we in the U.S. closest to the sun? combined with several more questions from the National Science Foundation’s Survey of Public Attitudes toward and Understanding of Science and Technology. Rice’s study identified several alternative conceptions held by preservice and in-service teachers alike. A few alternative conceptions pertaining to Earth science include: humans and dinosaurs co-existed; the Earth orbits the Sun in one day, and the Earth is closer to the Sun during the summer.

Leslie, Dockers, and Wavering (2005 & 2006) identified several possible alternative conceptions during the course of piloting the instrument, Alternative Conceptions in Earth Science – A Questionnaire (ACES-Q). Eighty-two Master of Arts in teaching students pursuing elementary, middle, and secondary certification and 56 elementary education seniors in their methods courses participated in these pilots. The samples were predominantly women and elementary preservice teachers. Alternative conceptions identified included:

- Antarctic is tundra.
- The Earth is closer to the Sun in the summertime in the Northern Hemisphere.
- Inertia causes a bowling ball to fall through the Earth and to keep on going.
- All rivers flow North to South in the Northern Hemisphere.
- The Coriolis Effect impacts a river’s path.
- Diamonds are the only minerals that can scratch glass.
- Igneous and metamorphic rocks are just as likely as sedimentary to contain fossils.

Findings from these pilot studies corroborate the findings from Schoon (1992 & 1995), Trundle (1999), Atwood and Atwood (1995 & 1996) and others.
Much like the research on children’s alternative conceptions in earth science, studies involving teachers and preservice teachers tend to gravitate toward astronomy concepts. Studies that investigate alternative conceptions or content knowledge in the areas of Earth’s history and Earth’s systems are few in number.

Test Construction

As indicated in the section on identifying alternative conceptions, individual student interviews are “a fruitful means for researchers to identify students’ misconceptions in science, this methodology may not be equally useful for teachers” (Haslam & Treagust, 1987; Sadler, 1998). Nevertheless, a teacher needs a starting place for addressing known alternative conceptions as well as possibly revealing unknown alternative conceptions. It stands to reason that “reliable and valid multiple-choice diagnostic tests incorporating students’ reasons as alternative responses would appear to provide a relatively straightforward method” (p. 203). The choice to research and to develop a multiple-choice instrument stemmed from the success of other researchers as well as from the format’s many inherent positive traits. Bouwens (1986) and Atwood (2006) used multiple-choice inventories to explore alternative conceptions in light. Halloun and Hestenes (1985) developed an instrument to evaluate students’ understanding of mechanics. Lightmen and Miller (1989), Sadler (1998), Trumper (2001a & 2001b), and Kalkan and Kiroglu (2007), to name a few, have employed this format to assess misconceptions in astronomy. Schoon (1988) used a multiple-choice survey to investigate an array of earth science topics. Multiple-choice instruments boast a variety of positive attributes. These include:
• Multiple-choice items are versatile (Marrielli, 1995).
• Ease in administration, especially to large groups.
• Ease in scoring and analyzing (Marrielli, 1995; Sadler, 1998).
• They may sample a broader range of topics than essays or interviews. Additionally, they can be developed for nearly any content area (Marrielli, 1995).
• Increased reliability, compared to interviews or essays, via an increase in number of items and restricted response.
• The format is familiar to a broad audience (Marrielli, 1995).
• The instrument developed may take the form of an exam, survey or questionnaire, or inventory (CTL, 1990; Sampson, 2006).

Oftentimes multiple-choice tests are given poor evaluations or said to only evaluate lower cognitive skills like recall of facts. However when test options require the reader to use judgment, critical thinking, and application of concepts learned, these “multiple-choice exams can test many of the same cognitive skills that essay tests do” (¶ 1, Center for Teaching and Learning [CTL], 1990). Multiple choice instruments may vary a great deal from researcher to researcher.

Libarkin and Anderson (2005) relay that most existing instruments utilize a number of common approaches: 1) using a predetermined content focus via expert opinion, texts, or evaluation of standards; 2) designing alternative responses based on experiences in the classroom and existing literature, and 3) choosing similar subjects to pilot the study. These guidelines have their roots in the research put forth by Treagust (1988) and Tamir (1971, 1989, & 1990). These gentlemen offer very specific guidelines for developing an instrument that will be valid, reliable, useful, and objective. Tobin and Capie (1980 & 1981) piloted the Test of Logical Thinking (TOLT). The TOLT consisted of multiple-choice questions paired with a written justification. Later these written justifications were replaced with a second set of multiple-choice distractors resulting in a two-tiered approach to investigating ideas, beliefs, and understanding of participants.
Building on Wandersee’s (1983) required addition of written justifications on the Photosynthesis Concepts Test and Treagust (1986 & 1988), Tamir (1970, 1989, & 1990), and Tobin & Capie’s (1980 & 1981) research into developing multiple-choice justifications Franklin (1992) created a forty item, two-tiered, multiple-choice instrument to identify alternative conceptions in physical science (Misconceptions in Science – A Questionnaire [MIS-Q]). Franklin was successful in developing a valid and reliable instrument to identify the alternative conceptions of both students and preservice teachers.

“Two-tiered tests can be used to help identify what students know instead of what they do not know” (Sampson, 2006, p. 49) as well as to identify alternative conceptions and inform instruction. As with most multiple-choice tests, “there is a higher probability of getting a correct answer in a multiple-choice item by an educated guess,” yet the addition of “a correct justification requires full knowledge” of the topic or concept (Tamir, 1989, p. 286-287). The addition of justifications, whether open-ended or multiple-choice, was found to be a “sensitive and effective means to assessing meaningful learning” (p. 292).

Haslam and Treagust (1987) suggest designing multiple-choice items that are specifically designed to “identify misconceptions and misunderstandings in a limited and clearly defined content area” (p. 203). Treagust (1986 & 1988) suggests ten specific stages divided into three broad areas that will enable researchers to develop their own diagnostic instruments. These are:

I. Defining the content (4 stages)
   A. Identifying propositional knowledge statements
   B. Developing a concept map
   C. Relating propositional knowledge to the concept map
D. Validating the content

II. Obtaining information about student misconceptions (3 stages)
   A. Examining the related literature
   B. Conducting student interviews
   C. Developing multiple choice content with free response

III. Developing a diagnostic test (3 stages)
   A. Developing a two tier diagnostic test
   B. Designing a specification grid
   C. Continuing refinements (Treagust, 1986 & 1988)

In addition to Treagust’s (1986 & 1988) outline above, there is a good amount of research offering suggestions for instrument development at the item-level. Items must be worded so they do not reward test wise students nor penalize student whose skills are not as developed (CTL, 1990). Special attention should be given to ensure that students are not rewarded for guessing by using carefully worded distractors. These distractors should be similar in length and special jargon should be avoided. Marrielli (1995) suggests using common misconceptions as plausible distractors. Piloting of the items combined with item analyses are strongly recommended to refine the instrument (Marrielli, 1995; Sampson, 2006; Treagust 1986 & 1988).

Summary

Alternative conception research involving earth science is dramatically less than in other areas of science (Pfundt & Duit, 2004; Trundle, 1999). There a dearth of studies involving areas of earth science outside of astronomy and the solar system. Despite this, findings from these studies have informed science educators and teachers about alternative conceptions in earth science. Additionally, this body of research has informed and guided this study and the instrument used.
The review of the literature revealed lacunae in the research conducted on alternative conceptions in earth science in three areas. First, there are scant few research articles covering alternative conceptions in earth science and even fewer involving areas outside of astronomy. Second, while there were several studies involving interviews and paper and pencil instruments, usually multiple-choice questionnaires, very few of them included alternative conceptions regarding Earth’s history and systems or climate and weather. Third, research indicates that two-tiered, multiple-choice, instruments can be a valid and reliable avenue for identifying alternative conceptions. Instruments in this format have appeared in biology (Treagust, 1988) and physical sciences (Franklin, 1992), but remain virtually unexplored in the realm of earth science. This study was designed to address these current needs by developing and validating a two-tiered, multiple-choice instrument to identify alternative conceptions in earth science.
Chapter 3:
Methodology

The purpose of this study was to find evidence of reliability and validity for a two-tiered, multiple-choice instrument designed to identify alternative conceptions in earth science. Additionally, this study sought to identify possible alternative conceptions in earth science held by preservice teachers, to investigate the relationships between self-reported confidence scores and understanding of earth science concepts, and to describe the relationship between content knowledge and alternative conceptions and planning instruction in the science classroom.

This chapter provides a description of the methods that were used to conduct this study including: the process of instrument development, subject selection, and design procedures for the completion of the study. After a review of the literature (Doran, 1972; Franklin, 1992; Haslam & Treagust, 1987; Tamir, 1971 & 1990; Wandersee, 1983), the decision to create a multiple-choice, pencil and paper instrument was made due to its ease of administration and scoring, as well as ease in the establishment of reliability and validity. Tamir (1990) suggested several justifications for using multiple-choice instruments to identify alternative conceptions. Some of these included: they are easier in scoring, they do not penalize poor writers, they are objective in terms of scoring and are therefore more reliable, and they can be used to measure different levels of learning (Tamir, 1971, 1972, 1989, & 1990).

Items for the different forms of the Alternative Conceptions in Earth Science – A Questionnaire (ACES-Q) (Leslie, Dockers, & Wavering, 2005), Alternative Conceptions
in Earth Science – A Questionnaire II (ACES-Q II) (Leslie, Dockers, & Wavering, 2006),
and the Alternative Conceptions in Earth Science – A Questionnaire II-Revised (ACES-Q
II-R) (Leslie & Wavering, 2009) were derived from Arkansas State Frameworks
(Arkansas Department of Education [ADE], 2005) and National Science Education
Standards (NSES) (National Research Council [NRC], 1996). The review of literature
allowed for the creation of distractors based on alternative conceptions held by teachers
and students alike. The various forms of the ACES-Q were administered to 225
preservice teachers at all certification levels enrolled in classes at the University of
Arkansas, Fayetteville.

**Pilot Test – ACES-Q**

**Administration of the First Instrument**

The ACES-Q II-R was developed to discover if a paper and pencil based
instrument could serve to detect possible alternative conceptions in earth science. The
questionnaire was piloted twice (Alternative Conceptions in Earth Science- A
Questionnaire & Alternative Conceptions in Earth Science- A Questionnaire II). The
purpose of piloting these instruments was to lend insight into the validity and reliability
of the two-tiered, multiple-choice format chosen for this study.

**Instrument Development**

Based on Franklin’s (1992) Misconceptions Identification in Science
Questionnaire (MISQ), a two-tiered, multiple-choice test to assess alternative conceptions
in physical science, a ten question instrument (See Appendix A for a copy of the ACES-
Q) was created to determine preservice teachers’ knowledge, understanding, and

39
confidence in specific earth science topics (Leslie, Dockers & Wavering, 2005). These topics were based on content standards delineated by NSES (NRC, 1996) as well as the Arkansas Science Frameworks (ADE, 2005). The term questionnaire was used instead of test to remove the stigma of testing for grades.

Multiple testing formats were combined to create several two-tiered questions for the first instrument. Treagust (1986 & 1988), Haslam & Treagust (1987), Tamir’s (1989 & 1990), and Franklin’s (1992) success with multiple-choice formats and Osborne and Freyberg’s (1985) Interview About Instances approach to identifying alternative conceptions in science were incorporated to create the ACES-Q. Each question consisted of a diagram and written description of the situation or event, a question related to the event, a list of possible answers to the question, a list of possible reasons or justifications for the chosen answer, and two five point Likert scales to assess whether or not the concept made sense and how confident the participant was about his or her answers (See Diagram 3.1 for an example). The ACES-Q (Leslie, Dockers, & Wavering, 2005) concluded with an opened ended question requesting the participants to share how they would teach solar eclipses for the grade level of their choice. A series of demographic questions was also included.
Sample Question:
Miss Boka pours herself a glass of water. She asks her third graders what would happen to the ice if she added it to the glass. Her students give several different answers, which one is correct?

Answers:
1) The ice will float, raising the water level.
2) The ice will sink, lowering the water level.
3) The ice will float, lowering the water level.
4) The ice will hover in the middle of the drink and there will be no water level change.

Reasons:
A) The temperature of the ice is significantly less than the water it is in. This difference in temperature affects the position of the ice in the drink.
B) Ice has air pockets locked inside causing it to weigh less than the water.
C) The crystalline structure of the ice causes it to be less dense than the water.
D) The surface area of the ice causes it to suspend itself in the water.

Subjects
The sample of convenience for this pilot study included 82 Master of Art in Teaching (M.A.T.) interns at the University of Arkansas, Fayetteville. These participants completed their college content courses and their Bachelor's degrees and were currently serving a year of preservice teaching while taking their Master's level course work. These M.A.T. interns came from a variety of undergraduate degree backgrounds and were pursuing a variety of certification levels. Table 3.1 (Leslie, Dockers, & Wavering, 2005) delineates these. Because of these preservice teachers' wide spread undergraduate degree programs, there was a large range in the number of science classes the participants had taken. Fifty percent of the students had taken at least one earth science course and 34% of the students had taken two earth science courses. Eighty-four percent of these participants
were women and 16% were men. Their ages ranged from 21 to 55 years old with a mean age of 26 years (Leslie, Dockers, & Wavering, 2005).

Table 3.1  
*M.A.T. intern degrees and certification levels*

<table>
<thead>
<tr>
<th>Undergraduate Degree</th>
<th>Percentage of Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elementary Education</td>
<td>50.0%</td>
</tr>
<tr>
<td>Natural Sciences (Biology, Physics, Chemistry)</td>
<td>3.7%</td>
</tr>
<tr>
<td>Social Sciences (Political Science, History)</td>
<td>14.4%</td>
</tr>
<tr>
<td>Speech/ Drama/Language/English</td>
<td>16.1%</td>
</tr>
<tr>
<td>Mathematics</td>
<td>3.7%</td>
</tr>
<tr>
<td>Middle School</td>
<td>11.1%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Certification Levels Interns are Pursuing</th>
<th>Percentage of Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elementary School</td>
<td>50%</td>
</tr>
<tr>
<td>Middle Level</td>
<td>11%</td>
</tr>
<tr>
<td>High School</td>
<td>39%</td>
</tr>
</tbody>
</table>

*n=87*

**Procedure**

During the fall semester of 2004, participants were identified via enrollment in their M.A.T. fall courses. The researcher met with each level of M.A.T. interns to inform them of the assessment and to gain their consent to participate.

Data were gathered and then examined with several factors in mind (gender, age, certification level, undergraduate degree, college science courses taken, and earth science courses). The focus was on analyzing similarities and differences of test scores across these subgroups.

**Results**

The ten item questionnaire was designed to assess content knowledge of particular concepts in earth science as well as to determine if such a format would allow for the identification of alternative conceptions of those individuals taking the questionnaire.
Results of the ACES-Q were inconclusive. Despite the multiple-choice format, responses from participants appeared to be confusing. On several occasions, participants chose the incorrect answer, yet provided the scientific reason for the phenomenon in question indicating they most likely made a guess. However, it was determined that the format of the questionnaire, including the component containing the two Likert scales for confidence and understanding provided a depth of knowledge into areas where possible alternative conceptions might exist. Individual instrument items were analyzed to discover their ability to discriminate between participants who scored well and those who did not. These item analyses as well as experts’ comments made while establishing face validity were used to modify the questions, answers, and reasons to discourage guessing.

The following items from the ACES-Q were removed: the sample question, Question 2, and Question 4 (See Appendix A for a copy of the ACES-Q.). The sample question was omitted due to the obvious nature of the question and its lack of sophistication. Question 2 was removed due to its low discrimination indices. Question 4 was removed because both the experts and researchers believed it to be more of a chemistry question than an earth science question. Question 4 was later used as the sample questions for both the ACES-Q II and the ACES-Q II-R. Questions 1, 3, 5, 6, 7, 8, 9, and 10 were retained for inclusion on the second version of the instrument.

Question 3, (Where would a bowling ball land if dropped through a hole that went all the way through the Earth?), was changed the most before being included on the next instrument. First the graphic was altered to illustrate four different possible answers. These illustrations were used as possible answers instead of the original written descriptions. These illustrations more closely matched those found in the literature.
(Nussbaum & Novak, 1976). Reasons were altered slightly to conform to the new format of the illustrated answer choices. The remaining items in questions received only formatting or grammatical changes before being included on the second instrument.

ACES-Q II – The Second Study

Administration of the Second Instrument

Instrument Development

The second instrument (ACES-Q II) consisted of 20 questions (Leslie, Dockers, & Wavering, 2006). Three of the original questions were omitted because they were naïve or they did not stand up to the rigors of item analysis. Question 2 from the ACES-Q was omitted on the second instrument. Question 4 from the ACES-Q became the new sample question for the ACES-Q II. Questions 1, 3, 5, 6, 7, 8, 9, and 10 were reorganized and rewritten for inclusion on the ACES-Q II (See Appendix B for a copy of the ACES-Q II.). These questions, retained for the second instrument as well as new questions, were focused under four areas of earth science:

1) solar system, objects and changes in the Earth and sky;
2) Earth’s history, structure and surface of Earth;
3) Earth’s systems, rock and water cycles; and
4) climate, weather, and atmosphere (Leslie, Dockers, & Wavering, 2006).

These four broad topics of earth science were chosen because they closely represent the subcategories listed on both the Arkansas State Frameworks (ADE, 2005) and the NSES (NRC, 1996). By ensuring that the instrument closely follows these four areas the instrument’s content validity was improved.
A more extensive review of the literature was used to refine distractors from the original instrument. Additional questionnaire items were also selected from those used by other researchers, as reported in the literature (e.g. Educational Testing Services’ Earth and Space Sciences: Content Knowledge, The Praxis Series (ETS, 2005) and Libarkin et al.’s Geoscience Concept Inventory (2002)), then modified to fit the two-tiered format described earlier. Like the ACES-Q, the ACES-Q II ended with the open ended question asking participants how they would teach about the solar eclipse as well as several demographic questions to aid in data analysis.

Subjects

Another sample of convenience was used for the administration of the ACES-Q II. The second instrument was administered to 56 preservice elementary teachers enrolled in their senior block courses at the University of Arkansas. These students had completed their science coursework and were scheduled to take their methods courses in the spring of 2006. They were a semester away from graduation. Their ages ranged from 20 years old to 40 years old with the average being approximately 23 years old. Fifty of the participants were female, five were male, and one chose not to answer (Leslie, Dockers, & Wavering, 2006).

Procedure

During the fall semester of 2005, participants were identified via enrollment in their senior block courses. Three cohorts were chosen to participate in this study. The researchers met with each group to inform them of the questionnaire and to gain their consent to participate.
Data were gathered and then examined with several factors in mind (gender, age, college science courses taken, and Earth science courses taken). The researchers focused on analyzing the similarities and differences of test scores across these subgroups (Leslie, Dockers, & Wavering, 2006).

**Results**

Several alternative conceptions revealed via this study (Leslie, Dockers, & Wavering, 2006) matched those found in the literature (e.g. Atwood & Atwood, 1995 & 1996; Trundle, 1999). These results indicated that the two-tiered, multiple-choice format with the Likert component to measure confidence and understanding did enable the identification of possible alternative conceptions. After analyzing the results it was decided to continue with the format, however to reorganize questions into four earth science subcategories (solar system, Earth’s history, Earth’s systems, and climate). Additionally, Question 13 (bowling ball through Earth’s center) was again revised. Item analysis indicated that one of the illustrations was not chosen as a reason making it a poor distractor. An alternate illustration for a fourth answer choice was submitted. These changes were made and a new questionnaire (ACES Q II-R) was created.

**Administration of the Second Instrument**

**ACES-Q II-R**

**Instrument Reconstruction**

The ACES-Q II-R consisted of the same 20 questions from the ACES-Q II. However, after close inspection of the distractors via item analysis several questions and distractors were reworded and reorganized. Distractors that were consistently not chosen
were omitted completely. Questions were also organized according to the four subcategories for the ACES-Q II (solar system, Earth's history, Earth's systems, and climate and weather). The two five point Likert scales were retained as they lend depth to the multiple-choice format, allowing participants to rate how sure they are of their answers and whether or not the concept makes sense. Like the first two instruments the ACES-Q II-R ended with an open ended question asking participants to share how they would teach about a solar eclipse as well as several demographic questions to aid in data analysis. Please see Appendix C for a complete copy of the ACES-Q II-R.

Subjects

The ACES-Q II-R was administered to 87 preservice teachers enrolled in their Master's of Art in Teaching (M.A.T.) degree. These participants were chosen because they had completed their college content courses and their Bachelor's degrees and they were currently serving a year of preservice teaching while taking their master's level course work. These M.A.T. interns came from a variety of undergraduate degrees (e.g. elementary education, middle level education, literature, chemistry, mathematics, etc.) and were pursuing a variety of certification levels (elementary, middle level, and secondary).

Procedure

During the spring semester of 2008, participants were identified via enrollment in their M.A.T. courses. The researcher met with each level of M.A.T. interns to inform them of the assessment and to gain their consent (Appendix D) to participate.

Due to time and to travel constraints a stratified random sample of eleven students was identified for interviews with the researcher. These subjects were chosen based on
their ACES-Q II-R scores. Items on the ACES-Q II-R were scored according to the correct answer and the correct reason. An item with a correct answer and a correct reason earned a point value of one. An item with any combination of an incorrect answer or an incorrect reason earned a point value of zero. Three participants were randomly chosen from the lowest quartile (Q1), five participants were randomly chosen from the two middle range quartiles (Q2 and Q3), and three participants were randomly chosen from the highest quartile (Q4) to participate in interviews (For a discussion of the descriptive statistics please see Chapter 4.). Comparing these student interviews with their actual scores on the ACES-Q II-R provided the researcher rich data regarding alternative conceptions as well as avenue for measuring response validity.

Participants in the interviews were shown each item on the ACES-Q II-R without the reason section. The questions or statements were read silently by the participants. Students then chose an answer and the researcher prompted participants to offer an explanation for their choices. Additional questions were posed in an attempt to elucidate participant explanations using Osborne and Freyburg’s (1985) interview about instances approach. Interviews were recorded on audiotape and then transcribed (See Appendix E for sample transcriptions.).

Quantitative Data

Data were gathered and examined with several factors in mind (gender, certification level, and number of college science courses taken). The focus was on analyzing similarities and differences of tests scores across these subgroups as well as providing descriptive statistics for identification of alternative conceptions. Correlations
using the sense and confidence data gathered via the two, five point Likert scales were calculated as well.

Student interviews were analyzed by the researcher. The responses given during interviews were compared to those on the pen and paper instrument. Following Franklin (1992) an Agreement Rate (AR) was determined using the two sets of responses (pen and paper instrument and interview about instances) to determine the existence of any differences between the two methods. If reasons for the interviewee’s answers matched those s/he chose on the paper instrument the question received an Agreement Rate (AR) of one. If their answers did not match, the question received an AR of zero. By calculating this agreement rate, the researcher was able to ascertain the kind of relationship that existed between the answers subjects provided on instrument and those they provided in the interview.

**Qualitative Data**

Question 21 on the ACES-Q II-R was designed to allow participants to share their thoughts regarding teaching and content. The question asked participants how they would teach about a solar eclipse to the grade level of their choice. Responses to question 21 were coded and investigated according to content and pedagogy.

Additionally, if participants did not find the answer or reasons choices provided for each of the 20 items acceptable, they were welcome to write in their own answers. These write-in responses were analyzed for possible alternative conceptions or science fragments.
Interviews were conducted with the intent of calculating an Agreement Rate (AR) and to elicit alternative conceptions that may not have been present in the literature and therefore may not have been listed as a distractor for the reason section of the instrument. Transcriptions of these interviews were analyzed for salient themes, scientific fragments, and possible alternative conceptions (See Appendix E for a sample transcription of the interviews.)

Validity

Validity is the degree to which a test measures what it is supposed to measure (Gay, 1992) and there are several ways to ensure the validity of an instrument. Face validity refers to the extent to which a test appears to measure what it says it measures (Gay, 1992). While face validity may not be a statistically sound way to estimate validity, it can be used to initially screen instruments. Face validity was determined by subjecting the ACES-Q II-R to the scrutiny of ten professionals in the field of science education. Science teachers and science teacher educators were solicited for interest in participation via email or telephone conversations.

Content validity was further determined by identifying each of the NSES earth science content standards (NRC, 1996) and the Arkansas State Frameworks (ADE, 2005) that each of the 20 questions addressed. Additionally, bibliographic information regarding specific alternative conceptions associated with each question has been provided. See Appendix G for the complete table of specifications. Item validity and sampling validity (Gay, 1992) were both ensured and are evidenced via this table of specifications.
Additionally content validity was evaluated by the same set of content experts recruited to establish face validity. Experts included (but were not limited to) Lynne Hehr, M.S., Dr. Caroline Beller, Dr. Ruth Burkett, Dr. Richard Frazier, and Dr. Sally Zellers. Lynne Hehr, M.S., is the Director for the Center for Mathematics and Science Educators at the University of Arkansas. Her interests lie in earth sciences with an emphasis in soil sciences. Dr. Caroline Beller is Assistant Professor of Science Education at Oklahoma State University’s School of Teaching and Curriculum Leadership. Dr. Ruth Burkett and Dr. Richard Frazier are professors of science education at the University of Central Missouri in Warrensburg, Missouri. Dr. Sally Zellers is a professor of earth science at the University of Central Missouri in Warrensburg, Missouri. These experts were asked to rate individual questions on the ACES-Q II-R based on their congruence (Hambleton, 1978; Rovinelli & Hambleton, 1977) with the four topics in Earth science. They were also asked to indicate expected grade levels of the individual items as well as whether or not preservice teachers may hold alternative conceptions in the areas covered on the ACES-Q II-R. These ratings were conducted via the U.S. mail.

An index of item-objective congruence (IIOC) (Hambleton, 1978; Rovinelli & Hambleton, 1977; Turner & Carlson, 2003) given to these ten experts who evaluated each item’s alignment with one of the four identified and operationally defined areas of earth science (See Appendix G for a copy of the IIOC survey.). For this study, earth science was defined as any of several of the geologic sciences that are concerned with the origin, structure, and physical phenomena of the Earth, including the Earth as a body in space. For the purpose of this study the researcher divided the topic of earth science into four
distinct constructs. Each item on the ACES-Q II-R consisted of at least one aspect of the four areas of earth science. Operational definitions for each of these constructs are listed below:

- **Solar System**: the area of earth science directly concerned with the Earth as a member of the solar system, Earth’s place in space, and relationships with other bodies in space.
- **Earth’s History**: the area of earth science that focuses on the origin of the Earth, how rocks provide a history the Earth, and palaeontology.
- **Earth’s Systems**: an area of earth science directly concerned with water cycle, rock cycle, the atmosphere and the hydrosphere.
- **Climate**: the area of earth science that focuses on the study of weather, weather over time, or climate, and the impact these have on Earth.

The experts were then asked to rate how well each item was a measure of each particular Earth science construct using the following rating system:

1: An item is a clear measure of the construct, according to the operational definition.

0: An item is an unclear measure of the construct, according to the operational definition. The item may be somewhat related to the construct or a slight measure of the construct, but is not a clear or clean measure of the construct.

-1: An item is clearly not a measure of the construct, according to the operational definition. (Turner & Carlson, 2003)

The combined ratings of the experts for each item are the indices of item objective congruence. The range of possible scores for each item is -1 to +1. An index is calculated by finding the mean of the experts’ scores. An index of .75 indicates that three quarters of the experts agreed that an item is a clear measure of the defined construct (Hambleton, 1978; Rovinelli & Hambleton, 1977; Turner & Carlson, 2003). Indices acquired from analyzing the responses to the IIOC were used to explore each of the 20
items and whether or not the experts felt they measured a particular content area according to the four operational definitions of the earth science categories represented on the instrument.

Reliability

Test reliability is the degree to which a test consistently measures whatever it measures (Gay, 1992). Gay suggests several ways to ensure test reliability. Rational equivalence reliability estimates internal consistency by determining how all of the times on a test relate to all other items on the test. This can be calculated via the Kuder-Richardson 20 (KR20) formula. Cronbach’s alpha, a coefficient of reliability or consistency (Gay, 1992) can be used as an indicator of reliability. Another way to ensure reliability is to conduct a “split-half procedure” (Gay, 1992). By administering the instrument to a single group, dividing the scores in half, and correlating the scores, the researcher can measure the split-half reliability of an instrument. These indicators were calculated for both the entire instrument as well as for each of the subtests. Gay (1992) also suggests using the standard error of measurement to express the validity of an instrument.

Summary

A major component of this study was to develop a reliable and valid, pencil and paper instrument to identify alternative conceptions in earth science among preservice teachers. This task was accomplished by piloting the instrument and revising the instrument based on findings from the pilot studies (See timeline below in Table 3.2). The questionnaire was relatively short, containing only 20 multiple-choice questions and one open response question, and is easy to administer. These characteristics make the
ACES-Q II-R a useful tool for the exploration of alternative conceptions in earth science.

Test items were developed based on research and on personal experiences of the researcher. The questionnaire, in its various forms, was administered to 225 preservice teachers at the University of Arkansas.

Table 3.2
Research Timeline

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>December 2004</td>
<td>Pilot ACES-Q</td>
</tr>
<tr>
<td>January &amp; February 2005</td>
<td>Data Analysis &amp; Instrument Revision</td>
</tr>
<tr>
<td>December 2005</td>
<td>Pilot ACES-Q II</td>
</tr>
<tr>
<td>January &amp; February 2006</td>
<td>Data Analysis &amp; Instrument Revision</td>
</tr>
<tr>
<td>November 2007</td>
<td>Gain IRB Approval</td>
</tr>
<tr>
<td>January &amp; February 2008</td>
<td>Administer ACES-Q IIR</td>
</tr>
<tr>
<td>February 2008</td>
<td>Conduct Interviews</td>
</tr>
<tr>
<td>June 2008</td>
<td>Analyses of Data</td>
</tr>
<tr>
<td>July and August 2008</td>
<td>Transcription of Interviews</td>
</tr>
<tr>
<td>June 2009</td>
<td>Analysis of Interview Data</td>
</tr>
<tr>
<td>July 17, 2010</td>
<td>Dissertation to Committee Chair</td>
</tr>
<tr>
<td>July 27, 2010</td>
<td>Dissertation to Committee</td>
</tr>
<tr>
<td>August 6, 2010</td>
<td>Defend Dissertation</td>
</tr>
</tbody>
</table>
Chapter 4:

Results

The purpose of this study was to find evidence of reliability and validity for the Alternative Conceptions in Earth Science – A Questionnaire II Revised (ACES-Q II-R), an instrument designed to identify alternative conceptions in earth science based on K-12 science standards for Arkansas and the nation. The study also included identifying possible alternative conceptions held by preservice teachers regarding space science, Earth’s systems, Earth’s history, and climate and weather. Additionally, preservice teachers’ confidence levels and understanding of earth science concepts were investigated as well as discovering if having alternative conceptions impacts preservice teachers’ pedagogical choices.

This chapter describes data collected with the questionnaire, ACES-Q II-R, data collected via student interviews, as well as a survey of experts. The instrument was analyzed to determine its reliability and validity. Statistical means, frequencies, discrimination indices, and reliability measures, including the standard error, for the instrument were calculated. In addition, a survey to establish item objective congruence was analyzed. This survey also requested experts to share appropriate grade levels of each question on the ACES-Q II-R and to indicate whether or not they believed preservice teachers held alternative conceptions regarding each of the concepts covered. Alternate responses on the ACES-Q II-R and responses to the open-ended question, # 21, were coded for salient themes. Additionally, student interviews were used to establish response validity; these interviews were transcribed and coded for themes as well.
Validity

The simplest definition of validity is an instrument’s or test’s ability to measure what it is supposed to measure (Gay, 1992). It is important to remember that validity can be evaluated only in “terms of purpose” (p. 155). The purpose of the ACES-Q II-R is to easily identify alternative conceptions in earth science held by preservice teachers. Validity of the ACES-Q II-R was evaluated based on the following measures: content validity, item validity, sampling validity, face validity, and response validity.

Content validity is the “degree to which a test measures an intended content area” (Gay, 1992, p. 156). Item and sampling validity are both necessary components for ensuring content validity. Item validity is concerned with whether the instrument’s items “represent measurement” (p. 156) in the content area being considered. Sampling validity focuses on how well the instrument samples the total content area. Every effort was employed to ensure the validity of the ACES-Q II-R.

Face validity, often considered a sub form of content validity was determined by asking ten professionals in the field of science education (public school teachers, science professors, and science educators) to determine their perceptions of the instrument items. These experts agreed that the ACES-Q II-R measures content knowledge in the following areas of earth science: solar system, Earth’s systems, Earth’s history, and climate and weather.

Sampling validity, a component of content validity, was determined by identifying each of the earth science content standards based on the National Science Education Standards (NSES) (National Research Council [NRC], 1996) and Arkansas
Table 4.1

<table>
<thead>
<tr>
<th>Questions 1-2 (of 6), Solar System, objects and changes in the Earth and Sky</th>
<th>Arkansas Frameworks</th>
<th>NSES</th>
<th>Research in Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
<td>Desmond measures his shadow at noon for several months. He notices that as the year progresses his shadow lengthens and then shortens. Desmond realizes that he might be able to correlate the season based on the length of his shadow. What season is it in Figure B?</td>
<td>Strand 4 Standard 10 ESS.10.3.2 Demonstrate the orbit of Earth and its moon around the sun ESS.10.3.3 Relate the Earth’s rotation to the day/night cycle</td>
<td>Content Standard D K-4 Objects in the sky have patterns of movement K-4 Sun, moon, stars... all have movements that can be described 5-8 Most objects in the solar system are in regular and predictable motion.</td>
</tr>
<tr>
<td><strong>2</strong></td>
<td>Ursula, Desmond’s sister, decides to measure her shadow every two hours for one day. At what point or points is Ursula’s shadow the longest?</td>
<td>Strand 4 Standard 10 ESS.10.3.3 Relate the Earth’s rotation to the day/night cycle ESS.10.7.1 Identify and model the causes of night and day</td>
<td>Content Standard D K-4 Objects in the sky have patterns of movement K-4 Sun, moon, stars... all have movements that can be described 5-8 Most objects in the solar system are in regular and predictable motion.</td>
</tr>
</tbody>
</table>
Additionally, item validity, another component of content validity, was measured by subjecting each of the questions to the scrutiny of 10 experts. Experts evaluated each of the questions via an index of item-objective congruence (IIOC) (Hambleton, 1978; Rovinelli & Hambleton, 1977; Turner & Carlson, 2003). This involved reading each item on the ACES-Q II-R and evaluating to what degree the item measured a specific construct or sub content area of earth science (For a description on how these indices were calculated please see page 51 in Chapter 3.). See table 4.2 below for the results of the IIOC.

Table 4.2
Results of Index of Item-Objective Congruence for the ACES-Q II-R

<table>
<thead>
<tr>
<th>Item</th>
<th>Solar System</th>
<th>Earth's History</th>
<th>Earth's Systems</th>
<th>Climate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.6</td>
<td>-1</td>
<td>-.6</td>
<td>-.6</td>
</tr>
<tr>
<td>2</td>
<td>.6</td>
<td>-1</td>
<td>-.7</td>
<td>-.8</td>
</tr>
<tr>
<td>3</td>
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<td>-.8</td>
<td>-1</td>
</tr>
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<td>4</td>
<td>.8</td>
<td>-1</td>
<td>-.7</td>
<td>-.9</td>
</tr>
<tr>
<td>5</td>
<td>.5</td>
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<tr>
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<td>-1</td>
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<td>-1</td>
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<td>17</td>
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<td>-.9</td>
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<td>-.7</td>
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</tr>
<tr>
<td>20</td>
<td>-.6</td>
<td>-.9</td>
<td>.1</td>
<td>.9</td>
</tr>
</tbody>
</table>

The results of the IIOC were used to confirm an item's association with a particular subcategory. If experts unanimously believed that an item measured a particular content area in earth science, the index for the item would be +1. Therefore
with ten expert judges, a score of .80 can be interpreted that eight of the ten judges felt that item was representative of a particular subcategory. Conversely, if an item’s index was -1, judges unanimously indicated that the item in question was not representative of said construct. Items with indices close to 0 indicate that the experts did not consider the question to be a clear measure of the earth science subcategory indicated (Turner & Carlson, 2003).

“There are no statistical tests for assessing significance of the measure” (Turner & Carlson, 2003, p. 166) therefore a substantive procedure is advised for determining criterion levels. Turner and Carlson suggest an index value of .75, suggesting that with a group of four expert judges, three of the four agreed that the item measured what it was intended to measure. For the purpose of this research endeavor, an index of .6, indicating six of the ten experts agreed to an item’s intended measure, was preferred. Table 4.3 shares the author’s expectations regarding the delineation of each item on the ACES-Q II-R as well as those indicated by the expert judges via the IIOC.

Table 4.3

<table>
<thead>
<tr>
<th>Content Area</th>
<th>Question Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar System/Astronomy</td>
<td>1, 2, 3, 4, 5, 6</td>
</tr>
<tr>
<td>Author</td>
<td>1, 2, 3, 4</td>
</tr>
<tr>
<td>Experts</td>
<td></td>
</tr>
<tr>
<td>Earth’s History</td>
<td>11,12, 13, 14</td>
</tr>
<tr>
<td>Author</td>
<td>9, 14</td>
</tr>
<tr>
<td>Experts</td>
<td></td>
</tr>
<tr>
<td>Earth’s Systems</td>
<td>7, 8, 9, 10,</td>
</tr>
<tr>
<td>Author</td>
<td>7, 10, 11, 12, 16</td>
</tr>
<tr>
<td>Experts</td>
<td></td>
</tr>
<tr>
<td>Climate/Weather</td>
<td>15, 16, 17, 18, 19, 20</td>
</tr>
<tr>
<td>Author</td>
<td>15, 18, 19, 20</td>
</tr>
<tr>
<td>Experts</td>
<td></td>
</tr>
</tbody>
</table>

*Experts indicated that Items 5, 6, 8, 9, 13, & 17 were not clear measures of any of the four subcategories of earth science on the ACES-Q II-R
For the most part, ratings from the judges served to reinforce the author’s classification of items with respect to the four constructs, or subcategories of earth science. However, there were six questions that the experts indicated uncertainty toward.

Question 5 asked participants to indicate the season the Northern Hemisphere was experiencing based on the relational positions of the sun and the Earth. According to the IIOC indices for each of the categories (.5, -.9, -.6, and -.3 respectively, please see Table 4.2 above) Question 5 was not a clear measure of any of the four subcategories of earth science. A closer look at the individual expert’s scores reveals a different story. Seven of the ten experts indicated that Question 5 was clearly an astronomy question. One indicated the question was not a clear measure of this construct, and two indicated that it was definitely not an astronomy question with a score of -1. This closer look at the experts’ data coupled with a thorough literature review of the item in question (Please see Appendix F for the complete Table of Specifications.) reassured the researcher that Question 5 is indeed a measure of astronomy and space science.

Question 6 asked participants to indicate where a bowling ball might come to rest if dropped through a hole that bisected the Earth. The purpose of this item was to discover a participant’s understanding of Earth’s gravity as well as Earth’s place in space. As indicated by the low indices (See Table 4.2.), expert judges felt this question was not quite a clear measure of any of the four constructs defined. Closer inspection revealed that four of the ten indicated that Item 6 was indeed a measure of the subcategory astronomy. Three of the ten indicated that it was neither a clear or unclear measure. And three of the ten indicated that it was definitely not an astronomy question. The researcher maintains that this concept is indeed an astronomy question and cites 13 studies spanning
over 30 years (e.g. Baxter, 1989; Nussbaum & Novak, 1976; Trembath, 1984). Please see Appendix F for the table of specifications.

There were some difficulties on the part of the experts to identify and delineate items in the Earth's history and Earth's systems subcategories. These difficulties were evidenced in the ratings that were inconsistent. This may be in part due to multidimensional nature of both of these subcategories, poor operational definitions, or confusion in completing the IIOC survey. Experts indicated that while Questions 8 and 13 were clearly not measures of meteorology or climate neither were they clear measures of astronomy or Earth's history or systems. Three experts rated Question 8 (item topic-minerals) as a clear measure of Earth's History; two rated it as an unclear measure (with a score of zero); and five clearly indicated that it was not a measure of Earth's history (-1) giving it an IIOC index of .2 for Earth's history. Additionally four experts rated this same question (#8) as a clear measure of Earth's systems; four rated it as an unclear measure; and two indicated that this question was clearly not a measure of this earth's science category. Similarly Question 13 (item topic- a river's path) earned IIOC indices that indicated it was not a clear measure of Earth's systems. Closer inspection of the individual expert's ratings reveals that seven experts scored this question as a clear measure of Earth's systems (+1); one rated this questions an unclear measure of this subcategory; and two indicated this questions was not a clear measure (-1). While the research regarding alternative conceptions of Earth's systems and Earth's history is not as abundant as astronomy, several studies have been cited (Please see Appendix F for the table of specifications.) to support the researcher's interpretations that Question 8 is an Earth systems item and Question 13 is an Earth's history item.
The literature review (See Appendix F for the table of specifications) indicated that Question 9 (item topic: rock cycle/rock type) is indeed an Earth’s systems item. However the presence of fossils in the sample in question may have led the experts to rate this item as a measure of the Earth’s history subcategory (IIOC index .7). Before administering the next version of the instrument, the researcher suggests combining the eight questions from both Earth’s history and systems categories into a single construct and analyzing the data from these subsets as one.

There was no consensus between experts regarding Question 17 (item topic-atmospheric pressure). Closer inspection of the individual ratings indicated that experts agreed that this item was not a clear measure of astronomy, Earth’s history, or climate and meteorology. And an IIOC index of .1 for the Earth’s systems subcategory indicated that there was not an agreement among the experts regarding this construct. Four experts rated this item as a clear measure of the construct; three indicated it was not a clear measure, and three indicated it was definitely not a measure of the Earth’s systems subcategory. The definition given for the Earth’s systems category indicated “an area of earth science directly concerned with the water cycle, rock cycle, the atmosphere and the hydrosphere.” (Please see Appendix G for the IIOC survey and the operational definitions of each of the four subcategories of earth science). Additionally, Giese (1987) clearly indicated that this was an Earth’s systems measure.

In addition to rating the instrument items according to index of item-objective congruence, experts were asked to share the appropriate grade level they thought each of the concepts should be taught at. Experts were also asked to indicate whether or not preservice teachers might hold alternative conceptions regarding each of the 20 concepts
covered on the ACES-Q II-R. These data were then compared with national and state recommendations as well as the review of literature.

Experts indicated appropriate grade level for each of the items on the ACES-Q II-R. These grade levels were divided into three broad categories: K-4, 5-8, and 9-12.

Table 4.4 below shows the frequency each grade level was chosen. Frequencies underlined and marked in bold text match both the National Science Education Standards (NRC, 1996) and the Arkansas State Frameworks (ADE, 2005) for science. As evidenced in the frequency table below, many of the experts correctly identified the appropriate grade level for the various concepts on the instrument. Yet, several of the experts overestimated the grade levels associated with each item.

Table 4.4
Suggested Grade Levels for Items on the ACES-Q II-R

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Grade Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Elementary (K-4)</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
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<tr>
<td>2</td>
<td>8</td>
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<td>6</td>
<td>1</td>
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<tr>
<td>7</td>
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<td>12</td>
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<td>15</td>
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<td>1</td>
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<tr>
<td>19</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
</tr>
</tbody>
</table>

Frequencies underlined and in bold match recommendations from NSES and Arkansas State Frameworks. n=10
Experts were asked to indicate if they believed that preservice teachers, K – 12, might hold alternative conceptions in each of the areas represented on ACES-Q II-R. Experts used a “Y” for yes and an “N” for no. These frequencies are indicated below in Table 4.5. The majority of experts indicated that preservice teachers indeed might hold alternative conceptions associated with each of the items on the instrument. These results were expected since these items were identified in the literature as areas of alternative conceptions for both children and teachers.

Table 4.5
Possible Alternative Conceptions Held by Preservice Teachers as Indicated by the Expert Panel

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
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<td>3</td>
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<td>4</td>
<td>9</td>
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<td>0</td>
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<tr>
<td>19</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>20</td>
<td>9</td>
<td>1</td>
</tr>
</tbody>
</table>

n = 10
Response validity was measured by calculating agreement rates (AR) between answers on the paper and pencil ACES-Q II-R and the oral version of the instrument. Following the “interview about instances” (Osborne & Freyburg, 1985) procedure described earlier in Chapter 3, eleven students were selected based on their scores from the paper and pencil version of the ACES-Q II-R for interviews. The results of these interviews (See Appendix E for a sample transcription of these interviews.) were then compared to the student’s original written responses of each of these eleven participants. An Agreement Rate (AR) was calculated to identify the degree to which responses given on both the written and oral forms of the instrument were similar. The Agreement Rate (AR) was calculated by dividing the number of responses for a particular item that were in agreement by the total number of responses (Franklin, 1992). The AR among all answers (n = 220, total number of responses = 20 questions x 11 participants interviewed) ranged from .91 to .32; among all reasons the range was .73 to .18; and for a combination of both the correct answer and reason the range was .73 to .09 (n = 220).

Inspection of the four subsections revealed that the ARs for subtests were generally consistent. In all cases the ARs decreased from answer to reason to both. Two reasons might be contributing to this pattern. Students were allowed to choose from the same set of answers during both the written and oral forms of the ACES-Q II-R. Additionally the answer section typically had fewer distractors to choose from, thus increasing the odds of selecting the same response. However, reasons, while provided in a multiple-choice format on the written form of the ACES-Q II-R, were not available on the oral form, thus increasing the chances of a wider variety of reasons being provided by participants, and therefore diminishing the reliability of the oral format as well as
lowering the AR. Overall the ARs were higher for the subtest, solar system, followed by Earth’s systems, climate and weather, and Earth’s history.

**Reliability**

Reliability is best described as the degree to which a test or instrument “consistently measures whatever it measures” (Gay, 1992, p. 161). That is, the more reliable an instrument, the more likely similar scores would be obtained if the test was given a second time. Reliability is “expressed numerically” (p. 162), and often as a coefficient. A higher coefficient indicates a higher reliability. Nunnally (1970) suggests that an acceptable test reliability coefficient should be greater than or equal to .70. However, according to Gay (1992) “when tests are developed in new areas, one usually has to settle for lower reliability, at least initially” (p. 168). Several measures of reliability were investigated as part of this study. They included discrimination indices, Kuder-Richardson 20 (KR20), Cronbach’s Coefficient Alpha, Split-Half Reliability, and calculating the standard error of measurement for the instrument as a whole.

Overall test reliability using Cronbach’s Alpha was determined to be .69. Cronbach’s Alpha was also calculated for each of the four subtests on the ACES-Q II-R. These measures can be found below in Table 4.6.
Table 4.6  
*Reliability Measures for the ACES-Q II-R Subtests using Cronbach’s Alpha*

<table>
<thead>
<tr>
<th>Subtests</th>
<th>Kuder-Richardson 20</th>
<th>Cronbach’s Alpha Coefficient</th>
<th>Spearman-Brown Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar System (6 items)</td>
<td>.48</td>
<td>.47</td>
<td>.34</td>
</tr>
<tr>
<td>Earth’s History (4 items)</td>
<td>.43</td>
<td>.42</td>
<td>.42</td>
</tr>
<tr>
<td>Earth’s Systems (6 items)</td>
<td>.47</td>
<td>.48</td>
<td>.49</td>
</tr>
<tr>
<td>Climate &amp; Weather (4 items)</td>
<td>.03</td>
<td>.02</td>
<td>-.03*</td>
</tr>
<tr>
<td>All 20 Items</td>
<td>.62</td>
<td>.69</td>
<td>.61 (odd/even)</td>
</tr>
</tbody>
</table>

*The correlation between the items in Climate & Weather is negative. This violates reliability model assumptions. See paragraph below for discussion.*

Split-half reliability refers to measure of internal consistency reliability (Gay, 1992). Reliability of the entire questionnaire via the split-half approach was conducted by comparing the first ten questions to the last ten questions. Additionally even questions were compared to odd questions to see if participants growing weary impacted the reliability of the instrument. Split-half reliability comparing the first ten items to the last ten items was calculated to be .69. Split-half reliability comparing odd versus even questions was calculated to be .61. If text exhaustion were impacting the instrument, the effect would be quite different and reliability between odd and even questions would be expected to be higher. It is therefore possible that test exhaustion might not have been a factor influencing the internal reliability of this instrument.

Additionally split-half reliability coefficients for each of the four subtests of the ACES-Q II-R were calculated. The Spearman-Brown Coefficients are listed above in Table 4.6. It is important to note that length of the instrument impacts its overall reliability (Gay, 1992). When evaluating the subtests, ranging in question length from
four to six questions, the dramatic decrease in the number of items will reduce the reliability coefficients. With this in mind, the lower reliability scores for the subtests were expected.

It is important to note that the correlation between the items in the climate and weather subtests was calculated to be -0.03. This negative correlation indicates a violation of reliability model assumptions. This negative correlation is a result of two items (Question 15 and Question 20) that had poor discrimination indices.

“Reliability can also be expressed in terms of the standards error of measurement” (Gay, 1992, p. 169) and is often reported for tests or similar instruments. Unlike reliability coefficients where the higher the coefficient, the more reliable an instrument, “a small standard error of measurement indicates high reliability” (p. 169). The standard error of measurement is calculated by multiplying the standard deviation of the test scores by the square root of one minus the reliability coefficient (Gay suggests using the split-half reliability coefficient.). The standard error of measurement for the ACES-Q II-R was calculated to be 1.89, indicating a moderate level of reliability.

Item analysis was performed to identify those items with the greatest ability to discriminate between those who had higher scores on the ACES-Q II-R and those who did not score well. This included a calculation of both difficulty and discrimination indices for both tiers of the instrument: correct answer and correct reason or explanation. Difficulty indices simply indicate the proportion of students that chose the correct answer. Discrimination indices may be used as a basic measure of an item’s validity and describes the relationship between those who scored well on an instrument and chose the correct answer and those who did not score well on an instrument and chose the correct
answer. A positive number indicates that there is a relationship between knowledge and choosing the right answer or reason. A number that is closer to 1.0 indicates a stronger relationship between students with high scores choosing the correct answer. Difficulty and discrimination indices for items on the ACES-Q II-R were calculated by hand and therefore the upper 25% and lower 25% participant scores were used. These indices are listed below in Table 4.7.

### Table 4.7

**Difficulty and Discrimination Indices for the ACES-Q II-R**

<table>
<thead>
<tr>
<th>Item</th>
<th>Difficulty Indices</th>
<th>Discrimination Indices</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>Answer</td>
<td>Reason</td>
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<td>.55</td>
</tr>
<tr>
<td>20</td>
<td>.15</td>
<td>.05</td>
</tr>
</tbody>
</table>

All comparisons based on upper and lower 25%, n=44.

It is important to remember that discrimination indices are useful when the purpose of a test is to provide a range of scores, very common for norm-referenced tests. This instrument is a criterion-referenced test; the hope being that each participant has mastered the content covered and earns the highest scores possible. Regardless,
discrimination indices can be useful in the task of evaluating an item’s validity as well as indicating possible issues with the clarity and readability of the question itself.

ACES-Q II-R Data Analysis

Quantitative Results

Descriptive statistics were calculated for the data gathered on the ACES-Q II-R. Data from the ACES-Q II-R were also analyzed via an analysis of variance using the general linear model relative to gender and certification area, for each of the four subtests as well as the instrument as a whole. Additionally, Person Correlation Coefficients were calculated for the sense and confidence ratings for each question on the instrument.

Each of the 20 questions was designed to assess earth science content knowledge in one of four specific categories. Each question consisted of five parts: a diagram and a description of the situation or event, a question related to the event, a list of possible answers, a list of possible reasons for the answer chosen, and two Likert scales to assess whether or not the concept made sense and how confident or certain the participant was about his/her answers (See Appendix C for the ACES-Q II-R.). Distractors for the multiple-choice reason section were chosen from alternative conceptions present in the literature. Table 4.8 below shows the specific concepts for each of the questions followed by the percentage of participants who chose the correct answer and the correct response. Participants’ responses to the five point Likert scale questions were averaged for each of the questions items as well. Participants were to choose a number from 1 (just a blind guess) to 5 (I am sure I am right) when asked ‘how sure are you of your answer?’
Additionally, participants were to choose a number from 1 (makes no sense) to 5 (makes perfect sense) when asked 'does this concept make sense to you?'

Table 4.8
Questions on the ACES-Q II-R
Percentage of Participants with the Correct Answer & Mean Confidence and Sense Score

<table>
<thead>
<tr>
<th>Question</th>
<th>Concept</th>
<th>Answer Correct</th>
<th>Reason Correct</th>
<th>Confidence Mean</th>
<th>Sense Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shadow/Year</td>
<td>34.5%</td>
<td>48.3%</td>
<td>2.7</td>
<td>2.9</td>
</tr>
<tr>
<td>2</td>
<td>Shadow/Day</td>
<td>62.1%</td>
<td>75.9%</td>
<td>3.3</td>
<td>3.3</td>
</tr>
<tr>
<td>3</td>
<td>Lunar Surface</td>
<td>63.2%</td>
<td>39.1%</td>
<td>2.7</td>
<td>2.8</td>
</tr>
<tr>
<td>4</td>
<td>Lunar Phases</td>
<td>46.0%</td>
<td>54.0%</td>
<td>2.9</td>
<td>3.1</td>
</tr>
<tr>
<td>5</td>
<td>Earth’s Seasons</td>
<td>51.7%</td>
<td>33.3%</td>
<td>2.8</td>
<td>3.0</td>
</tr>
<tr>
<td>6</td>
<td>Gravity</td>
<td>50.6%</td>
<td>64.4%</td>
<td>2.4</td>
<td>2.5</td>
</tr>
<tr>
<td>7</td>
<td>Acid Rain</td>
<td>26.4%</td>
<td>32.2%</td>
<td>2.3</td>
<td>2.6</td>
</tr>
<tr>
<td>8</td>
<td>Mineral Hardness</td>
<td>51.7%</td>
<td>55.2%</td>
<td>2.8</td>
<td>3.0</td>
</tr>
<tr>
<td>9</td>
<td>Rock Types</td>
<td>49.4%</td>
<td>43.7%</td>
<td>2.5</td>
<td>2.7</td>
</tr>
<tr>
<td>10</td>
<td>Ocean Salinity</td>
<td>57.5%</td>
<td>28.7%</td>
<td>2.0</td>
<td>2.4</td>
</tr>
<tr>
<td>11</td>
<td>Run-off</td>
<td>82.8%</td>
<td>77.0%</td>
<td>2.5</td>
<td>2.7</td>
</tr>
<tr>
<td>12</td>
<td>Tides</td>
<td>83.9%</td>
<td>43.7%</td>
<td>2.1</td>
<td>2.2</td>
</tr>
<tr>
<td>13</td>
<td>River Formation</td>
<td>90.8%</td>
<td>52.9%</td>
<td>2.7</td>
<td>2.7</td>
</tr>
<tr>
<td>14</td>
<td>Dinosaurs</td>
<td>81.6%</td>
<td>47.1%</td>
<td>2.8</td>
<td>2.9</td>
</tr>
<tr>
<td>15</td>
<td>Biomes</td>
<td>12.6%</td>
<td>13.8%</td>
<td>3.3</td>
<td>3.2</td>
</tr>
<tr>
<td>16</td>
<td>Water Cycle</td>
<td>56.3%</td>
<td>54.0%</td>
<td>2.8</td>
<td>2.8</td>
</tr>
<tr>
<td>17</td>
<td>Pressure</td>
<td>52.9%</td>
<td>60.9%</td>
<td>2.8</td>
<td>2.9</td>
</tr>
<tr>
<td>18</td>
<td>Weather Prediction</td>
<td>41.4%</td>
<td>32.2%</td>
<td>2.4</td>
<td>2.5</td>
</tr>
<tr>
<td>19</td>
<td>Pressure</td>
<td>40.2%</td>
<td>70.1%</td>
<td>2.1</td>
<td>2.4</td>
</tr>
<tr>
<td>20</td>
<td>Weather/Laundry</td>
<td>25.3%</td>
<td>19.5%</td>
<td>3.6</td>
<td>3.7</td>
</tr>
</tbody>
</table>

\(n=87\)

There were twenty points possible on the ACES-Q II-R. Both parts of the two-tiered question had to be answered correctly for the participant to earn a score of one for that question. Any combination containing an incorrect response or an alternative conception earned a score of zero. Participants’ total scores ranged from one to 17 (Range = 16). The median score was a seven, the mode score was eight, and the mean score was 7.2 with a standard deviation of 3.4. Numbers and tables only tell part of the story. Figures 3.1, 3.2, and 3.3 display box plots for All Scores, Scores by Gender, and
Scores by Certification Level and provide an easy visual for viewing the differences between means among the subgroups as well as the positively skewed nature of the data.

Figure 3.1
*Total Scores on the ACES-Q II-R*
Figure 3.2
*Total Scores on the ACES-Q II-R for Women and Men*

![Box plot showing total scores for women and men.](image-url)
Differences in the means appeared between all subgroups (Table 4.9). On average, men scored higher than women on the ACES-Q II-R. These findings were consistent with those from the ACES-Q (Leslie, Dockers, & Wavering, 2005) as well as those from the ACES-Q II where women scored an average of 7.2 and men scored an average of 10.2 (Leslie, Dockers, & Wavering, 2006). Means for different certification levels as well as total number of science courses have been provided as well.
Table 4.9

ACES-Q II-R Means according to subgroups

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>68</td>
<td>6.86</td>
<td>3.11</td>
</tr>
<tr>
<td>Male</td>
<td>12</td>
<td>9.25</td>
<td>3.9</td>
</tr>
<tr>
<td><strong>Certification Level</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elementary</td>
<td>47</td>
<td>6.15</td>
<td>2.76</td>
</tr>
<tr>
<td>Middle</td>
<td>5</td>
<td>9.0</td>
<td>2.45</td>
</tr>
<tr>
<td>Secondary</td>
<td>29</td>
<td>8.69</td>
<td>3.64</td>
</tr>
<tr>
<td><strong>Total Science Courses Taken</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1, 2, or 3 courses</td>
<td>42</td>
<td>6.86</td>
<td>3.63</td>
</tr>
<tr>
<td>4, 5, or 6 courses</td>
<td>34</td>
<td>6.91</td>
<td>2.49</td>
</tr>
<tr>
<td>7 or more courses</td>
<td>11</td>
<td>9.45</td>
<td>4.27</td>
</tr>
</tbody>
</table>

*Missing data: 7 chose not to indicate their gender and 6 chose not to indicate their certification level.

A $t$ test was calculated as well as analyses of variance (ANOVA) via the statistical software package SPSS to see if difference among the means were significant at the alpha 0.05 level. A $t$ test comparing the mean scores of female and male participants found a significant difference between the means of the two groups, $t(78) = -2.35; p = 0.021$.

An analysis of variance was also calculated for the total number of science courses (rescored to three levels) and certification level on total score of earth science knowledge. The first analysis failed to reveal a significant effect at the alpha 0.05 level for total number of science courses on participants’ total scores, ($F(2,84) = 2.89, p = 0.06$). The second analysis revealed a significant effect for certification level, ($F(2, 78) = 6.94, p = 0.002$). Sample means may be found in Table 4.8. Tukey’s HSD test showed that participants in the secondary school certification program scored significantly higher on the ACES-Q II-R than did participants in the elementary certification program ($p = 0.002$). There were no significant differences between subjects in the middle school certification program and participants in the secondary school certification program.
Analyses of variance for gender and certification were also calculated for each of the subtests (See Table 4.10 through Table 4.13.). Analyses of the subtests yielded similar results to the analysis of the ACES-Q II-R as a whole. Differences among mean scores on each subtest according to gender, certification and gender by certification were noted, however, the only significant difference ($p < .05$) noted was between gender on the Earth’s systems subtest (See Table 4.11).

Table 4.10
A 2x3 General Linear Models Procedure on the ACES-Q II-R,
Subtest Solar System, Results for Gender,
Certification and Gender by Certification

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Effect</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>1.67</td>
<td>1</td>
<td>1.67</td>
<td>.84</td>
</tr>
<tr>
<td>Certification</td>
<td>.84</td>
<td>2</td>
<td>.42</td>
<td>.21</td>
</tr>
<tr>
<td>Gender by Certification</td>
<td>.41</td>
<td>1</td>
<td>.41</td>
<td>.21</td>
</tr>
<tr>
<td>Model</td>
<td>$13.81_4$</td>
<td>4</td>
<td>3.45</td>
<td>1.74</td>
</tr>
</tbody>
</table>

n = 87, *p < .05, a. R Squared = .085

Table 4.11
A 2x3 General Linear Models Procedure on the ACES-Q II-R,
Subtest Earth’s History, Results for Gender,
Certification and Gender by Certification

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Effect</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>.73</td>
<td>1</td>
<td>.73</td>
<td>.57</td>
</tr>
<tr>
<td>Certification</td>
<td>1.42</td>
<td>2</td>
<td>.71</td>
<td>.56</td>
</tr>
<tr>
<td>Gender by Certification</td>
<td>.40</td>
<td>1</td>
<td>.40</td>
<td>.32</td>
</tr>
<tr>
<td>Model</td>
<td>$10.98_4$</td>
<td>4</td>
<td>2.75</td>
<td>2.17</td>
</tr>
</tbody>
</table>

n = 87, *p < .05, a. R Squared = .104
Table 4.12
A 2x3 General Linear Models Procedure on the ACES-Q II-R, Subtest Earth's Systems, Results for Gender, Certification and Gender by Certification

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Effect</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>7.08</td>
<td>1</td>
<td>7.08</td>
<td>2.96*</td>
</tr>
<tr>
<td>Certification</td>
<td>10.91</td>
<td>2</td>
<td>5.46</td>
<td>2.96</td>
</tr>
<tr>
<td>Gender by Certification</td>
<td></td>
<td>1</td>
<td>1.84</td>
<td>.77</td>
</tr>
<tr>
<td>Model</td>
<td>26.62, a</td>
<td>4</td>
<td>6.65</td>
<td>2.78</td>
</tr>
</tbody>
</table>

n = 87, *p < .05, a. R Squared = .129

Table 4.13
A 2x3 General Linear Models Procedure on the ACES-Q II-R, Subtest Climate and Weather, Results for Gender, Certification and Gender by Certification

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Effect</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>.36</td>
<td>1</td>
<td>.36</td>
<td>.54</td>
</tr>
<tr>
<td>Certification</td>
<td>.98</td>
<td>2</td>
<td>.49</td>
<td>.75</td>
</tr>
<tr>
<td>Gender by Certification</td>
<td>.04</td>
<td>1</td>
<td>.04</td>
<td>.06</td>
</tr>
<tr>
<td>Model</td>
<td>5.87, a</td>
<td>4</td>
<td>1.47</td>
<td>2.24</td>
</tr>
</tbody>
</table>

n = 87, *p < .05, a. R Squared = .107

Additionally post hoc analyses were calculated for each of the subtests (See Table 4.14 through Table 4.17.).

Table 4.14
Comparison of Main Effects (Gender & Certification) Means using the Studentized Maximum Modulus Text on the ACES-Q II-R Subtest, Solar System

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Means</th>
<th>sd</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>2.18</td>
<td>1.32</td>
<td>68</td>
</tr>
<tr>
<td>Male</td>
<td>3.0</td>
<td>1.91</td>
<td>12</td>
</tr>
<tr>
<td>Certification</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elementary</td>
<td>1.98</td>
<td>1.26</td>
<td>47</td>
</tr>
<tr>
<td>Middle</td>
<td>2.60</td>
<td>.89</td>
<td>5</td>
</tr>
<tr>
<td>Secondary</td>
<td>2.79</td>
<td>.66</td>
<td>29</td>
</tr>
</tbody>
</table>

Total possible score 6.0

77
Table 4.15  
Comparison of Main Effects (Gender & Certification) Means using the Studentized Maximum Modulus Text on the ACES-Q II-R Subtest, Earth’s History  

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Means</th>
<th>sd</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>1.43</td>
<td>1.11</td>
<td>68</td>
</tr>
<tr>
<td>Male</td>
<td>2.0</td>
<td>1.35</td>
<td>12</td>
</tr>
<tr>
<td>Certification</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elementary</td>
<td>1.21</td>
<td>.71</td>
<td>47</td>
</tr>
<tr>
<td>Middle</td>
<td>2.0</td>
<td>.71</td>
<td>5</td>
</tr>
<tr>
<td>Secondary</td>
<td>1.93</td>
<td>1.30</td>
<td>29</td>
</tr>
</tbody>
</table>

Total possible score 4

Table 4.16  
Comparison of Main Effects (Gender & Certification) Means using the Studentized Maximum Modulus Text on the ACES-Q II-R Subtest, Earth’s Systems  

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Means</th>
<th>sd</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>3.07</td>
<td>1.50</td>
<td>68</td>
</tr>
<tr>
<td>Male</td>
<td>4.08</td>
<td>2.02</td>
<td>12</td>
</tr>
<tr>
<td>Certification</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elementary</td>
<td>2.87</td>
<td>1.33</td>
<td>47</td>
</tr>
<tr>
<td>Middle</td>
<td>4.6</td>
<td>1.82</td>
<td>5</td>
</tr>
<tr>
<td>Secondary</td>
<td>3.57</td>
<td>1.85</td>
<td>29</td>
</tr>
</tbody>
</table>

Total possible score 4

Table 4.17  
Comparison of Main Effects (Gender & Certification) Means using the Studentized Maximum Modulus Text on the ACES-Q II-R Subtest, Climate and Weather  

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Means</th>
<th>sd</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>.90</td>
<td>.76</td>
<td>68</td>
</tr>
<tr>
<td>Male</td>
<td>1.5</td>
<td>1.09</td>
<td>12</td>
</tr>
<tr>
<td>Certification</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elementary</td>
<td>.79</td>
<td>.75</td>
<td>47</td>
</tr>
<tr>
<td>Middle</td>
<td>1.20</td>
<td>.83</td>
<td>5</td>
</tr>
<tr>
<td>Secondary</td>
<td>1.29</td>
<td>.90</td>
<td>29</td>
</tr>
</tbody>
</table>

Total possible score 6

Correlations among the confidence scores, sensibility scores, age, total number of science course, and total scores were examined to see if any relationship exists. There
was a scant correlation between age and the total score ($r = -0.04$); this correlation was not significant at the alpha .05 level. There was a slight positive correlation ($r = 0.23$) between total number of science courses taken and total score on the ACES-Q II-R. There were also slight positive correlations between an individual’s confidence and sensibility scores and their total score (0.42 and 0.41 respectively). These three correlations were significant at the alpha 0.05 level. These correlations were similar to those on the ACES-Q (.46 and .46 respectively) and the ACES-Q II (0.42 and 0.32 respectively) (Leslie, Dockers, & Wavering, 2005 & 2006). It is interesting to note that there is a strong positive correlation ($r = 0.78$, $p = 0.01$) between the confidence scores and sensibility scores of the ACES-Q II-R. These closely mirror those of the previous two instruments (ACES-Q, $r = 0.75$, $p < 0.05$ and ACES-Q II, $r =0.76$, $p <0.05$) and Franklin’s (1992) MIS-Q ($r = 0.72$, $p < 0.05$).

**Qualitative Data**

Qualitative data gathered via the ACES-Q II-R and via the process of discerning the validity and reliability of the instrument provided the researcher with several interesting insights into alternative conceptions, content knowledge, and pedagogy. Participants were encouraged to write in their responses if they did not agree with an answer or response offered on the instrument. Additionally, Question 21, an open-ended question, allowed the researcher to investigate participants’ thoughts on pedagogy and content. Eleven interviews were conducted as part of administering the oral version of the ACES-Q II-R. Each of these avenues of data collection provided unique views into the thoughts of the participants.
Alternate Responses

The ACES-Q II-R, a two-tiered, multiple-choice instrument also allowed participants to share alternate answers or reasons. Students were encouraged via the instrument’s instructions to share their own responses if they found those on the instrument unsatisfactory. Space was provided on the answer sheet (See Appendix H.) for students to “write-in” these alternate responses. Twenty-two alternate responses were provided via the “write-in” option. Most of these responses restated alternative conceptions or did not appear to pertain to the topic at hand. However, Question 14 garnered the most “write-in” responses. When participants were asked if it was possible for dinosaurs and man to coexist, five alternate responses were provided:

- Some scientists say humans died; others say they hid in caves during the ice age.
- People are defined as what? Homo habilis, erectus...?
- Maybe not humans but some form of sapiens.
- Religion vs. science.
- Anything is possible.

These alternate responses were mirrored in the interviews with several participants identifying this question as a theology question and not a science question. For a complete list of the “write-in” responses see Appendix I.

Open Ended Question, Item # 21

The last question on each version of the ACES-Q was designed to allow participants to share their thoughts regarding teaching and content. The question asked participants how they would teach about a solar eclipse to the grade level of their choice. Only 77 of the 87 participants chose to respond to this question. Data collected from this question on previous versions of the ACES-Q resulted in some very plainly stated alternative conceptions: “I would explain that a solar eclipse is when the sun passes
between the earth and the moon..." and "I would hold a night session to watch a solar
eclipse" (Leslie, Dockers, & Wavering, 2005, p.12) and "I would incorporate a fun
activity such as [a] night observation" and "...then I would explain that the sun comes
between the earth and moon" (Leslie, Dockers, & Wavering, 2006, p. 14). Of the 77
responses provided on question 21 of the ACES-Q II-R there were no plainly stated
alternative conceptions nor were there clearly stated scientific understanding of the
concept. However, 14 individuals plainly stated that they would need to investigate the
topic further before teaching it. A list of several recurring themes and their frequency can
be found below in Table 4.18.

Table 4.18

<table>
<thead>
<tr>
<th>Pedagogy</th>
<th>Content Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Models (21)</td>
<td>I need more research (14)</td>
</tr>
<tr>
<td>Video (15)</td>
<td>Solar System (6)</td>
</tr>
<tr>
<td>Flashlight (12)</td>
<td>Moon blocks light of Sun (5)</td>
</tr>
<tr>
<td>Kinesthetic/Dramatic Play (8)</td>
<td>Occurrence of solar eclipse (3)</td>
</tr>
<tr>
<td>Demonstrate (6)</td>
<td>Sun, Moon, &amp; Earth (8)</td>
</tr>
<tr>
<td>Hands-on Activity (6)</td>
<td>Sun &amp; Moon (4)</td>
</tr>
<tr>
<td>Balls, fruit, globes (13)</td>
<td>Moon &amp; Earth (2)</td>
</tr>
<tr>
<td>Internet (4)</td>
<td>Phases of the Moon (2)</td>
</tr>
<tr>
<td>Pictures/Posters (15)</td>
<td>Orbit of the Earth (2)</td>
</tr>
<tr>
<td>Diagram (8)</td>
<td></td>
</tr>
<tr>
<td>Discuss/Explain/Lecture (5)</td>
<td></td>
</tr>
<tr>
<td>Write a Paragraph (2)</td>
<td></td>
</tr>
<tr>
<td>Cardboard Box/Pinhole Camera (6)</td>
<td></td>
</tr>
<tr>
<td>NASA/CMASE (2)</td>
<td></td>
</tr>
<tr>
<td>Assess Prior Knowledge (1)</td>
<td></td>
</tr>
<tr>
<td>Books</td>
<td></td>
</tr>
<tr>
<td>Textbooks (5)</td>
<td></td>
</tr>
<tr>
<td>Trade books (4)</td>
<td></td>
</tr>
<tr>
<td>Children's books (8)</td>
<td></td>
</tr>
</tbody>
</table>

Despite the lack of plainly stated scientific understandings or alternative
conceptions, it is possible to identify probable scientific fragments held by the
participants. Comments like "I would have Oreo cookies and have the students scrap
[sic] off the cream to show the different phases of the Moon. I would then talk about what would happen with the shadow of the Moon,” “Show how planets orbit the solar system and how the Moon orbits the Earth,” and “…I would bring in models that show the Moon going in the path of the Sun’s rays,” indicate that these participants may not have a complete understanding of the solar eclipse phenomenon.

**Participant Interviews**

Eleven preservice teachers were interviewed for the purpose of establishing response validity. However, these interviews, once transcribed and analyzed for salient themes, provided a wealth of insight into alternative conceptions that our preservice teachers may hold (See Appendix E for a sample of the interview transcriptions.). The ACES-Q II-R was divided into four main categories: solar system, Earth’s history, Earth’s systems, and climate and weather. As the interviews were analyzed and themes began to emerge, similarities emerged with concepts arising in both the Earth’s History and Earth’s Systems subsections. These subsections were combined for the purpose of reporting the findings.

**Solar System**

Astronomy is one of the more popular areas of alternative conception research (Baxter, 1989; Callison & Wright, 1993; Cohen & Kagan, 1979; Trumper, 2001a & 2001b; Schoon, 1995; Trundle, Atwood & Christopher, 2002, 2003, & 2006). The first six questions of the ACES-Q II-R covered topics associated with astronomy and space science. Topics included using sun angle with respect to seasonal or diurnal changes, causes of the seasons, lunar motion and phase changes, and gravity.
Interview data from the first question about sun angle and length of shadows during different seasons provided some serious insight into what preservice teachers are thinking. It is interesting to note that most of the alternative conceptions revealed by reviewing the data were about light and shadows, seasons were only tangentially discussed. One participant answered the first tier of the question correctly: we cast the longest shadow in winter. Her reasoning provided the researchers with an interesting alternative conception.

*Student:* The longest shadow? I would guess the winter solstice, whatever that means.

*Researcher:* What does that mean?

*Student:* When the sun is the furthest away from the Earth. You know, like the longest day of the year, the summer solstice, when the sun’s directly over your head, you won’t cast a shadow.

Additionally, another student similarly elaborated, “I’ve heard that in winter the sun is closer to the Earth so, uhm, if it is closer to an object it is going to cast a longer shadow.”

These participants were not alone in their thinking that an object’s proximity to a light source impacts the length of that object’s shadow, “It is summer. Because that’s the time, uhm that would mean that you’re closer to the Sun and so if it [sunlight] came down on him [pause] you would just have a longer shadow.”

Other alternative conceptions unearthed included those regarding the fact that shadows shorten or lengthen based on the length of day, “I’m not really fantastic with science, but I think in the winter the days are shorter, therefore the shadow your body will cast would be shorter”; “the Sun is always in the same place at noon, regardless of the season”; “impossible to tell the season... ‘cause at noon it should always be the same. The Sun should be in the same spot.” These beliefs may be evidence that these preservice teachers do not fully understand the concepts of shadow and light nor are they
fully aware of how the Sun’s position throughout the year impacts their shadow. Yet
another explanation for the different shadow lengths throughout the year was attributed to
cloud coverage, however the participant’s explanation was convoluted and difficult to
follow.

Because I would think that it has something to do with the clouds over the sun. In
the summer you generally don’t have as much cloud coverage. But that same
instance it could be a cloudy day in the summer, right? So it could be impossible
to tell. Maybe it’s a cloudy summer day. But if it was at high noon in the
summer that your shadow [pause] would, I don’t know. Maybe I’m wrong, but it
wouldn’t cast a shadow.

The second question asked students to identify the time of day, on any given
day, that a body would cast the longest shadow. Again, alternative conceptions regarding
the proximity of the light source to the object casting a shadow appeared.

Student: It is because the sun is the farthest away from you at that point.
Researcher: So it is the distance of the sun from Ursula that impacts the length of
her shadow?
Student: Yes, from the person. It is either further away or it’s overhead.

Another conversation indicated that the length of a person’s shadow from morning to
evening changes due to the Earth’s rotation and shape.

Student: Because of the sun’s position in the sky?
Researcher: What about the sun’s position in the sky?
Student: Well, when the sun is closer to the horizon the shadows are longer than
when the sun is directly above the object.
Researcher: Why?
Student: Ah, again, due to the Earth’s shape and rotation. It’s like turning on its
axis.

Other common alternative conceptions revealed by this question included the
misunderstanding that the higher the sun appears in the sky, the longer the shadow: “You
cast a longer shadow at noon because the sun is highest in the sky” and “because the sun is up higher and you will cast a longer shadow”.

The next question asks participants to identify the season based on a diagram indicating an Earth and sun relationship. The northern hemisphere has been indicated by the letter ‘N’. Several alternative conceptions about the cause of the seasons became evident. The most popular being that the seasons are a result of the Earth’s proximity to the Sun, “just that summer, that like, part of the Earth is closer to the Sun and in position C it looks like Arkansas is closer to the Sun”.

Several students expressed science fragments as part of their explanation. They remembered that the tilt of the Earth on its axis was a significant factor regarding seasons. But when asked to elaborate one student could not recall anything regarding the Earth’s tilt:

Student: We are experiencing summer time
Researcher: Summer time and why?
Student: Because we are tilted toward the sun.
Researcher: Can you add anything about the tilt of our Earth?
Students: Not really

Two other participants included the Earth’s tilt in their reasoning, “It has to do with the Earth’s rotation, ah, which way the Earth’s pointed on its axis” and “the tilting of the Earth [subject’s hand is tilted and indicates that as the Earth travels around the sun the tilt of the axis flip flops back and forth].” Both of these beliefs mirror the findings of other researchers indicating that people think the Earth’s axial tilt flips or Earth’s proximity to the Sun causes the seasons (Atwood & Atwood, 1996; Baxter, 1989; Schoon, 1995; Trumper 2001a & 2001b).
A space science question that generated several interesting notions asked
students if observers on Earth see the same side of the Moon and why or why not.
Participants answered both yes we only see one side of the Moon and no, observers on
Earth are able to view the entire lunar surface. However, regardless of their answers,
most participants in the interviews could be categorized into three groups: those who felt
the Moon must rotate on its axis,

• “The Earth spins on its axis, so I would assume the Moon would also spin on an
axis so we’re not always seeing the same side.”
• “I see the Earth as spinning and the moon is spinning itself as it goes around the
Earth [pause] so, ah, assuming that’s true we do see the other side of the Moon,
we just don’t realize we do.”

those who felt the moon did not rotate on its axis,

• “We only see one side of the Moon. Because the Moon doesn’t rotate.”
• “…the planets rotate, but if we had a Moon, the Moon is stationary, and the
Earth rotates. You still never see the, ah, the Moon never rotates. So you see the
same side.”

and those who were not sure if the Moon rotates.

• “Because the moon, ah, wait a minute, the Earth rotates around the Moon,
doesn’t it? [pause] Ah, no. Is that right? The Moon, Earth, I don’t know. Let’s
see [pause] the Moon rotates, doesn’t it? I don’t know.”
• “I’m not sure if it goes around the Earth or if it just spins.”

A response that stood out to the researchers, “I don’t think you can tell from Earth
without, you know, you’d need a telescope to tell,” indicated that the participant believed
that she needed a telescope to know the answer. While this concept, seeing the entire
lunar surface, is a known alternative conception (Plait, 2002) it is rarely discussed in
research literature as one identified by researchers.

The question asking participants to identify the lunar phase based on the
position of the Sun, Earth and Moon revealed that our participants hold alternative
conceptions that are very similar to those found in the literature. A pronounced theme for the cause of the lunar phases was that the shadow cast by the Earth blocks light to the Moon’s surface resulting in the apparent changes in the Moon, “The Earth creates a shadow… It blocks the Moon. The sun’s rays are not reaching the Moon” and “the Earth is blocking the light of the Sun to the Moon so we wouldn’t see it.” This alternative conception is very common among children and teachers alike (Dove, 2002; Rider; 2002; Schoon, 1995; Stahly, Krockover, & Sheppardson, 1999; Trumper, 200 a & 2001b; Trundle, 1999).

The final space science question prompts participants to explain where a bowling ball will “end up” and why if it was dropped through a hole carved through the center of the Earth. The answers and reasons for this question were rich with alternative conceptions. “So I don’t know where gravity switches or whatever… People on the other side, their gravity doesn’t work the same way ours does. So theoretically it [bowling ball] would probably drop and hit the side” sums up the beliefs of several students interviewed, believing that somehow, gravity on the far side of the Earth does not work in the same manner as on this side of Earth. When asked to explain gravity, one participant had a most interesting notion:

Researcher: So what does gravity mean?
Student: Uhm, the lunar pull on the Earth, I guess?
Researcher: Out of curiosity does anything else have a pull on Earth?
Student: Not that I’m aware of.

The beliefs about gravity expressed by our preservice teachers are not wildly different from those of school children: falling ‘down’ and landing inside of the ‘hole’ or falling ‘down’ away from the Earth (Bar, Sneider, & Martimbeau, 1997; Baxter, 1989;
Nussbaum, 1979; Nussbaum & Novak, 1976). It is evident that several of our preservice teachers’ understanding of the Earth as a cosmic body and gravity are similar to those of the children they will eventually teach.

**Earth’s Systems and History**

The next eight items of the ACES-Q II-R (Leslie & Wavering, 2009) cover areas of Earth’s systems and Earth’s history. Five of the eight questions generated responses that indicated possible alternative conceptions or science fragments. These are discussed below. Several content area gaps and possible alternative concepts have been illuminated by these interviews. With Question 8, several participants correctly indicated that Topaz is hard enough to scratch glass. However, their reasoning was often hard to follow and rife with science fragments.

- “Topaz is stronger than glass.”
- “Quartz would have gone through the glass.”

Data from Question 12 about tides and tidal ranges indicated that several of our students may not understand the difference between tides and tidal waves:

- “… tidal waves have to do with the gravitational pull between the Moon and Earth.”
- “… a more narrow coast, it might make a tidal wave.”
- “Storm out in the ocean or a boat has trouble or even earthquake.”

Like the previous comment including storms as a possibility for differences in tidal ranges, other students attributed tidal ranges to the weather:

- “…tidal range, ah, because it’s something about the winds, I guess.”
- “I’d say it is possible because, um, it would be due to weather phenomenon.”

These findings support those of Trembath (1984) and Viiri (2004).
Question 10 asked students if there was a difference in the salinity of sea water in Gulf Shores and Hawaii. Several students mentioned that there was an equilibrium achieved by the ocean and that there would be no discernable difference in the ocean’s salinity geographically. Conversely, several noted that the shape of the gulf might promote an environment for higher salinity of the water as noted in the comments and interview excerpt to follow. “You must look at the shape of the gulf” and “there’s not much open water for it to have an opportunity to dissipate in or drain out in.”

Student: The gulf traps the salt.
Researcher: How does the gulf trap the salt?
Student: It land locks it, maybe. Ah, less current.

It is not surprising to the researchers that students may have difficulties understanding tides or the salinity of ocean water. Many of them have not seen an ocean.

Question 9 asked students to identify a rock (igneous, sedimentary, or metamorphic) based on its geographical location and the fact that it contained crinoids and fossils of other prehistoric sea creatures. A possible alternative conception revealed by the interview data is that fossils grow. “Igneous is made from volcanic [pause], ah, I don’t think that fossils can grow [in igneous rock].” The following interview excerpt is a sad commentary on one preservice teacher’s exposure to geology.

Researcher: And why do you think it is sedimentary?
Student: Because it is the only one I have ever heard of.
Researcher: So you’re saying you’ve never heard of igneous rock?
Student: Maybe I’ve heard of it, but it is not familiar.
Researcher: What about metamorphic?
Student: Ah, no.

These students’ fragmented understanding and possible misconceptions mirror the findings of Stofflett (1993).
Question 13 poses the question ‘does the Amazon River flow west to east?’ and produced several interesting, albeit expected, comments. A common alternative conception that all rivers flow north to south in the northern hemisphere (Beaty, 2004; Philips; 1991) is evidenced in several participant’s comments.

Student: I know it [rivers] typically flows to a larger body of water. Say a river flows from west to east to meet up with a river flowing north to south, going to the ocean.”
Researcher: Do rivers ever flow south to north?
Student: Yeah, I guess in the southern hemisphere they do. Doesn’t the Nile flow south to north? I’m pretty sure it does.
Researcher: It does. Is the Nile in the northern hemisphere?
Student: Southern.
Researcher: Are you sure?
Student: Yes.

Additionally, another participant shared that water flows down hill, via the path of least resistance and eventually to lakes and oceans, however when discussing well-known rivers (e.g. Amazon, Mississippi, Arkansas, and Nile) the student falls back on a common alternative conception when thinking about why the Nile flows south to north.

Student: I don’t know why the Nile flows south to north. It is the opposite of what I think it should be.
Researcher: What do you think it should be?
Student: That it should flow from the north to south instead.

Another interview revealed, “While rivers flow, uhm, north to south, he could be like at a bend in the river that makes it seem like it’s going in that particular direction [west to east], when in actuality, it is flowing north to south.”

Two other participants mentioned that the Amazon River may indeed flow west to east. The first stating all rivers flow west to east and the second attributing the flow of a river to weather patterns, and that the Amazon flowing from west to east was likely because weather patterns move from west to east. When asked to elaborate on the impact
of weather patterns, she reverted to “I am thinking of all the rivers I know and they all flow north to south.”

One student called on the Coriolis Effect, albeit not by name, “...I believe that the Amazon River may be below the equator. But I can’t remember exactly. And I am thinking about the toilets going backwards below the equator [giggle] and that makes me think it is possible [for the Amazon River to flow west to east]...”

The question that received the most “write in” or alternate responses on the three forms of the ACES-Q (Leslie, Dockers, & Wavering, 2005 & 2006; Leslie & Wavering, 2009) is the question asking if man and dinosaurs roamed the Earth at the same time. With this said, it is not surprising that this interview question generated a wealth of comments citing religious beliefs as a basis for man and dinosaurs coexisting.

- “...the Earth was created in seven days and that humans and dinosaurs were created on day six, or day four, and that they lived together in the Garden of Eden. And there’s been a place where dinosaur footprints and human footprints are in the same layer of sediment. It might be Texas.”
- “Adam and Eve, according to my religion, were the first living, breathing things, and dinosaurs came after that, according to my religion.” She goes on to say “I realize that the scientific answer is no. But facts differ from that.... Dinosaurs are older than the creation of Earth according to every Christian religion.”
- “Because coming from a religious background, I’m taught that the Earth is, in church, not nearly as anywhere near how old the scientists think the Earth [sic].... But now I would have to remember if animals were created before humans.”
- “…my explanation for that would be that there is a higher being that created us and we don’t understand all that and there is no way for us to understand all that.”

A participant, fairly certain that dinosaurs and humans did not exist together shared that religion was a confusing factor in understanding this concept.

Student: I suppose I would say that dinosaurs and humans did not live at the same time.
Researcher: And why not?
Student: This gets interesting. There’s all kinds of crazy stuff.
Researcher: What do you mean by crazy stuff?
Student: You know, religion, evolution, and the Bible, I don’t even know where to begin to explain that. But I would say no, dinosaurs came long before humans.

Finally, a student comments on our current lack of scientific data, “Ah, it’s possible [dinosaurs and man coexisting], uh, especially since we don’t know a whole lot about evolution, well, we think we do, but we really don’t, so anything is possible.” These comments are not unexpected (Ault, 1982; Beaty, 2004; Libarkin & Anderson, 2005; Libarkin et al., 2005; Philips, 1991; Schoon, 1992 & 1995) for the population investigated.

Climate and Weather

The two most commonly missed questions on all versions of the ACES-Q (Leslie, Dockers, & Wavering, 2005 & 2006; Leslie & Wavering, 2009) involved identifying Antarctica’s biome (Question 15) and the weather factors involved in laundry drying effectively on the clothesline (Question 20). Fewer than 15% on all three pilots correctly identify Antarctica as a desert. The most common incorrect response was tundra. Interviews provide insight into the thinking of our preservice teachers.

- “Antarctica is just frozen water.”
- “Tundra means ice.”
- “Antarctica is very cold. It is a tundra.”
- “It’s cold, a tundra. Like Alaska, land of the midnight sun, you know?”
- “Because I am pretty sure tundra is a cold environment.”
- “I don’t remember Antarctica having anything to do with ice.”

One participant correctly identified Antarctica as a desert, but she remains uncertain of her reasoning.

Student: Because Antarctica is a desert.

Researcher: How do you know that?
Student: Because there is land underneath it [the ice]... Scientists kind of argue about this. Some say that deserts lack water. Others say it is because no plants grow there.

The most common factor identified as an influence in laundry drying was humidity. Comments made by participants indicate that they may hold scientific fragments regarding humidity. It is interesting to note that not a single student on the ACES-Q II-R (Leslie & Wavering, 2009) or during the interviews identified sunlight, shade, wind speed, or temperature of the water used to wash the laundry as factors in estimating drying time.

- “Humidity is water in the air.”
- “Humid air is not likely to pull the moisture out of the clothes.”
- “Humidity causes moisture which would make things not dry faster.”

The comments about humidity reflect the fact that relative humidity is one of the most misunderstood terms used to describe moisture in the air (Lutgens & Tarbuck, 2007).

Another climate and weather question, Question 18, asks participants if a severe winter can be predicted by signs in nature. This question provided researchers with a variety of comments:

- “There are tons of predictors that one can use to guess if there was going to be a very cold winter.”
- “I think that insects and the way... [pause and then unclear, in a louder voice] I say yes, yes we can. Because there are things in nature that can determine that.”
- “How much rain we have, how bad the bugs are...”
- “Yes, like the groundhog. And I’ve heard things about acorns or something in the trees being thick, and then about caterpillars or something.”
- “I think maybe animals, ah; it is possible that their coats may grow in more densely...”
- “We can predict the severity of a winter based on using a historical approach, like tree rings, to make predictions.” (Leslie, Zellers, & Wavering, 2010, p. 11-12)
These comments clearly mirror several alternative conceptions found in the literature as well as common folklore. Another student purports that a higher power can impact weather patterns.

*Student:* Yeah, based on the history of science. We’ve been keeping up with writing all this stuff down for a very long time. Yeah, I think you can see some common trends in science, but being able to predict, I’d say probably no.

*Researcher:* Why not?

*Student:* Based on what I know of research it is hard to predict things. And you know there’s [sic] spiritual aspects too. The higher power, and [unclear].

Interviews conducted for the paper Persistence of Meteorological Misconceptions (Zellers & Leslie, 2009) revealed similar alternative conceptions regarding using signs in nature to predict winter:

- “I know the old wives’ tales, you look at the persimmons. If it is a fork, spoon, or knife… but I don’t know what they mean.”
- “I’ve heard about woolly bears. The thicker the caterpillar’s fur, the colder the winter.”
- “The amount of fat on a deer indicates how cold it will be. We always go with that.”
- “If you have a severe or hot summer, you’ll probably have a very frigid winter. We’ve had a mild summer, so we’ll probably have a mild winter.”

According to Page (1977), most weather folklore that can be used to actually forecast the weather are linked to farming and seafaring; these methods are used to predict short term changes in the weather (hours to days), not predictions months into the future. Perhaps the alternative conceptions about organisms being used to predict future weather and climate have their origin in animal based weather folklore.

The alternative conceptions and science fragments present in the interview data are mirrored in the research over the past twenty years (Bar, 1989; Philips, 1991; Schoon, 1995). Interestingly, other patterns from the data emerged as well. Participants with lower scores on the ACES-Q II-R logged the longest interview times at nearly 50
minutes. Conversely participants with high scores averaged 20 minutes for their interviews. This may have been caused in part because students who were uncertain of their answers also had more verbal tics (e.g. ah, er, uhm), had more prolonged pauses, and often changed their answers during their explanations.

Summary

This chapter provided a description of the results of the study. Issues of validity and reliability with respect to the instrument, Alternative Conceptions in Earth Science-A Questionnaire II-R (ACES-Q II-R), were discussed. Discussion of the validity of the instrument included areas of content validity, item validity, sampling validity, and response validity. Several reliability coefficients were calculated for the questionnaire as a whole and for each of the four subtests. These reliability coefficients included Cronbach’s Coefficient Alpha, Kuder Richardson 20 (KR20) and Spearman-Brown split-half coefficient. Instrument reliability was determined to be .62 using the KR-20 and .69 using Cronbach’s Coefficient Alpha. Split-half reliability was calculated twice. Comparing odd numbered questions to even numbered questions resulted in a reliability coefficient of .61. Comparing the first ten questions to the last ten questions resulted in a reliability coefficient of .69. The standard error of measurement was 1.89.

Statistical analysis of the ACES-Q II-R data, as well as the four subtests, revealed differences among all subgroups relative to gender and certification area. A t-test indicated significant differences between gender on the ACES-Q II-R total score (t (78) =-2.35; p=.021). An analysis of variance investigating the impact of certification area and gender on the total score revealed significant differences (F (2, 78) =6.94, p. =.002).
An analysis of variance exploring the impact of the number of science courses taken and gender on the total score failed to reveal significant differences (F(2,84)=2.89, p=.06). Differences among scores relative to gender and certification area were noted on all subtests of the ACES-Q II-R, however the only significant difference (p < .05) revealed was on the Earth’s systems subtest with respect to gender (See Table 4.11.). Gender by certification mean comparisons indicated that male preservice teachers generally outperformed female preservice teachers and secondary and middle school preservice teachers generally outperformed elementary preservice teachers.

In general, participants with higher scores on the ACES-Q II R reported higher confidence and sense ratings. The highest possible rating for confidence and sense scores was 5; the lowest was 1. Despite higher scoring participants reporting higher ratings on these two measures, the confidence (“How sure are you of your answer?”) rating for the 20 items ranged from 2.0 to 3.6 and the sense (“Does this concept make sense to you?”) rating ranged from 2.2 to 3.6. It is possible that these preservice teachers are not confident of their earth science content knowledge and may still be confused by many common earth science concepts.

Qualitative data, including alternate, “write-in” responses, answers to the open-ended question, #21, and eleven participant interviews were reviewed and coded for salient themes. These data identified that our preservice teachers may possess several alternative conceptions in earth science identified in the literature.
Chapter 5:
Discussion & Implications

The purpose of this study was to find evidence of reliability and validity for the Alternative Conceptions in Earth Science – A Questionnaire Revised II (ACES-Q II-R), an instrument to identify alternative conceptions in earth science based on K-12 science standards for Arkansas (Arkansas Department of Education [ADE], 2005) and the nation (National Research Council [NRC], 1996). The study also included identifying possible alternative conceptions held by preservice teachers regarding space science, Earth’s systems, Earth’s history, and climate and meteorology. Additionally, preservice teachers’ confidence levels and understanding of earth science concepts were investigated, as well as the question of whether having alternative conceptions impacts preservice teachers’ pedagogical choices.

This chapter is divided into four sections. The first section discusses the validity and reliability results for ACES-Q II-R. The second section discusses alternative conceptions identified via this study held by preservice teachers in earth science. These alternative conceptions were identified by both the ACES-Q II-R as well as via the interviews. This section also includes a discussion of how confident students are regarding earth science content and whether or not the concepts presented made sense to them. A discussion of the impact of having alternative conceptions on pedagogical choices can be found in section three. The fourth section presents conclusions drawn and implications for instruction and further research and a summary of the study completes the chapter.
Validity and Reliability Implications

The first question guiding this study was: What evidence of reliability and validity exists for the ACES-Q II-R, a two-tiered, multiple-choice instrument used to give insights into what alternative conceptions preservice teachers may hold in the areas of earth science? Evidence has been presented via this report that a two-tier, multiple-choice instrument can be developed to provide valid and reliable information on alternative conceptions in earth science. Validity was ensured by exposing the ACES-Q II-R to the scrutiny of ten experts to establish content validity, including face validity and item validity. Additionally, a rigorous review of the literature and perusal of the national and state science standards (ADE, 2005; NRC, 1996) provided a solid foundation for sampling validity, another component of content validity.

The ACES-Q II-R was found to have a moderate level of statistical reliability for an instrument in the first stages of development. Coefficients calculated for the overall instrument ranged from .61 to .69, approaching Nunnally’s (1970) recommendation of a reliability coefficient of at least .70. Item analysis showed that certain items did not discriminate well between those who scored higher on the questionnaire and those who did not (particularly Question 15 and Question 20). Furthermore, reliability coefficients were calculated for each of the ACES-Q II-R sub tests: solar system, Earth’s history, Earth’s systems, and climate and weather. The reliability of these subsections was found to be rather low; however, it was anticipated due to the reduced number of items and the low discrimination indices for some of the questions. It is expected that these measures can be improved via item modification, the development of new items, increasing the length of each subtest, and determining new alternative conceptions.
Alternative Conceptions

The second question guiding this study was: What alternative conceptions do preservice teachers hold regarding specific earth science concepts based on National Science Education Standards (NSES) (NRC, 1996) and Arkansas State Frameworks (ADE, 2005)? Alternative conceptions in earth science held by preservice teachers were identified in several ways throughout the study. Multiple-choice responses for each of the 20 two-tiered items were analyzed to see which alternative conceptions were chosen by the participants in the study. Additionally alternate write-in responses and answers to Question 21, an open-ended question, were investigated for the presence of alternative conceptions or science fragments. Interviews with 11 participants via the oral version of the ACES-Q II-R also provided a wealth of alternative conceptions.

Data from the means (Table 4.9) and correct responses for each question (Table 4.8) indicated that these preservice teachers, regardless of certification level or total number of science courses taken, were familiar with less than half of the content covered on the instrument; and that they may still hold alternative conceptions in various areas of earth science appropriate for K-12 learners. The overall average on the ACES-Q II-R was 7.2 out of 20 questions. These findings are similar to Libarkin and Andersons’ (2005) results on the Geoconcepts Inventory as they reported that participants in their study scored an average of seven out of 20 questions. Areas that these preservice teachers experienced the most difficulties with included: sun angle, lunar phases, seasons, Earth’s gravity, rocks and minerals, biomes, climate, and weather prediction. The following subsections, mirroring the subtests on the ACES-Q II-R, describe this study’s
findings as well as similarities to current literature. Findings shared were evidenced in the results of the written and oral forms of the ACES-Q II-R.

**Solar System**

Astronomy just might be one of the most popular areas of alternative conception research. Studies about Sun, Earth, and Moon relationships have appeared for the past several decades (Baxter, 1989; Callison & Wright, 1993; Cohen & Kagan, 1979; Trumper, 2001a & 2001b; Schoon, 1995; Trundle, Atwood, & Christopher, 2002, 2003, & 2006). The first six questions of the ACES-Q II-R covered topics associated with astronomy and space science. (Refer back to Table 4.8 for percentage of correct responses and mean confidence and sensibility scores for the following discussion.)

The first two questions of the ACES-Q II-R asked the participants to indicate what season and what time of day best corresponds with a child’s shadow. It was interesting to note that only 34.5% of the participants correctly identified winter as providing the longest shadow while 62.1% of participants correctly identified that a child’s shadow would be longer earlier or later (closest to sunrise or sunset) in the day due to the decreased angle of the sun. The mean confidence score (How sure are you of your answer?) and mean sensibility score (Does this concept make sense?) for the first question was nearly 0.5 lower on the first question than the second question possibly indicating that students were less familiar with this topic. It can be concluded that while over half of the preservice teachers in this study have connected the Sun’s angle with time of day, that many (nearly 70%) have not yet made the connection to sun angle and seasonal changes?
Alternative conceptions revealed by these questions via the interview and questionnaire included “seasons are caused by the distance between the Earth and Sun” and the “Sun is directly overhead at noon.” Interesting to note was that just over one-fifth (20.7%) of the participants indicated that the longest shadow would be cast with the Sun directly overhead. This secondary alternative conception (Schoon, 1995) is mirrored in the literature (e.g. Adams, 2008; Atwood & Atwood, 1995; Baxter, 1989; Jones, Lynch, & Reesink, 1987; Zeilik & Bisard, 2000).

The next two items in the ACES-Q II-R asks interns to share their understanding of lunar motion and phase changes. While 63.2% agreed that observers on Earth could only see one side of the Moon, only 39.1% of the participants correctly indicated that the Moon’s rotational period was nearly the same as its rotation. And fewer than half (46%) of our participants were able to predict the Moon’s phases based on its relative position to the Earth and Sun. It is important to note here that a popular misconception “the Earth will cast a shadow that will cover the moon resulting in a new Moon” was chosen by over 30% of our preservice teachers. This alternative conception is common among preservice teachers and children alike (Dove, 2002; Rider, 2002; Schoon, 1995; Stahly, Krockover, & Shepardson, 1999; Trumper, 2001a & 2001b; Trundle, 1999). Additional alternative conceptions revealed in the interviews included “the Moon does not rotate” and “the Moon is stationary and the Earth rotates.”

Item five asked participants to predict the season based on a diagram indicating an Earth and Sun relationship. The northern hemisphere has been indicated by the letter ‘N’. While 51.7% chose the correct answer “summer” only 33.3% chose the scientific explanation. Another popular alternative conception, “the Earth is closer to the Sun in
"the summer time resulting in warmer temperatures” was chosen by 26.4% of our preservice teachers. During the course of the interviews responses several science fragments were shared: “it has to do with the Earth’s rotation, ah, which way the Earth’s pointed on its axis” and “the tilting of the Earth [subject’s hand is tilted and indicates that as the Earth travels around the sun, the tilt of the axis flip flops back and forth].” These are fairly common alternative conceptions and science fragments of both children and adults found in literature (Atwood, 1996; Baxter, 1989; Callison & Wright, 1993; Schoon, 1995; Trumper 2001a & 2001b).

Item six asked participants to indicate where on a diagram the bowling ball will end once it is dropped in relation to the earth. Roughly half (50.6%) of our sample chose the correct answer. While over half of the participants chose the scientific reason for the bowling ball to end at the center of the earth, the second most popular choice (nearly 20%) was that the law of inertia would allow the bowling ball to keep moving until acted on by an outside force. However, nearly 20% chose answers that are more popular among school children: falling ‘down’ and landing inside of the ‘hole’ or falling ‘down’ away from the Earth. All three of these secondary alternative conceptions have been identified in the literature (e.g. Bar, Sneider, & Martimbeau, 1997; Baxter, 1989; Nussbaum, 1979; Nussbaum & Novak, 1976). An interesting comment made by one interviewee, “people on the other side, their gravity doesn’t work the same way ours does. So theoretically it [bowling ball] would probably drop and hit the side” sums up the beliefs of several participants interviewed, believing that somehow, gravity on the far side of the Earth does not work in the same manner as on this side of Earth. It was
evident that several of the preservice teachers' understanding of the Earth as a cosmic body and gravity are similar to those of the children they will eventually teach.

**Earth’s Systems & History**

The next eight items covered areas of Earth’s systems and Earth’s history. Several content area gaps and possible alternative conceptions may have been illuminated via these questions. While the majority of our preservice teachers correctly chose Topaz (Question 8) as being hard enough to scratch glass, over a quarter of the participants indicated that diamonds were the only minerals hard enough to scratch glass (Beatty, 2004; Philips, 1991; Schoon, 1995; Ucar, Trundle, & Krissek, 2006). Additionally, one interviewee suggested, “quartz would have gone through the glass.” Over half of our participants did not correctly identify sedimentary rock as having fossils, indicating that igneous and metamorphic rock (despite the way they are formed) also contain fossilized plants or animals. This particular finding supports Stofflett’s (1993) study. One hundred and eleven preservice teachers were unable to differentiate between sedimentary, igneous, and metamorphic rocks. An alternative conception unearthed in the interview data is that fossils grow. “Igneous is made from volcanic [pause], ah, I don’t think that fossils can grow [in igneous rock].”

Question 10 asked participants to indicate whether the Gulf waters might be more or less salty than the waters surrounding Hawaii. This was a yes or no question and the answers were nearly split in half. Interestingly, so were each of the four reasons—receiving approximately 21% to 29% of the responses. Fewer than 30% of the participants correctly answered this question (both a correct answer and a correct reason must be provided for a correct answer). It is possible, due to the distribution of answer
and reason choices as well as having the lowest confidence mean scores and the second lowest sensibility mean, that many participants may have just guessed. Several students mentioned via the interviews that the shape of the gulf might promote an environment for higher salinity of the water as illustrated in the following interview excerpt, “you must look at the shape of the gulf” and “there’s not much open water for it [salt] to have an opportunity to dissipate in or drain out in.”

Question 13 asked students to indicate whether it was possible for the Amazon River to flow west to east? Just over half (52.9%) indicated that yes, the Amazon River may flow from west to east because “rivers form by eroding channels, taking the path of least resistance, regardless of cardinal direction.” Conversely, the other half of participants chose answers such as “all rivers flow ‘down’, from North to South because of gravity” (10.3%), “rivers in the Southern Hemisphere flow from south to north” (5.7%), and the most popular of the alternative conceptions chosen, “the Coriolis Effect causes water to flow in a different direction in the Southern Hemisphere” (29.9%). Interview data revealed two alternative explanations to those present in the literature or identified via the ACES-Q II-R. The first stating that all rivers flow west to east and the second attributing the flow of a river to weather patterns, and that the Amazon flowing from west to east was likely because weather patterns move from west to east. The last comment shedding light on a possible alternative conception or science fragment related to meteorology.

While approximately half of our preservice teachers answered Question 14 regarding dinosaurs and man correctly, this question received the most ‘write in’ responses of any of the twenty items. It also stimulated the most discussion on the
interviews. As mentioned earlier, students were given multiple choices for the answers and reasons to each of the questionnaire items. If they did not like the choices available, they were encouraged to write their own response. Responses for this item were varied. “Some scientists say humans died; others say they hid in caves during the ice age,” indicates this participant’s belief that it was the ice age that killed dinosaurs and that people survived by living in caves. Other participants were concerned with the term “human” as indicated by these responses: “people are defined as what homo erectus, habilis, etc…?” and “maybe not humans but some form of sapiens”. Most interesting were those that insisted that this item was a question of religion, and not science: “Religion versus science”, “with God anything is possible”, and “my church teaches that God created man first and therefore he named the dinosaurs”. These ‘write-in’ responses were mirrored in the interviews with comments like “… the Earth was created in seven days and that humans and dinosaurs were created on day six, or day four, and that they lived together in the Garden of Eden” and “Adam and Eve, according to my religion, were the first living, breathing things, and dinosaurs came after that, according to my religion.” Rice (2005) sums it up nicely “…this finding is perhaps reflective of conservative religious beliefs common to the region of the U.S. where these data were collected” (p. 1070).

Weather and Climate

The last items on the ACES-Q II-R covered concepts related to Earth’s weather and climate. Answers and responses to these questions also indicated several content area gaps and possible alternative conceptions. Question 15 has appeared on each version of the ACES-Q (Leslie, Dockers, & Wavering, 2005 & 2006) and asks
participants to identify Antarctic’s biome. Only 12.6% of participants successfully did this, linking the term desert with precipitation and not temperature. These findings closely mirror those of the ACES-Q (11%) and the ACES-Q II (14.4%). Interviews provided insight into the thinking of these preservice teachers: “Antarctica is just frozen water,” “Tundra means ice,” and “I don’t remember Antarctica having anything to do with ice.” These comments illustrate preservice teachers’ uncertainty regarding Antarctica’s biome.

Preservice teachers also struggled with the water cycle (Question 16), water pressure (Question 17), and atmospheric pressure (Question 19). Over half of the preservice teachers participating in this study indicated that the severity of winter (Question 18) could be predicted based on animal coverings, extreme summer heat, or plant coverings, making this a primary alternative conception (Schoon, 1995). A popular sentiment of the participants interviewed can be summarized by, “yes, like the groundhog, and I’ve heard things about acorns or something in the trees being thick, and then about caterpillars or something.” Nearly 12% of the participants indicated that only scientists could predict the extremity of a winter based on their calculations on the distance between the Earth and the Sun! Again, reiterating the common alternative conception that seasons are caused by the distance between the Earth and Sun (Atwood & Atwood, 1996; Callison & Wright, 1993; Gunstone & White, 1980; Matteson & Kambly, 1940; Stein, 2007; Tsai & Chang, 2005).

The last two-tiered, multiple choice item on the ACES-Q II-R (Question 20) asked students if they could predict the speed of laundry drying. This question, like Question 15 (Antarctica) was one of the most often missed questions. The most popular
reason chosen (75.3%) from those provided on the instrument was “The relative humidity or amount of water vapor in the air, in Florida is much higher… Thus slowing the drying of laundry.” This was true for the interview data as well. The most common factor identified as an influence was humidity. Comments made by participants indicate that they may hold science fragments regarding humidity: “humidity is water in the air;” “humid air is not likely to pull the moisture out of clothes;” and “humidity causes moisture which would make things not dry faster.” These comments about humidity reflect the fact that relative humidity is one of the most misunderstood terms used to describe moisture in the air (Lutgens & Tarbuck, 2007). It is interesting to note that not a single student identified sunlight, shade, wind speed, or temperature of the water used to wash the laundry as factors influencing the drying time of laundry.

Alternative conceptions in meteorology may exist for a variety of reasons including experience (not hearing thunder when seeing lightning), inadequate vocabulary (using the terms reflection and refraction instead of scattering to explain sky color), and oversimplification of concepts such as relative humidity. It is clear that regardless of the preservice teacher’s certification area, undergraduate degree, or age, that gaps in basic earth science are evident and that alternative conceptions indicated in the literature also exist in this sample.

Confidence and Understanding

The third question guiding this study was “how confident are preservice teachers in their earth science understandings and/or with the alternative conceptions they may hold?” In attempting to answer this question, indications of confidence and understanding of concepts (Table 4.8) were investigated. Each of the 20 two-tiered,
multiple-choice items on the ACES-Q II-R was followed by two Likert scales. The first, a measure of confidence, asked participants to rate how sure they were of their answer. A score of 1 indicated that the participant was making a blind guess and a 5 indicated that they were sure they were correct. Additionally the second Likert scale served as a measure of understanding or “sensibleness” and asked participants to rate whether the concept made sense to them or not. A score of 1 indicated that the concept made no sense to the participant and a score of a 5 indicated that the concept made perfect sense to the participant. Our participants overall expressed a lack of confidence in their answers and a lack of understanding of many of the concepts presented on the ACES-Q II-R. The average confidence score was 2.7 and the average sensibility score was 2.8. This indicated that the participants were not particularly sure of their answers nor were the concepts completely familiar to them. It is important to remember that most of the concepts included on the ACES-Q II-R were present in the K-4 and 5-8 Earth science standards for both the nation and Arkansas. Regardless of whether these preservice teachers participated in an earth science course during their undergraduate coursework, they are expected to not only be familiar with these concepts but to have mastered them.

There was a significant (p < .05) slight positive correlation (0.42 and 0.41 respectively) between an individual’s confidence and understanding scores possibly indicating that the more a concept makes sense to the individual, the more certain they are of their answers and responses. It is interesting to note that the two questions with the lowest percentage of correct answers and responses (Question 15 and Question 20) had the highest overall confidence and sense scores. This may reinforce the finding that
alternative conceptions are not only prevalent, but they are quite resistant to change (Franklin, 1992; Wandersee, Mintzes, & Novak, 1994).

At first these findings seem disheartening. However, Kuethe (1963) has a positive take considering regarding the mean score of 7.2 out of 20 on the ACES-Q II-R and the low confidence and sense ratings, “when a student replies ‘I do not know’ he is much more likely to investigate further than is the student who believes that he has full understanding” (p. 364). It is hoped that the low confidence scores of these preservice teachers are an indication that they are aware of their lack of understanding and will continue seeking out opportunities to gain content knowledge in earth science.

Implications on Pedagogy

The fourth question guiding this research was “does having alternative conceptions impact preservice teachers’ pedagogical choices?” Evidence for this question was gathered by analyzing the responses to the open-ended question on the ACES-Q II-R. Question 21 asked participants how they would teach about a solar eclipse to the grade level of their choice. Responses were coded for salient themes. These themes were divided into statements about content knowledge (including possible alternative conceptions or science fragments) and pedagogy choices (approaches employed when presenting the topic to a group of students) (See Table 4.17.).

While data from this report suggests that there may be a connection between content knowledge and pedagogical choices, the connection is tenuous at best. Students with higher scores on the ACES-Q II-R were more likely to admit that they needed to research the topic more fully before teaching it. These students were also more likely to
choose pedagogical approaches that included using models, hands-on activities, and video. Students with lower scores on the ACES-Q II-R were more likely to share science fragments and to employ pedagogical approaches that included lectures, pictures, and diagrams.

To further investigate this relationship between science content knowledge and alternative conception and their impact on pedagogical choices a study involving lesson plan analysis is suggested. Perhaps investigating more detailed accounts of lessons, either planned or executed, will give researchers more insight to the pedagogical choices made by teachers in the science classroom.

Conclusions

Identification of alternative conceptions is essential for the development for a scientifically literate society. Preservice teachers, K-12, in Arkansas will be responsible for teaching many of the concepts presented on the ACES-Q II-R. However, without proper instruction and attention given to these alternative conceptions, these preservice teachers are likely to pass on alternative conceptions to their students. Science educators are charged with the responsibility of promoting a scientifically literate citizenry. With this in mind, having preservice teachers with alternative conceptions in common earth science standards, both national and state, poses a serious threat to our nation’s scientific literacy.

Assuming that preservice teachers get the content and pedagogy necessary to teach earth science in their undergraduate science and pedagogy courses is unacceptable. The preservice teachers participating in this study will be responsible for teaching the topics presented on the ACES-Q II-R, so it is not unrealistic to expect them to possess
both a scientific understanding of the concepts as well as confidence in their content knowledge. Therefore raising awareness of common alternative conceptions in earth science with science professors, science educators, and public school teachers makes sense.

Rich insights into the understandings and beliefs of preservice teachers regarding common earth science topics, many found mirrored in current research and others new to this researcher were illuminated via the instrument and the 11 interviews. This investigation adds to the growing body of research being conducted on alternative conceptions in science and more specifically, earth science. It also raises the awareness that our preservice teachers may not be acquiring the required content knowledge necessary for successful teaching in their content and/or pedagogy courses.

Alternative conceptions, if not addressed, may remain unchanged and often impede the learning of new material. Research shows that people tend to distort new rules to fit their misconceptions or they ignore them entirely “except in the highly specific domains in which they were taught” (Franklin, 1992, p. 4-5). More importantly, an understanding of alternative conceptions held by preservice teachers is vitally important as teachers have a tendency to avoid teaching things that they do not fully understand (Hashweh, 1987); and therefore, may pass on alternative conceptions by omitting the content from the curriculum or by choosing unworthy representations of the concepts being taught. Additionally, alternative conceptions can be directly transmitted from teacher to student as facts.
Implications for Future Research

The findings and conclusions of the study lead to several recommendations for future research. One recommendation for a future study is to refine several of the items on the ACES-Q II-R to improve overall reliability, as well as the development and validation of additional items via continued research of alternative concepts in earth science and further study of the National Science Education Standards (NRC, 1996) and Arkansas State Frameworks (ADE, 2005). Continued refinement and research and increasing the number of items on the ACES-Q II-R will increase its reliability and validity.

Currently there is little research on the impact of alternative conceptions on planning and implementing instruction in the K-12 classroom. A thorough study involving the identification of alternative conceptions and content knowledge of preservice or in-service teachers and subsequently an evaluation of their lesson plan development and implementation may reveal insight into the connections between having alternative conceptions in science and instructional choices.

A third suggestion calls for further investigation into the teaching methods employed in the general science courses taken by preservice teachers. The intent of this suggestion is two-fold. The first and most obvious: Are these science instructors and professors aware of the alternative conceptions and other learning barriers that their students may have before instruction? The second involves forging alliances between education and science departments across colleges and universities for the mutual benefit of all involved. One such endeavor documents the development of a multiple-choice, two-tiered instrument to identify alternative conceptions in meteorology and the impact
this awareness has had on the science and education professors participating in this process. (Leslie & Zellers, 2010; Zellers & Leslie, 2009 & 2010).

Summary

This study was a snapshot, a single look, into what preservice teachers pursuing elementary, middle, and secondary school certification know regarding common earth science concepts. The findings of this study, from a mean score of roughly 7/20 (Libarkin & Anderson, 2005), reliability indices ranging from 0.61 to 0.69 (Franklin, 1992; Haslam & Treagust, 1987), and alternative conceptions identified (e.g., Atwood & Atwood, 1995 & 1996; Ault, 1982; Callison & Wright, 1993; Stein, 2007; & Trumper, 1999, 2001a, & 2001b) by both the instrument and interviews are consistent with findings in the literature. However, the extent of the impact of preservice teachers having alternative conceptions is still unknown.

This study provided evidence on the effectiveness of developing and validating a two-tiered, multiple-choice instrument to identify alternative conceptions. While the results of this study indicated that using a paper and pencil instrument can be an effective method of identifying alternative conceptions in Earth science the extent of these alternative conceptions is unknown. Nevertheless, this study clearly provides a basis for predicting the alternative conceptions held by other groups of preservice teachers. Using future research to confirm these findings will lend validity and reliability to this study. It will also allow for the generalization of these findings to a larger population.
References


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Bibliography


Appendix A:

Alternative Conceptions in Earth Science – A Questionnaire

ACES-Q
Alternative Conceptions
In Earth Science - A Questionnaire

November 2004

Dear Participant,

Thank you for agreeing to participate in this study. This study is designed to unearth what preservice teachers know about earth science. By completing this questionnaire, you are implying your consent to participate in the study. Anonymity is guaranteed. You may withdraw from this study at any point by contacting the investigators and requesting such.

Please write the number located in the top right hand corner of your answer sheet at the bottom of this letter. This will be the only way we can identify your answer sheet if you choose to withdraw at a later date.

If you have any further questions, please do not hesitate to contact us. And again, thank you for your time.

Katherine Leslie
Jean Dockers
Michael Waver
waver@uark.edu
575-4283

Alternative Conceptions
In Earth Science - A Questionnaire

Instructions:

This is a questionnaire to determine your understanding and beliefs about several Earth science topics. With each question, a situation will be described and a question will be asked. You will then be asked to choose the best answer from several choices as well as a reason for your answer. If you do not find an answer or reason that you agree with, use the blank space on your answer sheet for your own alternate responses.

You will be asked to rate how sure you are about your responses by choosing a number on a scale (5= very sure...1= blind guess). Circle the number that best indicates how sure you are of your response on the answer sheet where you see “Sure? 5 4 3 2 1”.

You will be asked to rate whether the responses you chose make sense to you by choosing the number on a scale (5 perfect sense....1 no sense). Circle the number that best indicates how much sense it makes to you on the sheet where you see “Sense? 5 4 3 2 1”.

Please do not write in this booklet.
Sample Question:

Joe noticed it gets dark, what is he experiencing?

Answers:
1) It is day.
2) It is night.

Reasons:
A) The sun rises in the east and sets in the west.
B) Apollo drives the sun across the sky in his chariot.
C) The earth rotates on its axis once about every 24 hours.
D) The earth revolves around the sun in one day.

I'm Sure I'm Right  5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense  5 4 3 2 1 It Makes No Sense

Question 1:

Based on the diagram above what season is it in Arkansas?

Answers:
1) Winter
2) Spring
3) Summer
4) Autumn

Reasons:
A) The Earth's orbit is an ellipse and the earth is closer to the sun in summer and farther from the sun in winter.
B) The Earth is tilted 23 1/2 degrees. This tilt causes the sun's rays to be dispersed more during the winter and focused more in the summer.
C) The sun shines on only one half of the Earth at any one time.
D) The Earth is neither tilted toward nor away from the sun. The seasons are caused by length of daylight.

I'm Sure I'm Right  5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense  5 4 3 2 1 It Makes No Sense
Question 2:

It is a cloudless day and Susie looks up at the sky. What color is it?

Answers:
1) Blue
2) Green
3) Turquoise
4) White

Reasons:
A) Photons are scattered by pollution in the atmosphere causing color shift.
B) Light passing through dust in the atmosphere is absorbed, while one of the above light colors and ultraviolet light are reflected.
C) Light is reflected by oceans and lakes on the earth which reflects the color of the water into the sky.
D) The color of the sky is a reflection of the atmosphere from above.

I’m Sure I’m Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense

Question 3:

Imagine a hole through the Earth from Fayetteville to Beijing. Bubba stands at the hole and drops a bowling ball into the hole. Where does the bowling ball stop?

Answers:
1) Beijing
2) The center of the Earth
3) It falls to Beijing returning to Fayetteville in a continuing pattern slowing until it stops at the center of the Earth.
4) Fayetteville

Reasons:
A) The Earth’s gravity pulls on everything at or near the Earth’s surface. This pull is always directed down toward the center no matter where on the Earth the object is located.
B) Gravity causes the bowling ball to fall in a straight line.
C) The law of inertia states that an object in motion stays in motion until acted on by an outside force.
D) The rotation of the earth causes the bowling ball to return to its original position in Fayetteville.

I’m Sure I’m Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense
Question 4:

Kat pours herself a glass of water. She asks her third graders what would happen to ice if she added it to the glass. Her students gave several different answers, which one is correct?

Answers:
1) The ice will float, changing the water level.
2) The ice will sink, raising the level of the water.
3) The ice will stick to the sides of the glass.
4) The ice will hover in the middle of the drink.

Reasons:
A) The temperature of the ice is significantly less than the water it is in. This difference in temperature affects the position of the ice in the drink.
B) Ice has air pockets locked inside causing it to weigh less than the water.
C) The crystalline structure of the ice causes it to be less dense than the water.
D) The surface area of the ice causes it to suspend itself in the water.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense

Question 5:

David wins a trip to Antarctica. He wants to learn more about the environment he will encounter. What biome should he investigate?

Answers:
1) Desert
2) Tundra
3) Grassland
4) Aquatic

Reasons:
A) Deserts receive very little precipitation in the form of rain or snow fall.
B) Grasslands have a wide variety of plant life that would support the diverse wildlife population that lives in Antarctica.
C) Tundra is characterized by frost molded landscapes and extend to the poles in the Northern Hemisphere.
D) Aquatic biomes are mostly water and make up 75% of the earth.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense
Question 6:

Emilio finds himself standing on a bank of the Amazon River. His compass indicates that the water is flowing west to east. Is his compass malfunctioning?

Answers:
1) Yes
2) No

Reasons:
A) All rivers flow down, from north to south, as aided by the force of gravity.
B) The Coriolis effect causes the water to flow in different directions depending on the position of the continent in the hemisphere.
C) Rivers form by eroding channels in the side of mountains by flowing toward the valley, taking the path of least resistance regardless of cardinal direction.
D) Rivers flow south to north in the Southern Hemisphere.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense

Question 7:

Mike attempted to break into the library by cutting through the glass door using information he learned in geology class. He finally gave up and ran away after the alarms were triggered. The university police found scratches on the window and traces of a mineral on the ground by the window. Using the Mohs hardness scale, what mineral could it have been?

Answers:
1) Fluorite
2) Topaz
3) Calcite
4) All of the above

Reasons:
A) All minerals that rate a 6 or higher on the Mohs hardness scale will scratch glass.
B) Calcite is a very strong mineral and has been known to scratch hard surfaces.
C) Fluorite makes up fluoride which makes teeth hard, therefore will scratch glass.
D) Mohs hardness scale has nothing to do with a minerals ability to scratch glass. All minerals will scratch glass.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense
Question 8:

Suzie is walking along the banks of Richland Creek. This area is known to be rich in fossils of trilobites, crinoids, and other ancient sea-faring creatures. Suzie bends to retrieve a particularly fascinating rock containing several impressions of crinoids. What kind of rock is Suzie most likely holding?

Answers:
1) Igneous
2) Metamorphic
3) Plutonic
4) Sedimentary

Reasons:
A) Seventy-five percent of the rocks on the earth’s surface are metamorphic.
B) Sedimentary rocks form strata, or layers, of sediment deposited in oceans or lakes.
C) Igneous rocks are formed beneath the earth’s surface, where plant and animal remains can be found.
D) Plutonic rock forms deep in the earth as molten lava.

I’m Sure I’m Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense

Question 9:

Martha has traveled extensively. Her favorite places to visit are sandy beaches around the world. One afternoon while drying in the warm sun of Gulf Shores, Alabama, Martha reflects on the saltiness of the gulf waters. If her memory serves her well, are the gulf waters saltier than the waters surrounding Hawaii?

Answers:
1) Yes
2) No

Reasons:
A) Gulf waters are much saltier than most other seas due to the influx of minerals coming from the Mississippi River.
B) Ocean waters in warm areas that receive little rain fall tend to have higher salinity due to evaporation.
C) In areas of the world where a great deal of fresh water flows into the ocean (e.g. Congo River, Amazon River), the fresh water mixes with the ocean water to reduce the salinity.
D) Both B and C.

I’m Sure I’m Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense
Question 10:

As a child, Jean remembers playing in the run-off channels around Fayetteville, AR. Despite the drought of the past few years, Jean feels she cannot allow her children to play in the run-off because there seems to be much more water in the channel after a rain since the city has developed and grown in the past 20 years. Is Jean being overly cautious with her children?

Answers:
1) Yes
2) No

Reasons:
A) Jean is being overly cautious. Several esteemed meteorologists have commented on the obvious lack of rain in Fayetteville over the last five years calling it a drought to remember.
B) Jean is being overly cautious. It has been 20 years since she played in the channels. Improved water management have led to controlled amounts of water in the channels.
C) Jean is not being overly cautious. Run-off is affected by many factors in addition to amount of rainfall, including surface characteristics and vegetation.
D) Jean is not being overly cautious. Water in the channels comes from many places not just Fayetteville.

I’m Sure I’m Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense

Question 11:

Use space on your answer sheet to write your response to the following situation.

How would you teach the following earth science concept to your favorite grade level?

Topic: Solar Eclipse

Guidelines:
1) Make sure you state what grade level you are addressing.
2) Include a full description of any teaching strategies, activities, and/or materials you might use.
Appendix B:

Alternative Conceptions in Earth Science –

A Questionnaire II

ACES-Q II
ACES-Q II

Alternative Conceptions
In
Earth Science -
A
Questionnaire

By
K. Leslie, J. Dockers, and M. Wavering

University of Arkansas
Curriculum and Instruction
2005
Dear Participant,

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You will be asked to rate how sure you are about your responses by choosing a number on a scale (5 = very sure... 1 = blind guess). Circle the number that best indicates how sure you are of your response on the answer sheet where you see “Sure? 5 4 3 2 1.”

You will be asked to rate whether the responses you chose make sense to you by choosing the number on the scale (5 = perfect sense... 1 = no sense). Circle the number that best indicates how much sense it makes to you on the sheet where you see “Sense? 5 4 3 2 1.”

Please do not write in this booklet.
Sample Question:

Miss Boka pours herself a glass of water. She asks her third graders what would happen to ice if she added it to the glass. Her students give several different answers, which one is correct?

Answers:
1) The ice will float, raising the water level.
2) The ice will sink, lowering the water level.
3) The ice will float, lowering the water level.
4) The ice will hover in the middle of the drink and there will be no water level change.

Reasons:
A) The temperature of the ice is significantly less than the water it is in. This difference in temperature affects the position of the ice in the drink.
B) Ice has air pockets locked inside causing it to weigh less than the water.
C) The crystalline structure of the ice causes it to be less dense than the water.
D) The surface area of the ice causes it to suspend itself in the water.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense
Question 1:

Desmond measures his shadow at noon for several months. He notices that as the year progresses his shadow
lengthens and then shortens. Desmond realizes that he might be able to correlate the season based on the length of
his shadow. What season is it in figure B?

Answers:
1) Winter
2) Spring
3) Summer
4) Fall
5) Impossible to tell!

Reasons:
A) It is impossible to tell. Seasons are caused by the distance between the Earth and the sun.
B) The sun is higher in the sky causing Desmond to cast a longer shadow.
C) The sun is lower in the sky causing Desmond to cast a longer shadow.

I’m Sure I’m Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense

Question 2:

Ursula, Desmond’s sister, decides to measure her shadow every two hours for one day. At what point or points is
Ursula’s shadow the longest?

Answers:
1) 8 AM and 4 PM
2) 10 AM and 2 PM
3) Local noon
4) Impossible to tell!

Reasons:
A) The sun reaches its zenith, or highest point
   in the sky, at local noon. Due to the in-
   creased angle of the sun, Ursula will cast a very long shadow.
B) It is impossible to tell without knowing what day of the year it is.
C) As the sun rises or sets it casts shadows of the greatest length. This is because of the decreased angle of the
   sun in relation to the earth.

I’m Sure I’m Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense
Question 3:

Bob notices that regardless of what phase the moon seems to be in, he always seems to see the same side of the moon. He wonders if this could possibly be true.

True or False? Observers on Earth never see the far side or back of the lunar surface.

Answers:
1) True
2) False

Reasons:
A) The moon orbits the Earth in approximately 29 days. Over this period of time, observers are able to watch the moon change “shapes” or phases. Because of this we are able to see 100% of the moon.
B) Only half of the moon is lit at any time. This is the side we see. The “back side” or “dark side” of the moon never receives sunlight.
C) The moon rotates, or spins on its axis, so quickly that we only seem to see half of the moon.
D) The moon does not rotate, or spin on its axis, therefore an observer on Earth will always see the same side of the moon.
E) The moon rotates, or spins on its axis, once in about 29 days. The moon also takes approximately 29 days to orbit the Earth. Because the period of the moon’s orbit is nearly the same as its rotation, observers on Earth will only see one side, or half, of the moon.

I’m Sure I’m Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense

Question 4:
The moon seems to change shapes as it orbits the Earth. To an observer on Earth, what phase would she see if the moon was in position C?

Answers:
1) New Moon
2) Full Moon
3) 1st or 3rd Quarter Moon

Reasons:
A) Only half of the moon is lit (illuminated) at a time so an observer on Earth would see a “half moon” or quarter moon.
B) The Earth’s shadow will cover the moon so an observer on Earth will see “no moon” or a new moon.
C) The illuminated side of the moon is fully visible to the observer. She will see a full moon.

I’m Sure I’m Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense.
Question 5:
According to the diagram below, what season is Arkansas experiencing in position C?

Answers:
1) Winter
2) Spring or Fall
3) Summer
4) Impossible to tell!

Reasons:
A) It is impossible to tell. More data is needed.
B) The Earth travels in an elliptical orbit causing it to be closer to the sun at certain times of the year. It is winter when the Earth is farther from the sun and summer when the Earth is closer to the sun.
C) The Earth is neither tilted toward or away from the sun. The seasons are caused by the length of daylight.
D) The Earth is tilted 23 1/2 degrees. This tilt causes the sun's rays to be dispersed more during the winter and focused more during the summer in the northern and southern hemispheres.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense

Question 6:
Which of the following man-made structures is most likely to be damaged by acid rain?

Answers:
1) Granite Monument
2) Marble Tombstone
3) Slate Roof

Reasons:
A) Marble is a metamorphic rock. It was formed using a great deal of heat and pressure, because of this there isn't anything stronger.
B) Slate is considered the lowest grade of metamorphic rock, therefore it is unlikely to hold up against acid rain.
C) Marble would be particularly susceptible to acid rain because it is made of calcite which is easily dissolved in acid.
D) Granite contains large amounts of silicates and would be susceptible to acid rain because silicates are readily dissolved in acids.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense
Question 7:
Stephen attempted to break into the library by cutting through the glass window using information he learned in geology class. He finally gave up and ran away after the alarms were triggered. The university police found scratches on the window and traces of a mineral on the ground by the window. Using the Mohs Hardness Scale, what mineral could it have been?

Answers:
1) Fluorite
2) Topaz
3) Calcite
4) All of the above
5) None of the above

Reasons:
A) All minerals that rate a 6 or higher on the Mohs Hardness Scale will scratch glass.
B) Calcite is a very strong mineral and has been known to scratch hard surfaces.
C) Fluorite makes up fluoride which makes teeth hard, therefore will scratch glass.
D) Mohs Hardness Scale has nothing to do with a mineral’s ability to scratch glass. All minerals will scratch glass.
E) It had to be a diamond; only diamonds are hard enough to scratch glass.

It Makes Perfect Sense 5 4 3 2 1 Just A Blind Guess
It Makes No Sense

Question 8:
Suzy is walking along the banks of the Richland Creek. This area is known to be rich in fossils of trilobites, crinoids, and other ancient seafaring creatures. Suzy bends to retrieve a particularly fascinating rock containing several impressions of crinoids. What kind of rock is Suzy holding?

Answers:
1) Igneous
2) Metamorphic
3) Plutonic
4) Sedimentary

Reasons:
A) Seventy-five percent (75%) of the rocks on the Earth's surface are metamorphic.
B) Sedimentary rocks form strata, or layers, of sediment deposited in oceans and lakes.
C) Igneous rocks are formed beneath the Earth's surface where plant and animal remains can be found.
D) Plutonic rock forms deep in the Earth as molten lava.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense
Question 9:

David wins a trip to Antarctica. He wants to learn more about the environment he will encounter. Which one of the following library books would be the most helpful?

Answers:
1) Deserts of the World
2) Explore the Tundra
3) Peaceful Grasslands of the Southern Hemisphere
4) Discover the Aquatic!

Reasons:
A) Antarctica is a desert because it receives very little precipitation in the form of rain or snow fall.
B) Antarctica is one of the most diverse continents. Grasslands have a wide variety of plant life that would support the diverse wildlife population that lives in Antarctica.
C) Antarctica is a frozen wonderland of diverse plants and animals. Tundra is characterized by frost molded landscapes and extends to the poles in the Northern Hemisphere.
D) Antarctica is made mostly of ice, which is frozen water. Aquatic biomes are mostly water and make up approximately 75% of the earth.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense

Question 10:

During which of the following processes in the water cycle do water molecules absorb energy?

Answers:
1) Condensation
2) Precipitation
3) Evaporation
4) Run Off

Reasons:
A) Evaporation is an endothermic, or heat absorbing, process where molecules of water change from a liquid to a gas.
B) Condensation is an endothermic, or heat absorbing, process where molecules of water change from a gas to a liquid or a solid.
C) Precipitation is an exothermic, or heat releasing, process where molecules of water become heavy and fall.
D) Run off is an endothermic, or heat absorbing, process where molecules of water move toward each other.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense
Question 11:

As a child, Nancy remembers playing in the run-off channels around Fayetteville, Arkansas. Despite the drought of the past few years, Nancy feels she cannot allow her children to play in the run-off because there seems to be much more water in the channel after a rain since the city has developed and grown in the past 20 years. Is Nancy being overly cautious?

Answers:
1) Yes
2) No

Reasons:
A) Nancy is being overly cautious. Several esteemed meteorologists have confirmed the obvious lack of rain in Fayetteville over the past few years, marking it as a “drought to remember.”
B) Nancy is being overly cautious. It has been 20 years since she played in the channels. Improved water management has lead to controlled amounts of water in the channels.
C) Nancy is not being overly cautious. Water in the channels comes from many places, not just Fayetteville.
D) Nancy is not being overly cautious. Run-off is affected by many factors in addition to amount of rainfall, including surface characteristics and vegetation.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense

Question 12:

Marta has traveled extensively. Her favorite places to visit are sandy beaches around the word. One afternoon while drying in the warm sun of Gulf Shores, Alabama, Marta reflects on the saltiness of the Gulf waters. If her memory serves her well, are the Gulf waters saltier than the waters surrounding Hawaii?

Answers:
1) Yes
2) No

Reasons:
A) Gulf waters are much saltier than most other seas due to the influx of minerals coming from the Mississippi River.
B) Ocean waters in warm areas that receive little rainfall tend to have a higher salinity due to evaporation.
C) In areas of the world where a great deal of fresh water flows into the ocean (e.g. Congo River, Amazon River), the fresh water mixes with the ocean water to reduce the salinity.
D) Both B and C.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense
Question 13:

Imagine that there is a hole through the Earth. Bubba stands at the hole and drops a bowling ball into the hole. Where will the bowling ball stop?

**Reasons:**

A) The Earth’s gravity pulls on everything at or near the Earth’s surface. This pull is always directed down toward the center no matter where on the earth the object is located.

B) Gravity causes the bowling ball to fall in a straight line.

C) The law of inertia states that an object in motion stays in motion until acted on by an outside force.

D) The rotation of the Earth will cause the bowling ball to stop at the other side of the Earth, or the bottom of the hole.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess

It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense

Question 14:

Jim and Calli both live on the Atlantic Seaboard. However, Jim lives 350 miles north of Calli. Is it really possible for Jim to experience tidal ranges over 50 feet in depth while Calli, only 350 miles south, experiences tidal ranges of less than ten feet?

**Reasons:**

A) The relative position of the moon and sun can greatly affect tidal levels at different places on Earth.

B) The Coriolis Effect and Earth’s rotation enhance tidal flow in the lower latitudes.

C) Trade Winds push the ocean’s water into tidal bulges near the lower latitudes.

D) Ocean floor topography and coastline serve to amplify tidal flow at specific locations.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess

It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense
Question 15:
Emilio finds himself standing on the bank of the Amazon River. His compass indicates that the water is flowing west to east. Is his compass malfunctioning?

Answers:
1) Yes
2) No

Reasons:
A) All rivers flow down, from north to south, as aided by the force of gravity.
B) The Coriolis Effect causes water to flow in different directions in Southern Hemisphere than the Northern Hemisphere.
C) Rivers form by eroding channels in the sides of mountains by flowing toward a valley, taking the path of least resistance regardless of cardinal direction.
D) Unlike rivers in the Northern Hemisphere, rivers flow south to north in the Southern Hemisphere.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense

Question 16:
In science class Marjorie and Dan were asked to fill a plastic milk jug with water. Approximately four centimeters from the bottom, they punctured the milk jug with a pencil. They placed three more holes vertically, one centimeter apart, directly above the first hole. Which hole will water stream out the farthest?

Answers:
1) Hole A
2) Hole B or C
3) Hole D
4) There is no difference!

Reasons:
A) Pressure increases with the depth of water and is therefore the greatest at the bottom of the jug.
B) Pressure decreases with each additional hole placed in the jug, therefore the hole at the top receives the most pressure and the hole at the bottom receives the least pressure.
C) Since there is only one gallon of water, there is no difference in pressure. Water will shoot out from each hole with the same force.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense
Question 11:

Danny, an Eagle Scout of 25 years, claims he can predict the occurrence of a very cold winter. Is this possible?

Answers:
1) Yes
2) No

Reasons:
A) Danny is in tune with nature. By observing the thickness of tree bark, animal fur, and insect coverings he can accurately predict the intensity of the coming winter.
B) A cold winter can be predicted by an extremely hot summer.
C) Both factors, A) and B) can be used to predict the intensity of winter.
D) It is impossible to predict the intensity of a winter based on reasons A) and B).
E) Only scientists can predict the extremity of a winter. They base their calculations on the distance between the Earth and the sun.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense

Questions 18:

The map below from Channel 40/29 KHOG shows a low pressure cell with accompanying fronts. Based on this map, which of the following statements are true.

Answers:
1) The absolute humidity of the surface at Point 1 is higher than at Point 3.
2) Surface wind at Point 2 is coming from the northwest.
3) The temperature at Point 1 is cooler than at Point 4.
4) The atmospheric pressure at Point 4 is higher than at Point 1.

Reasons:
A) On a weather map, "H" means "hot" and "L" means "cool."
B) On a weather map, "H" refers to areas of high barometric pressure and "L" refers to areas of low barometric pressure.
C) On a weather map, lines with triangles indicated the direction the wind is blowing.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense
Question 19:

George lives in Phoenix, Arizona. Martha lives in Tampa, Florida. One afternoon they both washed their laundry and hung it out to dry. It was a sunny day of 75 degrees Fahrenheit in both places. Who's laundry will dry first?

Answers:
1) George's
2) Martha's
3) Impossible to tell!

Reasons:
A) The relative humidity, or amount of water vapor in the air, in Florida is much higher than in Arizona. Thus slowing the drying of the laundry.
B) Despite the temperature readings, the sun is much more intense, or hotter, in Florida than in Arizona.
C) I am not sure. No only must I know the temperature outside, but I need to know the relatively humidity, if there is a breeze, the temperature of water they used to rinse their laundry, as well as the type of material their laundry is made from.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense

Question 20:

Miss Alayne, a first grade teacher, takes her students on a field trip to the museum. Billy, a particularly precocious student, asks if dinosaurs and humans lived at the same time. Is this possible?

Answers:
1) Yes
2) No

Reasons:
A) People and dinosaurs co-existed for about five thousand years.
B) People and dinosaurs co-existed for about five hundred thousand years.
C) Dinosaurs died out about five thousand years before people appeared on Earth.
D) Dinosaurs died out about five hundred thousand years before people appeared on Earth.
E) Dinosaurs died out about 50 million years before people appeared on Earth.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense

14
Question 21:

Use the space on your answer sheet to write your response to the following situation.

How would you teach the following Earth science concept to your favorite grade level?

**Topic:** Solar Eclipse

**Guidelines:**
1) Make sure you state what grade level you are addressing
2) Include a full description of any teaching strategies, activities, and/or materials you might use.

The demographic questions following question 21 on your answer sheet are strictly voluntary. The data collected from these questions will help us understand and utilize the data.

Graphics for sample and questions 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 18, and 19 were created by EyeGone Graphics, Fayetteville, AR.
Appendix C:

Alternative Conceptions in Earth Science –

A Questionnaire II-R

ACES-Q II-R
ACES-Q II-R

Alternative Conceptions In Earth Science - A Questionnaire

By Katherine Mangione Leslie

University of Arkansas Curriculum and Instruction
2008
Alternative Conceptions
In Earth Science ~ A Questionnaire

Spring 2008

Dear Participant,

Thank you for agreeing to participate in this study. This study is designed to unearth what preservice teachers know about earth science. Participation is strictly voluntary and will help researchers at the University of Arkansas to develop an instrument that will help professors assess earth science content. By signing this form and by completing this questionnaire, you are giving your consent to participate in the study. Completion of this questionnaire will take approximately 30 minutes and poses no risk to you, the participant. Participation is completely voluntary; there is no penalty for refusal to participate. For questions or concerns about your rights as a research participant, please contact Ro Windwalker, the University’s Compliance Coordinator (irb@uark.edu or 479-575-2208).

This form, including your name and questionnaire number, will be removed from the data record sheet. Your data will then only be identified by the assigned number located on the data record sheet.

At a later date, ten participants will be randomly chosen to participate in a private interview to discuss their thoughts and ideas about the ACES-Q II-R.

Confidentiality is ensured to the extent of the law and university policies. All name bearing data will be destroyed upon completion of this study.

You may withdraw from this study at any point by contacting the investigators and requesting such. Please make sure that the test number on this form matches that on your data record sheet. Two copies of this form have been provided so that you may keep one as record of your participation.

If you have any further questions, please do not hesitate to contact us. And again, thank you for your time.

Katherine Leslie
Michael Wavering
Dissertation Chair
wavering@uark.edu
575-4283
Alternative Conceptions
In Earth Science ~ A Questionnaire

Instructions:

This is a questionnaire to determine your understanding and beliefs about several earth science topics. With each question, a situation will be described and a question will be asked. You will then be asked to choose the best answer from several choices as well as a reason for your answer. If you do not find an answer or reason that you agree with, use the blank space on your answer sheet for your own alternate responses.

You will be asked to rate how sure you are about your responses by choosing a number on a scale (5 = very sure... 1 = blind guess). Circle the number that best indicates how sure you are of your response on the answer sheet where you see “Sure? 5 4 3 2 1.”

You will be asked to rate whether the responses you chose make sense to you by choosing the number on the scale (4 = perfect sense... 1 = no sense). Circle the number that best indicates how much sense it makes to you on the sheet where you see “Sense? 5 4 3 2 1.”

Please do not write in this booklet.
Sample Question:

Miss Boka pours herself a glass of water. She asks her third graders what would happen to the ice if she added it to the glass. Her students give several different answers, which one is correct?

Answers:
1) The ice will float, raising the water level.
2) The ice will sink, lowering the water level.
3) The ice will float, lowering the water level.
4) The ice will hover in the middle of the drink and there will be no water level change.

Reasons:
A) The temperature of the ice is significantly less than the water it is in. This difference in temperature affects the position of the ice in the drink.
B) Ice has air pockets locked inside causing it to weigh less than the water.
C) The crystalline structure of the ice causes it to be less dense than the water.
D) The surface area of the ice causes it to suspend itself in the water.

I’m Sure I’m Right  5  4  3  2  1  Just A Blind Guess
It Makes Perfect Sense  5  4  3  2  1  It Makes No Sense
Question 1:

Desmond measures his shadow at noon for several months. He notices that as the year progresses his shadow lengthens and then shortens. Desmond realizes that he might be able to correlate the season based on the length of his shadow. What season is it in figure B?

Answers:
1) Winter
2) Spring
3) Summer
4) Fall
5) Impossible to tell!

Reasons:
A) It is impossible to tell. Seasons are caused by the distance between the Earth and the sun.
B) The sun is higher in the sky causing Desmond to cast a longer shadow.
C) The sun is lower in the sky causing Desmond to cast a longer shadow.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense

Question 2:

Ursula, Desmond's sister, decides to measure her shadow every two hours for one day. At what point or points is Ursula's shadow the longest?

Answers:
1) 8 AM and 4 PM
2) 10 AM and 2 PM
3) Local noon
4) Impossible to tell!

Reasons:
A) The sun reaches its zenith, or highest point in the sky, at noon. Due to the increased angle of the sun, Ursula will cast a very long shadow.
B) It is impossible to tell without knowing what day of the year it is.
C) As the sun rises or sets it casts shadows of the greatest length. This is because of the decreased angle of the sun in relation to the earth.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense
Question 3:

Bob notices that regardless of what phase the moon seems to be in, he always seems to see the same side of the moon. He wonders if this could possibly be true.

True or False? Observers on Earth never see the far side or back of the lunar surface.

Answers:
1) True
2) False

Reasons:
A) The moon orbits the Earth in approximately 29 days. Over this period of time, observers are able to watch the moon change "shapes" or phases. Because of this we are able to see 100% of the moon.
B) Only half of the moon is lit at any time. This is the side we see. The "back side" or "dark side" of the moon never receives sunlight.
C) The moon rotates, or spins on its axis, so quickly that we only seem to see half of the moon.
D) The moon does not rotate, or spin on its axis, therefore an observer on Earth will always see the same side of the moon.
E) The moon rotates, or spins on its axis, once in about 29 days. The moon also takes approximately 29 days to orbit the Earth. Because the period of the moon’s orbit is nearly the same as its rotation, observers on Earth will only see one side, or half, of the moon.

I'm Sure I'm Right  5  4  3  2  1  Just A Blind Guess
It Makes Perfect Sense  5  4  3  2  1  It Makes No Sense

Question 4:

The moon seems to change shapes as it orbits the Earth. To an observer on Earth, what phase would she see if the moon was in position C?

Answers:
1) New Moon
2) Full Moon
3) 1st or 3rd Quarter Moon

Reasons:
A) Only half of the moon is lit (illuminated) at a time so an observer on Earth would see a "half moon" or quarter moon.
B) The Earth will cast a shadow that will cover the moon so an observer on earth will see "no moon" or a new moon.
C) The illuminated side of the moon is fully visible to the observer. She will see a full moon.

I'm Sure I'm Right  5  4  3  2  1  Just A Blind Guess
It Makes Perfect Sense  5  4  3  2  1  It Makes No Sense.
Question 5:

According to the diagram below, what season is Arkansas experiencing in position C?

Answers:
1) Winter
2) Spring or Fall
3) Summer
4) Impossible to tell!

Reasons:
A) It is impossible to tell. More data is needed.
B) The Earth travels in an elliptical orbit causing it to be closer to the sun at certain times of the year. It is winter when the Earth is farther from the sun and summer when the Earth is closer to the sun.
C) The tilt of the Earth does not impact seasons. The Earth rotates more slowly in the summer causing longer periods of day resulting in higher temperatures.
D) The Earth is tilted 23 1/2 degrees. This tilt causes the sun's rays to be dispersed more during the winter and focused more during the summer in the northern and southern hemispheres.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense

Question 6:

Imagine that there is a hole through the Earth. Bubba stands at the hole and drops a bowling ball into the hole. Where will the bowling ball stop?

Answers: Choose from the pictures to your right.

Reasons:
A) The Earth's gravity pulls on everything at or near the Earth's surface. This pull is always directed downward toward the center no matter where on the earth the object is located.
B) Gravity causes the bowling ball to fall in a straight line.
C) The law of inertia states that an object in motion stays in motion until acted on by an outside force.
D) The rotation of the Earth will cause the bowling ball to stop at the other side of the Earth, or the bottom of the hole.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense
Question 7:

Which of the following man-made structures is most likely to be damaged by acid rain?

Answers:
1) Granite Monument
2) Marble Tombstone
3) Slate Roof
4) Any of the above

Reasons:
A) All are equally susceptible to acid rain.
B) Slate is a metamorphic rock, therefore it is unlikely to hold up against acid rain.
C) Marble would be particularly susceptible as it is made of calcite.
D) Granite contains large amounts of silicates and it is igneous.

Question 8:

Stephen attempted to break into the library by cutting through the glass window using information he learned in geology class. He finally gave up and ran away after the alarms were triggered. The university police found scratches on the window and traces of a mineral on the ground by the window. Using the Mohs Hardness Scale, which of the following minerals could it have been?

Answers:
1) Fluorite
2) Topaz
3) Calcite
4) All of the above
5) None of the above

Reasons:
A) All minerals that rate a 6 or higher on the Mohs Hardness Scale will scratch glass.
B) Calcite is a very strong mineral and has been known to scratch hard surfaces.
C) Topaz crystal will only scratch glass if it has been cut and polished for jewelry.
D) Glass is a super-cooled liquid that any mineral can scratch.
E) It had to be a diamond; only diamonds are hard enough to scratch glass.

Moius Scale of Relative Mineral Hardness

1. Talc
2. Gypsum
3. Calcite
4. Fluorite
5. Apatite
6. Feldspar
7. Quartz
8. Topaz
9. Corundum
10. Diamond
Question 9:
Suzy is walking along the banks of the Richland Creek. This area is known to be rich in fossils of trilobites, crinoids, and other ancient seafaring creatures. Suzy bends to retrieve a particularly fascinating rock containing several impressions of crinoids. What kind of rock is Suzy holding?

Answers:
1) Igneous
2) Metamorphic
3) Sedimentary
4) Any of the above

Reasons:
A) Seventy-five percent (75%) of the rocks on the Earth's surface are metamorphic.
B) Sedimentary rocks form strata, or layers, of sediment deposited in oceans and lakes.
C) Igneous rocks are formed beneath the Earth's surface where plant and animal remains can be found.
D) All types of rocks contain fossils.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense

Question 10:
Marta has traveled extensively. Her favorite places to visit are sandy beaches around the world. One afternoon while drying in the warm sun of Gulf Shores, Alabama, Marta reflects on the saltiness of the Gulf waters. If her memory serves her well, are the Gulf waters saltier than the waters surrounding Hawaii?

Answers:
1) Yes
2) No

Reasons:
A) Gulf waters are much saltier than most other seas due to the influx of minerals coming from the Mississippi River.
B) Ocean waters in warm areas that receive little rainfall tend to have a higher salinity due to evaporation.
C) In areas of the world where a great deal of fresh water flows into the ocean (e.g. Congo River, Amazon River), the fresh water mixes with the ocean water to reduce the salinity.
D) Both B and C.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense
Question 11:

As a child, Nancy remembers playing in the run-off channels around Fayetteville, Arkansas. Despite the drought of the past few years, Nancy feels she cannot allow her children to play in the run-off because there seems to be much more water in the channel after a rain since the city has developed and grown in the past 20 years. Is Nancy being overly cautious?

Answers:
1) Yes
2) No

Reasons:
A) Nancy is being overly cautious. Several esteemed meteorologists have confirmed the obvious lack of rain in Fayetteville over the past few years, marking it as a “drought to remember.”
B) Nancy is being overly cautious. It has been 20 years since she played in the channels. Improved water management has led to controlled amounts of water in the channels.
C) Nancy is not being overly cautious. Water in the channels comes from many places, not just Fayetteville.
D) Nancy is not being overly cautious. Run-off is affected by many factors in addition to amount of rainfall, including surface characteristics and vegetation.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense

Question 12:

Jim and Calli both live on the Atlantic Seaboard. However, Jim lives 350 miles north of Calli. Is it really possible for Jim to experience tidal ranges over 50 feet in depth while Calli, only 350 miles south, experiences tidal ranges of less than ten feet?

Answers:
1) Yes
2) No

Reasons:
A) The relative position of the moon and sun can greatly affect tidal levels at different places on Earth.
B) The Coriolis Effect and Earth’s rotation enhance tidal flow in the upper latitudes.
C) Trade Winds push the ocean’s water into tidal bulges near the lower latitudes.
D) Ocean floor topography and coastline serve to amplify tidal flow at specific locations.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense
Question 13:

Emilio finds himself standing on the bank of the Amazon River. His compass indicates that the water is flowing west to east. Is his compass malfunctioning?

Answers:
1) Yes
2) No

Reasons:
A) All rivers flow down, from north to south, as aided by the force of gravity.
B) The Coriolis Effect causes water to flow in different directions in Southern Hemisphere than the Northern Hemisphere.
C) Rivers form by eroding channels in the sides of mountains by flowing toward a valley, taking the path of least resistance regardless of cardinal direction.
D) Unlike rivers in the Northern Hemisphere, rivers flow south to north in the Southern Hemisphere.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense

Question 14:

Miss Alayne, a first grade teacher, takes her students on a field trip to the museum. Billy, a particularly precocious student, asks if dinosaurs and humans lived at the same time. Is this possible?

Answers:
1) Yes
2) No

Reasons:
A) Dinosaurs died out about 50 million years before people appeared on Earth.
B) Dinosaurs died out about five hundred thousand years before people appeared on earth.
C) Dinosaurs died out about five thousand years before people appeared on Earth.
D) People and dinosaurs co-existed for about five hundred thousand years.
E) People and dinosaurs co-existed for about five thousand years

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense
Question 15:

David wins a trip to Antarctica. He wants to learn more about the environment he will encounter. Which one of the following library books would be the most helpful?

Answers:
1) Deserts of the World
2) Explore the Tundra
3) Discover the Aquatic!

Reasons:
A) Antarctica lacks an availability of liquid water.
B) Antarctica is a frozen wonderland of diverse plants and animals. Tundra is characterized by frost molded landscapes and extends to the poles in the Northern Hemisphere.
C) Antarctica is made mostly of ice, which is frozen water. Aquatic biomes make up approximately 75% of the earth.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense

Question 16:

During which of the following processes in the water cycle do water molecules absorb energy?

Answers:
1) Condensation
2) Precipitation
3) Evaporation
4) Run Off
5) Both 2 & 4

Reasons:
A) Evaporation is an endothermic, or heat absorbing, process where molecules of water change from a liquid to a gas.
B) Condensation is an endothermic, or heat absorbing, process where molecules of water change from a gas to a liquid or a solid.
C) The movement of water in both the precipitation and run off stages indicates kinetic energy.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense

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Question 17:

In science class Marjorie and Dan were asked to fill a plastic milk jug with water. Approximately four centimeters from the bottom, they punctured the milk jug with a pencil. They placed three more holes vertically, one centimeter apart, directly above the first hole. Which hole will water stream out the farthest?

Answers:
1) Hole A
2) Hole B or C
3) Hole D

Reasons:
A) Pressure increases with the depth of water and is therefore the greatest at the bottom of the jug.
B) Pressure decreases with each additional hole placed in the jug, therefore the hole at the top receives the most pressure and the hole at the bottom receives the least pressure.
C) Water will shoot out from each hole with the same force.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense

Questions 18:

Danny, an Eagle Scout of 25 years, claims he can predict the occurrence of a very cold winter. Is this possible?

Answers:
1) Yes
2) No

Reasons:
A) Danny is in tune with nature. By observing the thickness of tree bark, animal fur, and insect coverings he can accurately predict the intensity of the coming winter.
B) A cold winter can be predicted by an extremely hot summer.
C) Both factors, A) and B) can be used to predict the intensity of winter.
D) It is impossible to predict the intensity of a winter based on reasons A) and B).
E) Only scientists can predict the extremity of a winter. They base their calculations on the distance between the Earth and the sun.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense
Question 19:

The map to your right from Channel 40/29 KHOG shows a low pressure cell with accompanying fronts. Based on this map, which of the following statements are true.

Answers:
1) The absolute humidity of the surface at Point 1 is higher than at Point 3.
2) Surface wind at Point 2 is coming from the northwest.
3) The temperature at Point 1 is cooler than at Point 4.
4) The atmospheric pressure at Point 4 is higher than at Point 1.

Reasons:
A) On a weather map, "H" means "hot" and "L" means "cool."
B) On a weather map, "H" refers to areas of high barometric pressure and "L" refers to areas of low barometric pressure.
C) On a weather map, lines with triangles indicate the direction the wind is blowing.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense

Question 20:

George lives in Phoenix, Arizona. Martha lives in Tampa, Florida. One afternoon they both washed their laundry and hung it out to dry. It was a sunny day of 75 degrees Fahrenheit in both places. Whose laundry will dry first?

Answers:
1) George's
2) Martha's
3) Impossible to tell!

Reasons:
A) I am not sure. Not only must I know the temperature outside, but I need to know the relative humidity, if there is a breeze, the temperature of water they used to rinse their laundry, as well as the type of material laundry is made from.
B) Despite the temperature readings, the sun is much more intense, or hotter, in Florida than in Arizona.
C) The relative humidity, or amount of water vapor in the air, in Florida is much higher than in Arizona. Thus slowing the drying of laundry.

I'm Sure I'm Right 5 4 3 2 1 Just A Blind Guess
It Makes Perfect Sense 5 4 3 2 1 It Makes No Sense.
Question 21:

Use the space on your answer sheet to write your response to the following situation.

How would you teach the following Earth science concept to your favorite grade level?

**Topic:** Solar Eclipse

**Guidelines:**
1) Make sure you state what grade level you are addressing
2) Include a full description of any teaching strategies, activities, and/or materials you might use.

The demographic questions following question 21 on your answer sheet are strictly voluntary. The data collected from these questions will help to understand and utilize the data.

Graphics for sample and questions 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 15, 16, 17, 19, and 20 were created by EyeGone Graphics, Warrensburg, MO.
Appendix D: Consent Form ACES-Q II-R
Dear Participant,

Thank you for agreeing to participate in this study. This study is designed to unearth what preservice teachers know about Earth science. Participation is strictly voluntary and will help researchers at the University of Arkansas to develop an instrument that will help professors assess Earth science content. By signing this form and by completing this questionnaire, you are giving your consent to participate in the study. Completion of this questionnaire will take approximately 30 minutes and poses no risk to you, the participant. Participation is completely voluntary; there is no penalty for refusal to participate. For questions or concerns about your rights as a research participant, please contact Ro Windwalker, the University’s Compliance Coordinator (irb@uark.edu or 479-575-2208).

This form, including your name and questionnaire number, will be removed from the data record sheet. Your data will then only be identified by the assigned number located on the data record sheet.

At a later date, ten participants will be randomly chosen to participate in a private interview to discuss their thoughts and ideas about the ACES-Q II-R.

Confidentiality is guaranteed. All name bearing data will be destroyed upon completion of this study.

You may withdraw from this study at any point by contacting the investigators and requesting such. Please make sure that the test number on this form matches that on your data record sheet. Two copies of this form have been provided so that you may keep one as record of your participation.

If you have any further questions, please do not hesitate to contact us. And again, thank you for your time.

Respectfully,

Katherine A. Leslie
Dr. Wavering
wavering@uark.edu
479-575-4283
Appendix E:
Sample Transcription
Participant Interviews
Subject Interviews

Subject (S)
Researcher (R)

Subject 002
Elementary Education
Total Score Written (W): 6/20
Total Score Oral (O):
18 minutes 19 seconds

<table>
<thead>
<tr>
<th>Question 1</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>Oh my gosh! [pause] I think it’s winter time?</td>
</tr>
<tr>
<td>R</td>
<td>Alrighty, and why?</td>
</tr>
<tr>
<td>S</td>
<td>Because um, Desmond is... we are tilted away from the sun during the winter time and so it will probably make a difference in the shadow.</td>
</tr>
<tr>
<td>R</td>
<td>Okay, so you believe that we’re tilted away from the sun in the winter and that would probably impact the shadow?</td>
</tr>
<tr>
<td>S</td>
<td>Um, yes.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>8:00 a.m. and 4 p.m.?</td>
</tr>
<tr>
<td>R</td>
<td>Okay, you stated 8:00 a.m. and 4 p.m. Why?</td>
</tr>
<tr>
<td>S</td>
<td>Because the sun is [pause then laughter] to the side of it [Ursula]. It is not straight up in the sky so it will create a longer shadow.</td>
</tr>
<tr>
<td>R</td>
<td>Okay, your reason is that the sun is lower in the sky and creates a longer shadow.</td>
</tr>
<tr>
<td>S</td>
<td>Yes.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question 3</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>True. We never see the far side of the lunar surface.</td>
</tr>
<tr>
<td>R</td>
<td>Because...?</td>
</tr>
<tr>
<td>S</td>
<td>Um [pause], I don’t know why.</td>
</tr>
<tr>
<td>R</td>
<td>Can you hazard a guess?</td>
</tr>
<tr>
<td>S</td>
<td>I just... ‘Cause [very long pause]... No, I don’t know.</td>
</tr>
<tr>
<td>R</td>
<td>Okay.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question 4</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>Um, is the new moon when it is all dark?</td>
</tr>
<tr>
<td>R</td>
<td>Yes, the new moon is when it is all dark. We do not see the moon during this phase.</td>
</tr>
<tr>
<td>S</td>
<td>Yes, it would be a new moon.</td>
</tr>
<tr>
<td>R</td>
<td>Okay, so in position c it would be a new moon?</td>
</tr>
<tr>
<td>S</td>
<td>Uhm hmmm [affirmative].</td>
</tr>
<tr>
<td>R</td>
<td>Why do you say that?</td>
</tr>
<tr>
<td>S</td>
<td>Because the earth is creating a shadow.</td>
</tr>
<tr>
<td>R</td>
<td>So the earth creates a shadow. What happens with that shadow?</td>
</tr>
<tr>
<td>---</td>
<td>-------------------------------------------------------------</td>
</tr>
<tr>
<td>S</td>
<td>It blocks the moon. The sun’s rays are not reaching the moon.</td>
</tr>
<tr>
<td>R</td>
<td>Okay, thank you.</td>
</tr>
</tbody>
</table>

**Question 5**

<table>
<thead>
<tr>
<th>S</th>
<th>We are experiencing summer time.</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>Summer time and why?</td>
</tr>
<tr>
<td>S</td>
<td>Because we are tilted toward the sun.</td>
</tr>
<tr>
<td>R</td>
<td>Can you add anything about the tilt of our earth?</td>
</tr>
<tr>
<td>S</td>
<td>Not really.</td>
</tr>
<tr>
<td>R</td>
<td>Okay.</td>
</tr>
</tbody>
</table>

**Question 6**

<table>
<thead>
<tr>
<th>S</th>
<th>I guess the bowling ball will [pause] would stop in the middle because that’s where the center of gravity comes from?</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>Okay, so think that the ball would stop at the center of the earth because that is where the center of gravity is?</td>
</tr>
<tr>
<td>S</td>
<td>Yes.</td>
</tr>
<tr>
<td>R</td>
<td>Why is that [location] the center of gravity on earth?</td>
</tr>
<tr>
<td>S</td>
<td>I do not know why.</td>
</tr>
<tr>
<td>R</td>
<td>Okay. I am just repeating your answers to make sure that I understand you.</td>
</tr>
<tr>
<td>S</td>
<td>That’s okay</td>
</tr>
<tr>
<td>R</td>
<td>Good. I just didn’t want you to freak out.</td>
</tr>
</tbody>
</table>

**Question 7**

<table>
<thead>
<tr>
<th>S</th>
<th>Oh, this is one that I did not know. I don’t know [pause].</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>Alright, we’re looking at manmade structures. Which one do you think will be damaged by acid rain?</td>
</tr>
<tr>
<td>S</td>
<td>[Very long pause]</td>
</tr>
<tr>
<td>R</td>
<td>You’ve got a monument, a tombstone, and a slate roof.</td>
</tr>
<tr>
<td>S</td>
<td>I’m not sure. I don’t know</td>
</tr>
<tr>
<td>R</td>
<td>You’re welcome to take a guess.</td>
</tr>
<tr>
<td>S</td>
<td>I guess I would go with maybe a slate roof?</td>
</tr>
<tr>
<td>R</td>
<td>Alright, you’ve guessed slate roof. Why would you think that would be more susceptible to acid rain?</td>
</tr>
<tr>
<td>S</td>
<td>I would say something maybe [pause]... I can’t tell you. I don’t know. It could be all of them.</td>
</tr>
</tbody>
</table>

**Question 8**

<table>
<thead>
<tr>
<th>S</th>
<th>Well [very long pause] I would say calcite because it is the hardest one mentioned there.</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>Okay, so you say calcite because it is the hardest mineral listed as...</td>
</tr>
<tr>
<td>S</td>
<td>Oh, okay stop. Alright stop. [giggle] I read this wrong. I know diamond is the hardest and it is at the bottom so I am going to go with, I guess, topaz.</td>
</tr>
<tr>
<td>R</td>
<td>Why topaz?</td>
</tr>
</tbody>
</table>

174
Because, you know, it’s the highest on the um hardness scale.

**Question 9**

<table>
<thead>
<tr>
<th>S</th>
<th>Because, you know, it’s the highest on the um hardness scale.</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>Well [pause], ah, I would pick either igneous or sedimentary.</td>
</tr>
<tr>
<td>R</td>
<td>What if you could only pick one?</td>
</tr>
<tr>
<td>S</td>
<td>So I am going to go with [very long pause] igneous.</td>
</tr>
<tr>
<td>R</td>
<td>Alright, and why igneous?</td>
</tr>
<tr>
<td>S</td>
<td>‘Cause when I think of sedimentary I just think of sediments settling [giggle].</td>
</tr>
<tr>
<td>R</td>
<td>What do you think of when you think of igneous?</td>
</tr>
<tr>
<td>S</td>
<td>I don’t know. I don’t think of anything. I’ve totally forgotten my geology. And I took geology.</td>
</tr>
<tr>
<td>R</td>
<td></td>
</tr>
</tbody>
</table>

**Question 10**

| S  | I’m going to say no. I believe that ocean is… that salt water is equally distributed throughout the ocean. |
| R  | Okay, salt water is equally distributed throughout the ocean. Do you recall hearing or reading about the salinity of the oceans? |
| S  | No.                                                        |

**Question 11**

| S  | No, I don’t believe she’s being overly cautious. |
| R  | And why not?                                    |
| S  | Because I believe that the type of chemicals, runoff chemicals from say golf courses and chicken plants is running into our drains. I bet that has increased over the past few years. |

**Question 12**

| S  | I would say yes it is probable or possible. |
| R  | Why.                                        |
| S  | Sea currents can be stronger in certain areas. Maybe the shores are probably rockier up north [very long pause]. |
| R  | Alright, so you think that maybe tidal ranges may be impacted by sea currents that may be stronger in certain areas as well as the um, geography, rather geology of the shoreline. |
| S  | Yeah.                                       |
| R  | Is there any reason you think that sea currents may be stronger in different areas? |
| S  | Only because I’ve seen maps of, like, uh all those rivers of sea currents. I don’t understand it, but I know there is a difference. |
| R  | Do you know what a sea current is?           |
| S  | I guess just a strong flow of water in a certain direction. Like a river in the ocean. |
| R  | Okay. Thank you.                            |
### Question 13

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<table>
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<tr>
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<tbody>
<tr>
<td>S</td>
<td>I don’t think his compass is malfunctioning.</td>
</tr>
<tr>
<td>R</td>
<td>Why not?</td>
</tr>
<tr>
<td>S</td>
<td>Because rivers can flow west to east.</td>
</tr>
<tr>
<td>R</td>
<td>Why?</td>
</tr>
<tr>
<td>S</td>
<td>Why? Um [very long pause]</td>
</tr>
<tr>
<td>R</td>
<td>How do rivers decide which direction to flow in?</td>
</tr>
<tr>
<td>S</td>
<td>Mmmm, just depends on how the water is draining [pause] and [pause] maybe, I don’t know [very long pause].</td>
</tr>
<tr>
<td>R</td>
<td>So you don’t have an idea how water might flow?</td>
</tr>
<tr>
<td>S</td>
<td>From the tallest point down. So if that is from west to east that is fine.</td>
</tr>
</tbody>
</table>

### Question 14

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<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>S</td>
<td>That’s a good question. I say no.</td>
</tr>
<tr>
<td>R</td>
<td>Okay, why not?</td>
</tr>
<tr>
<td>S</td>
<td>Only because I feel like I have heard that. It was a very long time afterwards [dinosaurs because extinct] [pause] that we had any knowledge of humans. I don’t know. I just say no.</td>
</tr>
<tr>
<td>R</td>
<td>Alright.</td>
</tr>
</tbody>
</table>

### Question 15

<p>| | |</p>
<table>
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<tr>
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<tbody>
<tr>
<td>S</td>
<td>Deserts of the World. Because Antarctica is a desert.</td>
</tr>
<tr>
<td>R</td>
<td>How do you know that?</td>
</tr>
<tr>
<td>S</td>
<td>Because there is land underneath it [the ice]. Deserts really... I guess [pause] scientists kind of argue about this. Some people say that deserts lack water. Other people say it is because no plants grow there.</td>
</tr>
</tbody>
</table>

### Question 16

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</thead>
<tbody>
<tr>
<td>S</td>
<td>Hmmm. Gosh. I’m going to say evaporation. But only because the molecules are heating up and that makes me think of energy and</td>
</tr>
<tr>
<td>R</td>
<td>So you think evaporation because the molecules are heating up and that makes you think of...</td>
</tr>
<tr>
<td>S</td>
<td>Energy.</td>
</tr>
<tr>
<td>R</td>
<td>Any other reasons?</td>
</tr>
<tr>
<td>S</td>
<td>No.</td>
</tr>
</tbody>
</table>

### Question 17

<p>| | |</p>
<table>
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<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>S</td>
<td>[Sigh] I would probably say hole D because there’s more pressure [pause].</td>
</tr>
<tr>
<td>R</td>
<td>More pressure?</td>
</tr>
<tr>
<td>S</td>
<td>Meaning like there’s probably... I don’t want to say weight. Maybe weight. I don’t know. [unclear] Maybe the weight of the other water on the top will push it out more and it would stream out farther.</td>
</tr>
</tbody>
</table>

### Question 18

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<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>S</td>
<td>Um, I think no.</td>
</tr>
<tr>
<td>R</td>
<td>Okay, so you don’t think one can accurately predict the occurrence of a cold winter. Why not?</td>
</tr>
<tr>
<td>----</td>
<td>------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>S</td>
<td>Just because, um [long pause] seems like our climate has been changing so much lately… I don’t know if there’s anything set in stone. Of course there are tons of predictors that one can use to guess if there was going to be a very cold winter. But I don’t know if you can tell for absolute certain.</td>
</tr>
</tbody>
</table>

**Question 19**

<table>
<thead>
<tr>
<th>S</th>
<th>Okay, I guess [very long pause]…</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>Okay, we now it’s a guess.</td>
</tr>
<tr>
<td>S</td>
<td>[giggle] I would say that surface wind at point two is coming from the northwest. But only ‘cause I’m looking up at this H and imagining things kind of moving down and that may be kinda winds would be moving down from that way.</td>
</tr>
<tr>
<td>R</td>
<td>Do you know what that H means?</td>
</tr>
<tr>
<td>S</td>
<td>High pressure?</td>
</tr>
<tr>
<td>R</td>
<td>Okay. [Pause] You think that maybe the high pressure may be pushing down in that direction.</td>
</tr>
<tr>
<td>S</td>
<td>Possibly. [very long pause].</td>
</tr>
</tbody>
</table>

**Question 20**

<table>
<thead>
<tr>
<th>S</th>
<th>I would say that George’s would probably dry quicker because there’s not really that much humidity, I believe, in Phoenix, AZ compared to Tampa, FL.</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>So, there’s probably less humidity and it might not take quite as long to dry.</td>
</tr>
<tr>
<td>R</td>
<td>[unclear]</td>
</tr>
<tr>
<td>S</td>
<td>Humidity is water in the air.</td>
</tr>
</tbody>
</table>
Subject 008  
Elementary Education  
Total Score (W): 11/20  
Total Score (O):  
34 minutes 28 seconds  

Question 1  
R: Okay, why would you guess winter?  
S: Ah, um, ah [very long pause] well, [unclear] Uhm, you may regret picking me as a subject. I’ve heard that in winter the sun is closer to the earth so, ahm, if it is closer to an object it is going to cast a longer shadow.  
R: Okay.  
S: But if I didn’t have to use your answers I would be confused because I thought if the sun was directly above you, you wouldn’t have a shadow.  
R: So,  
S: I would say that ‘cause the sun be closer to the earth it will cast a longer shadow. Because when it is closer to an object... on one side of it, it will cast a longer shadow.  

Question 2  
S: Ah, okay, I would say her shadow is the longest at 8:00 and 4:00.  
R: Why?  
S: Because the sun, because the sun will be relatively low in the sky so when it is shining on the person it will cast a longer shadow.  
R: Okay.  
S: Or if it is directly above or at a bigger angle from horizon, I don’t know how to describe it... the shadow won’t be as long.  
R: You’re doing fine. So you’re telling me the shadow would be longest at 8:00 and 4:00 because the sun is lower in the sky and that when the sun is at a higher angle objects cast shorter shadow?  
S: Ah, sure.  

Question 3  
S: Uhm, I would say, I would say it is false because I think, well I know that, that, the earth spins on its axis, so I would assume the moon would also spin on an axis so we’re not always seeing the same side.  
R: Okay, so you know the earth spins and you assume that moon spins so you would not always see the same side?  
S: Yes, that’s correct.  

Question 4  
S: Okay. Uhm [long pause]v [Clears throat] I would think that it would be number 3, a first or third quarter moon, because the sun shines its light, uhm, uhm,
because the sun is bigger than the earth it would shine its light kinda past the earth in order to get to the moon. Ah... [Very long pause]

R  So you think that when the sun shines past the earth on the moon we see a first or third quarter moon.

S  Ah, yeah. I don’t like that answer very much.

R  Do you want to change your answer?

S  I think it is the one that makes the most sense to me, but I don’t think it is right.

R  The answer that makes the most sense to you is first or third quarter?

S  Yeah. Because in A the sun is shining [pause] you wouldn’t be able to see it because the light is reflected back to the sun and we wouldn’t see it, it would be a new moon.

R  Okay

S  [unclear] Then it would look like [unclear mumble]. So my guess is first or third quarter.

R  So you’re saying that the sun is larger than the earth so it would shine around the earth and illuminate the moon and give us the first or third quarter?

S  Yeah, that is my final answer.


S  But I want to know the answer when I am done. Can we come back to it?

R  Yes.

Question 5

S  Uhm, [long pause] So in question, my guess would be winter.

R  Okay, why?

S  I guess because I hear in winter the earth, part of the earth, is closer to the sun.

R  Okay.

S  And so yeah [long pause].

R  Do you want to add to that?

S  Ah, no [pause] just that winter, that like, part of the earth is closer to the sun and in position C it looks like Arkansas is closer to the sun.

R  Okay.

Question 6

S  Um [humming]. Ah, my guess would be number one [center of the earth] because of gravity. Gravity is like; gravity is like going toward the center of the earth. Ah, ah when it gets to the center it gets, gravity gets, strong

R  Okay, when it gets to the center, gravity gets strong.

S  [giggle]

Question 7

S  [Whispers questions to self]. Ah, I would say not granite. Or not any of the above. I would say it would be marble or slate, um, [long pause] uhm, ah, I would probably guess uhm, [giggle], uhm; I’m trying to think about rocks. I’m sorry.

R  That’s okay.
<table>
<thead>
<tr>
<th><strong>S</strong></th>
<th>Uh, [very long pause] I would probably guess slate.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>R</strong></td>
<td>Okay, why did you guess slate?</td>
</tr>
<tr>
<td><strong>S</strong></td>
<td>Uh, well because this is a roundabout way of doing this, but ah, because there are lots of monuments and old buildings that are made of marble that are still standing today and they have been hit by acid rain I'm guessing and we don't have a lot of, uhm, things, monuments made, well I don't know of anything made of slate.</td>
</tr>
<tr>
<td><strong>R</strong></td>
<td>So you're using, ah...</td>
</tr>
<tr>
<td><strong>S</strong></td>
<td>It's not really very scientific.</td>
</tr>
<tr>
<td><strong>R</strong></td>
<td>You're using your personal experiences to explain your answer which is exactly what we humans do.</td>
</tr>
</tbody>
</table>

**Question 8**

<table>
<thead>
<tr>
<th><strong>S</strong></th>
<th>Uhm, [very, very long pause], shh, shh, shh, uhm, [very long pause] ahm, [very long pause], ahm [unclear], I think it probably could have been all of the above.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>R</strong></td>
<td>Okay and why?</td>
</tr>
<tr>
<td><strong>S</strong></td>
<td>I think on Moh's scale of hardness that glass is around, ah, a 7 or a 5 I think, and if there are traces on the ground it couldn't be fluorite or calcite, because they're not as strong as glass. Glass could have caused them to break up. But topaz is stronger than glass, and it could have scratched. It seems to be wrong. In my mind it is a little confusing. Because if it can scratch glass it then, well can I change my mind?</td>
</tr>
<tr>
<td><strong>R</strong></td>
<td>Yes, you may.</td>
</tr>
<tr>
<td><strong>S</strong></td>
<td>Yes, topaz is my final answer. I'm sorry this is taking so long, I feel so [unclear]...</td>
</tr>
<tr>
<td><strong>R</strong></td>
<td>No, Name, this is the best part, finding out how people think about things.</td>
</tr>
</tbody>
</table>

**Question 9**

<table>
<thead>
<tr>
<th><strong>S</strong></th>
<th>I would say that the answer is sedimentary rock?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>R</strong></td>
<td>Okay</td>
</tr>
<tr>
<td><strong>S</strong></td>
<td>Because I think that, lots of fossils are found in sedimentary rock because of the way it is made, because it is layers of sediment and dirt that are layered and pressed together. SO things can be pressed into those layers and create impressions.</td>
</tr>
<tr>
<td><strong>R</strong></td>
<td>Okay</td>
</tr>
<tr>
<td><strong>S</strong></td>
<td>Igneous is made from volcanic I don't think that fossils can grow.</td>
</tr>
<tr>
<td><strong>R</strong></td>
<td>What about metamorphic</td>
</tr>
<tr>
<td><strong>S</strong></td>
<td>Metamorphic is made from changes in temperature and pressure. It is pressed together and below the earth [unclear].</td>
</tr>
<tr>
<td><strong>R</strong></td>
<td>So we wouldn't find fossils in metamorphic rock because it is pressed together or because it is under the earth?</td>
</tr>
</tbody>
</table>
Ah, because it is rock that changes because of the temperature and pressure and that the changes would harm something that was in the rock.

Question 10

S: Uh [long pause] [clicks tongue] uhm, I would say no they’re not saltier.
R: And why not.
S: Well, I have two guesses.
R: Okay.
S: Well, I am not sure, but I am assuming that Gulf Shores is very close to the coastline and if water gets to the beach from the coast isn’t not going to be salt water. There’s fresh water coming into the area so it’s going to dilute the saltiness, and ah. My second guess is that in general the Spacific [sic] water around Hawaii is warmer than the Atlantic so more water would evaporate and would leave the Spacific [sic] ah, saltier. But I have no scientific backing for this, [giggle].
R: Alright.

Question 11

S: [Very long pause] Ah, uhm, I would say, uhm, well I wanna say yes, but this isn’t my real answer, because I think she should allow her kids to play there. But scientifically, it is possible that there is more runoff because as cities develop and grow they sometimes, um, lead to more erosion and like a disruption of like where water might have run off as much...
R: So what you’re saying to me is that it is possible there is more runoff as city develops and grows because they lead to more erosion?
S: Yes, and it disrupts the natural.
R: How does it disrupt the natural?
S: Like, um, depending on where they are, if they like cut through ah, uhm, hill, it looks like often the side of the hill is eroding more than the hilltop, if there is an over flow there, it is eroding more, the water can runoff.
R: Okay.
S: They disrupt the natural path of rivers and streams so the water doesn’t have as many places to go.
R: Okay.

Question 12

S: Uhm, [very long pause] I would say that it is possible.
R: Why is it possible?
S: Well, I think that it is possible because I think, ah, I think if the coastline is drastically different it will affect how the tides [pause] are felt by the people on the shore.
R: Different how?
S: Ah, I guess, uhm, ah, [pause] if one location has a, like, I guess, a more narrow coast it might like narrower and deeper it mike make the tidal wave, or I mean
tides, seem a lot bigger, like whereas like another place, like a big broad and shallow area, you wouldn’t feel like deeper tides, or measure…

R You mean the actual shape of the coastline impacts how we perceive the tides?
S Yes.

Question 13

S Ah, [cough], uhm, [very long pause] uhm, I would say, I would say NO that his compass is not necessarily malfunctioning, because while rivers flow uhm, north to south, he could be like at a bend in the river that makes it seem like it’s going in that particular direction, when in actuality, it’s flowing north to south.

R So, his compass is not malfunctioning, because rivers flow north to south, and he could be at a bend in the river making it seem that that section of the river is flowing from west to east.
S Yes.

R That’s a big smile.
S Yes, I have two answers to the question.
R Give me your first answer.

S I would say it is not possible, based on the fact that there is, like, they’ve measured the age of fossils and sediment and said that dinosaurs like lived so many million years before humans did and could not have lived at the same time as humans.

R Okay. And your next answer?
S Yes, if you take a Biblical view of creation and say that the earth was created in seven days and that humans and dinosaurs were created on day six, or day four, and that they lived together in the Garden of Eden. And there’s been a place where dinosaur footprints and human footprints are in the same layer of sediment. It might be Texas.

Question 15

S Uhm, I would say number two.
R And why are we going to visit the tundra?
S Ah, uhm, [long pause] the tundra, the tundra is like a really cold place where, ah, nothing but lichens and moss grow… I used the process of elimination; the aquatic is oceans and sea life. And desert is where there is very little rainfall. I’m really good at talking myself out of answers. Tundra might be a mountainous area above the frost zone where like things don’t grow. I know like in Antarctica it doesn’t rain a lot, it’s just frozen water, but I don’t think if you picked up a book on deserts it would tell you much about Antarctica, but I think number one [Deserts of the World] is possible.

R Okay.
### Question 16

**S** Ah, uhm [very long pause] I would say [pause] ah, uhm, [pause] I would probably say evaporation.

**R** Okay, and why evaporation?

**S** Because [pause] oh, man I guess, ah, [pause] uhm, I may want to change my answer; I'm so sorry.

**R** Okay.

**S** It's either evaporation or number five [Both 2 & 4/Precipitation and Runoff].

**R** Okay, number five is both 2 and 4 which would be precipitation and runoff. Neither of which are condensation.

**S** Okay, well, okay. I think something, how energy, alight, oh, maybe, okay [pause] the more energy something has the faster the molecules move and so [pause] it could be evaporation, but uhm, yea, that's my answer.

### Question 17

**S** Uhm [pause] I would say it goes farther out of hole d.

**R** Why is that?

**S** 'Cause when, uhm, there is, ah, more pressure of the water above it pressing down on the water, ah, the water will stream out hole d farthest.

**R** Okay.

### Question 18

**S** Uhm, I would say it's, I would say it's possible, because I think that there are certain things, this sounds silly, uhm, there are certain things in nature that you can observe...

**R** Like what?

**S** I think maybe animals, ah, [long pause] it is possible that their coats may grown in more densely, ah, uhm, [pause]

**R** Any other examples?

**S** Well, in general, I know that they say that it's like it goes with the nature, but you know how they say if you have a mild summer you might have a colder winter.

**R** Ah, yeah, maybe [laughter].

### Question 19

**S** [Sigh] Uhm, [long pause] uhm, [pause] oh goodness, I would probably say that, number 4

**R** Number 4 the atmospheric pressure at point four is higher than the pressure at point one. Can you tell me why you picked that answer, Name?

**S** Uhm, because there is a lower pressure, I would say that the L stands for low pressure, near point one and then my guess would be that H stands for high pressure [long pause].

**S** Okay.
<table>
<thead>
<tr>
<th>S</th>
<th>I would say, [pause] I would say George’s laundry would probably, ah, dry first.</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>Why?</td>
</tr>
<tr>
<td>S</td>
<td>Because it is, ah, less humid, in Arizona, generally, and humidity is the amount of moisture in the air, and when you’re trying to dry clothes, it’s best to have less moisture in the air.</td>
</tr>
<tr>
<td>R</td>
<td>Okay, thank you.</td>
</tr>
</tbody>
</table>
Question 1

S: The shadow lengthens then shortens [reading question aloud quietly]. I’m going to say that figure B is summer!

R: Summer? Will you tell me why?

S: Because that’s the time um, that would mean that you’re closer to the sun and so [laughter] it came down on him and you would just have a longer shadow.

Question 2

S: I am going to say that at 12:00 [not an option] her shadow is going to be longer? Because at 12:00 noon the sun is the highest in the sky and so maybe that would have something to do with a longer shadow? Maybe?

R: Okay, so you’re saying at noon, or 12:00 noon rather, the sun is highest in the sky...

S: Yes...

R: And that you would cast a longer shadow.

S: Right.

R: Okay.

Question 3

S: Sight [very long pause] Well, right [pause].

R: Take your time and think about it.

S: As you stand on the earth it tilts around the sun the earth [long pause]. [Reads question aloud to self.] Observers on Earth never see the far side or back of the lunar surface. [long pause].

R: Is that true or is that false?

S: Well, my first choice would be that they would, they would, that it would be [long pause]. I would think that he wouldn’t always see the same part of it. I would think that he, as we go around on Earth that [very long pause]

R: Okay. So you see, you believe that that statement is false. That he does see different sides of the moon because as we go around...

S: Yeah, the earth rotates around. The earth spins around as you know it orbits [long pause].

R: Okay, so since the earth rotates as it orbits, we can see different parts of the moon?

S: Mmm hmm [affirmative]... Although I don’t think you can really tell from Earth without [unclear] without, you know, you’d need a telescope to tell what sides we were looking at...

R: Okay, so you think we would need a telescope to tell?

S: [Nod]
Do you want to add anything to your answer?

No.

**Question 4**

What part of Earth is the observer standing on?

It doesn’t matter?

Well, if the moon was in position C and you could see it from earth, the moon is not in the shadow so you could see a full moon. Because a new moon is shadow.

Alright, so in position C you would see a full moon, because a new moon is in the shadow.

Yeah, you would be able to see all of the moon.

Okay.

**Question 5**

Well, the earth doesn’t look exactly marked where you can tell where people are.

So I would say that it is impossible to tell. I can’t really tell. Is that supposed to be the United States marked?

Ah, actually that is the northern hemisphere...

Oh, oh, oh, oh, oh, oh...

So you can see that the northern hemisphere is...

Oh, okay, I see. [Very long pause]. Well I would say. I would say that it is either winter, spring, or fall. I would say spring or summer. Because we’re getting sun.

So you would say spring or summer because we’re getting sun.

Yeah, because the way we’re tilted we’re getting sunshine.

What causes the seasons?

The tilting of the earth [subject’s hand is tilted and indicates that as the earth travels around the sun the tilt of the axis flip flops back and forth].

**Question 6**

Uh, ah, bowling ball? Where would the bowling ball stop? [Continues reading question aloud to self.] How can you tell? Does the hole go all the way through?

Yes the hole goes all the way through. ‘Imagine there’s a hole through the center of the Earth. The ball is dropped into the hole. Where will the ball stop?’

Well, if there’s gravity on earth, then theoretically it would go all the way through, but I don’t know, but no but... Just because we’re on one side of it [the Earth] people on the other side’s gravity will go the other way. So I don’t know which choice that would be. I mean, I don’t know where gravity switches, or whatever, you know? People on the other side, their gravity doesn’t work the
same way ours does. So he could drop it straight through the earth [unclear]. Theoretically it would probably drop and hit the side, so I guess my answer is picture two.

R Number two? And that is due to what?
S The rotation of the earth around, the spinning.
R Okay.

Question 7
S [Long pause] I remember we talked about this. [Pause] Ah, [unclear], no that's not right, I am going to say ‘Any of the above’ because all outside are, I mean, [very long pause].
R Alright, you’re saying answer four, ‘Any of the above,’ because they’re all outside structures and subject to acid rain?
S Theoretically yes.

Question 8
S [Reading aloud to self, somewhat unclear.] A hardness of one means... Ah, traces of a mineral were found. [Long pause] I don’t think it would be calcite, because it isn’t hard enough to do it [scratch glass].
R S
S But topaz [unclear and then pause], well topaz is the hardest of the choices, so maybe it is two, topaz. [Giggle] but then it might be too hard to... [Giggle]
R You’re doing fine. So we have Stephen who is trying to break into the library by cutting glass and they found scratches on the glass and he left whatever mineral he was using.
S Um hmm [affirmative]...
R It could have been fluorite, it could have been topaz, it could have been calcite, it could have been all of the three, or none of the three. You said no it is not calcite, because that is too soft and you thought topaz because it is the hardest one of the choices.
S I think that number 10, the hardest one [diamond] can cut glass. I think that is what it means. I mean I remember something about glass. So yeah, I say topaz.
R Alright.

Question 9
S Ah, um, I’m gonna say sedimentary?
R And why?
S Because is it, isn’t it along the banks [referring to situation in question], so it could have been under water at some point and I believe that that is the type of rock that is found at the bottom [pause] of, you know, water. The sediment goes through it.
R Let me repeat. You think that it is sedimentary because it is found along the banks and it might have been underwater and you think sedimentary rocks form under lakes?
S Yes, under lakes and rivers.

187
R  Okay.

**Question 10**

<table>
<thead>
<tr>
<th>S</th>
<th>Hmm! [Very long pause] I have absolutely no idea about this one. You know, I don’t know.</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>Can you guess?</td>
</tr>
<tr>
<td>S</td>
<td>I’ve never heard of this before. I don’t know.</td>
</tr>
<tr>
<td>R</td>
<td>What might your guess be?</td>
</tr>
<tr>
<td>S</td>
<td>Ah, um, let’s see [rereads question to self aloud], well, I want to say that I have absolutely no idea, but I’ll say yes, they Gulf waters are saltier [than waters surrounding Hawaii]. The Gulf is a little bit different.</td>
</tr>
<tr>
<td>R</td>
<td>How or why?</td>
</tr>
<tr>
<td>S</td>
<td>Maybe it has something to do with the way the Gulf waters flow, maybe, ah, it can’t, maybe the salt can’t filter out as well or something.</td>
</tr>
<tr>
<td>R</td>
<td>Okay so you think this has something to do with the way Gulf waters flow that prevents the salt from filtering out?</td>
</tr>
<tr>
<td>S</td>
<td>Yes, hmm mm.</td>
</tr>
</tbody>
</table>

**Question 11**

<table>
<thead>
<tr>
<th>S</th>
<th>Well, I don’t think so because if you’re playing in a channel and they seem higher to her they probably are. I mean if there has been some development maybe some of the channels have been blocked or [unclear]…</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>Okay.</td>
</tr>
</tbody>
</table>

**Question 12**

<table>
<thead>
<tr>
<th>S</th>
<th>Hunh! I don’t know either. Let’s say yes because, tidal range, ah, because it’s something about the winds, I guess. Tidal range? I don’t even know what that is.</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>This question asks us to consider that tides may appear deeper in some areas than others, or that more surface of the shore is covered during a tide in one area as compared to another.</td>
</tr>
<tr>
<td>S</td>
<td>So it’s possible they have the same tides and ranges?</td>
</tr>
<tr>
<td>R</td>
<td>Yes. In this case, they live 350 miles apart on the same coast. Jim’s tidal ranges are over 50 feet in depth, while Callie’s tidal ranges are usually less than ten feet. Could this happen?</td>
</tr>
<tr>
<td>S</td>
<td>I’d say yes, I’ve been to the beach.</td>
</tr>
<tr>
<td>R</td>
<td>This is an interesting question. Many of us in Arkansas don’t have the opportunity to visit a beach very often. What might be some causes of this range?</td>
</tr>
<tr>
<td>S</td>
<td>The wind.</td>
</tr>
<tr>
<td>R</td>
<td>Okay</td>
</tr>
</tbody>
</table>

**Question 13**

<table>
<thead>
<tr>
<th>S</th>
<th>[Long pause, rereads question to self, giggles.]</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>The question here is how rivers flow.</td>
</tr>
<tr>
<td>Question 14</td>
<td></td>
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<tr>
<td>-------------</td>
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</tr>
<tr>
<td>S</td>
<td>I don’t know. I suppose I would say that dinosaurs and humans did not live at the same time?</td>
</tr>
<tr>
<td>R</td>
<td>And why not?</td>
</tr>
<tr>
<td>S</td>
<td>This gets interesting. There’s all kinds of crazy stuff.</td>
</tr>
<tr>
<td>R</td>
<td>What do you mean by crazy stuff?</td>
</tr>
<tr>
<td>S</td>
<td>You know, religion, evolution, and the Bible, I don’t even know where to begin to explain that. But I would say that no, dinosaurs came long before the humans.</td>
</tr>
<tr>
<td>R</td>
<td>Do you know about how long before?</td>
</tr>
<tr>
<td>S</td>
<td>I knew [laughter] you would ask that, no! I don’t. A really, really long time.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question 15</th>
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<tbody>
<tr>
<td>S</td>
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<td>R</td>
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<td>S</td>
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<tr>
<td>R</td>
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<table>
<thead>
<tr>
<th>Question 16</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
</tr>
</tbody>
</table>
Yes, it absorbs the energy from the sun. It absorbs, you know.

R: Okay.

Question 17

S: [Reads and rereads question, quietly and out loud]. Stream out farthest? I think I’ve read this wrong. Which hole? How are the holes there?

R: Okay, imagine a water or milk jug filled completely with water. There are four holes spaced equally apart. They’re all punctured at the same time. Which hole would have water streaming out the farthest?

S: Uhm, well, I guess D.

R: Hole D

S: Because you go down A, you go down B, you go down C, and there’s always water down at the bottom. They’re always pressure at the bottom. There’s pressure, I don’t think that’s the right word, on the water.

R: Okay, so you’re saying that water would stream out Hole D because there’s always water on the bottom of the jug and that there’s pressure, although you’re not sure that’s the word,

S: Yes,

R: On the water.

S: Yes.

Question 18

S: I would say yes we can. I don’t know how we can, but I say yes.

R: And why do you say yes?

S: Well, I think that insects and the way... [pause and then unclear, in a louder voice] I say yes, yes we can. Because there are things in nature that can determine that.

R: Have you ever heard folks talking about ways to predict winter?

S: Yes, I have.

R: Can you think of any examples?

S: No, not really.

R: Okay.

Question 19

S: Ew, ah, I have no idea. I don’t have any idea how to read this map.

R: So you don’t have any idea how to read the map?

S: No, no idea.

R: Have you ever watched the news or the weather channel when they discuss the day’s weather?

S: Yeah, but I still don’t have any idea.

R: Can you guess?

S: [Rereads question aloud] I’m guessing H means humidity. [Long pause]. I’m going to say one. The absolute humidity of the surface at Point 1 is higher than at Point 3. Because of the H that is there. But that might not makes sense either. I really don’t now because I don’t know what all these little things mean. I guess
[very long pause], I guess I just don’t know.

R  Okay

<table>
<thead>
<tr>
<th>Question 20</th>
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<tbody>
<tr>
<td>S</td>
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<td>R</td>
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<td>S</td>
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<td>R</td>
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Appendix F:

Table of Specifications
<table>
<thead>
<tr>
<th>Questions 1 - 6, Solar System, objects and changes in the Earth and Sky</th>
<th>Arkansas Frameworks</th>
<th>NSES (National Science Education Standards)</th>
<th>Research in Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Desmond measures his shadow at noon for several months. He notices that as the year progresses his shadow lengths and then shortens. Desmond realizes that he might be able to correlate the season based on the length of his shadow. What season is it in Figure B?</td>
<td>Strand 4 Standard 10 ESS.10.3.2 Demonstrate the orbit of Earth and its moon around the sun ESS.10.3.3 Relate the Earth’s rotation to the day/night cycle</td>
<td>Content Standard D K-4 Objects in the sky have patterns of movement K-4 Sun, moon, stars… all have movements that can be described 5-8 Most objects in the solar system are in regular and predictable motion.</td>
</tr>
<tr>
<td>2</td>
<td>Ursula, Desmond’s sister, decides to measure her shadow every two hours for one day. At what point or points is Ursula’s shadow the longest?</td>
<td>Strand 4 Standard 10 ESS.10.3.3 Relate the Earth’s rotation to the day/night cycle ESS.10.7.1</td>
<td>Content Standard D K-4 Objects in the sky have patterns of movement K-4 Sun, moon, stars… all have movements that can be described</td>
</tr>
<tr>
<td>3</td>
<td>Bob notices that regardless of what phase the moon seems to be in, he always seems to see the same side of the moon. He wonders if this could possibly be true. True or False? Observers on Earth never see the far side or back of the lunar surface?</td>
<td>Strand 4 Standard 10 ESS.10.2.2 Model the movement of the Earth and its moon ESS.10.3.2 Demonstrate the orbit of Earth and its moon around the sun</td>
<td>Content Standard D K-4 Objects in the sky have patterns of movement K-4 Sun, moon, stars... all have movements that can be described 5-8 Most objects in the solar system are in regular and predictable motion.</td>
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<tr>
<td>Str.</td>
<td>Task Description</td>
<td>Reference</td>
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</tbody>
</table>
| 4    | The moon seems to change shapes as it orbits the Earth. To an observer on Earth, what phase would she see if the moon was in position C? | •Stahly, Krockover, & Shepardson, 1999
•Stein, 2007
•Suzuki, 2003
•Taylor, 1996
•Trembath, 1984
•Trumper, 2001a & 2001b
•Trundle, 2003
•Trundle, Atwood, & Christopher, 2002, 2003, & 2006
•Trundle, Willmore, & Smith, 2006
•Vosniadou & Brewer, 1984
•Zeilik & Bisard, 2000 |
|      | Strand 4                                                                          | Content Standard D K-4 Objects in the sky have patterns of movement K-4    |
|      | Standard 10                                                                        | Sun, moon, stars… all have movements that can be described 5-8             |
|      | ESS.10.2.1                                                                        | Most objects in the solar system are in regular and predictable motion.    |
|      | Illustrate four moon phases                                                       | •Ault, 1984                                                               |
|      | ESS.10.2.2                                                                        | •Baxter, 1989                                                             |
|      | Model the movement of the Earth and its moon                                      | •Beaty, 2004                                                              |
|      | ESS.10.3.2                                                                        | •Brunsell & Marcks, 2007                                                  |
|      | Demonstrate the orbit of Earth and its moon around the sun                        | •Callison & Wright, 1993                                                  |
|      |                                                                                   | •Cohen, 1982 & 2004                                                       |
|      |                                                                                   | •Cohen & Kagan, 1979                                                     |
|      |                                                                                   | •Daikidoy, Vosniadou, & Hawks, 1997                                       |
|      |                                                                                   | •Dove, 2002                                                              |
| 5 | According to the diagram below, Strand 4 | ESS.10.6.7 Model moon phases demonstrating the position of Earth, moon, and sun | •Jones & Lynch, 1987  
•Kalkan & Kiroglu, 2007  
•Lambert, 2006  
•Matteson & Kambly, 1940  
•Philips, 1991  
•Rider, 2002  
•Sadler, 1987 & 1998  
•Schoon, 1992 & 1995  
•Stahly, Krockover, & Shepardson, 1999  
•Stein, 2007  
•Suzuki, 2003  
•Taylor, 1996  
•Tregast, 1988  
•Trembath, 1984  
•Trumper, 2001a & 2001b  
•Trundle, 2003  
•Trundle, Atwood, & Christopher, 2002, 2003 & 2006  
•Trundle, Willmore, & Smith, 2006  
•Vosniadou & Brewer, 1984  
•Zeilik & Bisard, 2000  
•Adams, 2008 |
| 6 | Imagine that there is a hole through the Earth. Bubba stands at the hole and drops a bowling ball into the hole. Where will the ball go? | Strand 4
Standard 8
ESS.10.8.1
Summarize the effects | Content Standard D
5-8
Gravity is the force that keeps planets in orbit | • Bar, Sneider, & Martinbeau, 1997
• Baxter, 1989
• Beaty, 2004 |

| what season is Arkansas experiencing in position C? | Standard 10
ESS.10.3.2
Demonstrate the orbit of Earth and its moon around the sun
ESS.8.7.11
Analyze the effect of the shape of Earth and the tilt of Earth's axis on climate | K-4
Weather changes from day to day and over the seasons
5-8
Most objects in the solar system are in regular and predictable motion.
5-8
Seasons result from variations in the amount of the sun's energy hitting the surface, due to the tilt of the earth's rotation on its axis and the length of day | • Atwood & Atwood, 1996
• Baxter, 1989
• Beaty, 2004
• Callison & Wright, 1993
• Gunstone & White, 1980
• Jones & Lynch, 1987
• Kalkan & Kiroglu, 2007
• Lambert, 2006
• Lucas & Cohen, 1999
• Matteson & Kambly, 1940
• Philips, 1991
• Rice, 2005
• Sadler, 1998
• Schoon, 1995
• Stein, 2007
• Trembath, 1984
• Trumper, 2001a & 2001b
• Tsai & Chang, 2005
• Zeilik & Bisard, 2000 |
<table>
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<tr>
<th>bowling ball stop?</th>
<th>of gravity on bodies in space</th>
<th>around the sun and governs the rest of the motion in the solar system.</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>• Kalkan &amp; Kiroglu, 2007</td>
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<td></td>
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<td>• Libarkin &amp; Anderson, 2002</td>
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<td></td>
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<td>• Nobes, et al., 2003</td>
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<td></td>
<td></td>
<td>• Nussbaum, 1979</td>
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<td>• Nussbaum &amp; Novak, 1976</td>
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<td></td>
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<td>• Nussbaum &amp; Sharoni-Dagan, 1983</td>
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<td></td>
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<td>• Philips, 1991</td>
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<td></td>
<td></td>
<td>• Sneider &amp; Ohadi, 1998</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Trembath, 1984</td>
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<td></td>
<td></td>
<td>• Wunderlee, Libarkin, &amp; Rudders (2004)</td>
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</table>

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<tr>
<th>Questions 7 - 10 Earth’s systems, rock and water cycles</th>
<th>Arkansas Frameworks</th>
<th>NSES (National Science Education Standards)</th>
<th>Research in Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Which of the following man-made structure is most likely to be damaged by acid rain?</td>
<td>Strand 4 Standard 8 ESS.9.3.1 Analyze the effect of wind and water on the Earth’s surface ESS.8.7.14 Describe the causes and effect of acid precipitation</td>
<td>Content Standard D 5-8 Water is a solvent. Content Standard F K-4 Changes in the environment can be natural or influenced by humans. Content Standard B 5-8 Substances react chemically in</td>
</tr>
</tbody>
</table>
**8** Stephen attempted to break into the library by cutting through the glass window using information he learned in geology class. He finally gave up and ran away after the alarms were triggered. The university police found scratches on the window and traces of a mineral on the ground by the window. Using Mohs Hardness Scale, what mineral could it have been?

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<tr>
<th>Strand 4</th>
<th>Content Standard D K-4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard 8</td>
<td>Earth materials... have different physical and chemical properties</td>
</tr>
<tr>
<td>ESS.8.3.4 Identify the physical properties of minerals</td>
<td></td>
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<tr>
<td>ESS.8.5.3 Identify characteristics of minerals</td>
<td></td>
</tr>
<tr>
<td>ESS.8.5.4 Conduct investigations on mineral properties</td>
<td></td>
</tr>
</tbody>
</table>

**9** Suzy is walking along the banks of the Richland Creek. This area is known to be rich in fossils of trilobites, crinoids, and other ancient seafaring creatures. Suzy bends to retrieve a particularly fascination rock containing several impressions of crinoids. What kind of rock is Suzy holding?

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<tr>
<th>Strand 4</th>
<th>Content Standard D K-4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard 8</td>
<td>Fossils provide evidence about the plants and animals that lived long ago</td>
</tr>
<tr>
<td>ESS.8.3.1 Distinguish among Earth’s materials</td>
<td></td>
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<tr>
<td>ESS.8.3.3 Identify three categories of rocks</td>
<td></td>
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<tr>
<td>ESS.8.5.7 Identify characteristics of sedimentary, igneous, and metamorphic rocks</td>
<td></td>
</tr>
<tr>
<td>ESS.8.5.9 Classify the three basic types of rocks</td>
<td></td>
</tr>
</tbody>
</table>

- Beaty, 2004
- Philips, 1991
- Schoon, 1995
- Ucar, Trundle, & Krissek, 2006
- Ault, 1984
- Ford, 2003
- Lambert, 2006
- Libarkin & Anderson, 2005
- Libarkin et al., 2005
- Stofflett, 1993
<table>
<thead>
<tr>
<th></th>
<th>Describe the rock cycle</th>
</tr>
</thead>
</table>
| 10 | Marta has traveled extensively. Her favorite places to visit are sandy beaches around the world. One afternoon while drying in the warm sun of Gulf Shores, Alabama, Marta reflects on the saltiness of the Gulf waters. If her memory serves her well, are the gulf waters saltier than the waters surrounding Hawaii? | Strand 4  
Standard 8  
ESS.8.8.10  
Explain how weathering and erosion affect the oceans’ salinity | Content Standard D  
K-4  
‘Earth changes’ are due to slow processes such as erosion and weathering. | Philips, 1991 |
<table>
<thead>
<tr>
<th>Questions 11 - 14 Earth’s history, structure and surface of earth</th>
<th>Arkansas Frameworks</th>
<th>NSES (National Science Education Standards)</th>
<th>Research in Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>11</strong></td>
<td>As a child, Nancy remembers playing in the run-off channels around Fayetteville, Arkansas. Despite the drought of the past few years, Nancy feels she cannot allow her children to play in the run-off because there seems to be much more water in the channel after a rain since the city has developed and grown in the past 20 years. Is Nancy being overly cautious?</td>
<td>ESS.9.3.1 Analyze the effect of wind and water on the Earth’s surface</td>
<td>Content Standard D K-4 The surface of the earth changes…</td>
</tr>
<tr>
<td><strong>12</strong></td>
<td>Jim and Calli both live on the Atlantic Seaboard. However, Jim lives 350 miles south of Calli. Is it really possible for Jim to experience tidal ranges of over 50 feet in depth while Calli, only 350 miles south, experiences tidal ranges of less than ten feet?</td>
<td>Strand 4 Standard 8 ESS.10.8.3 Relate the effects of gravitation force on Earth’s ocean tides ESS.10.8.4 Identify the causes of high, low, spring, and neap tides</td>
<td>Content Standard D 5-8 Land forms are the result of a combination of constructive and destructive forces.</td>
</tr>
<tr>
<td><strong>13</strong></td>
<td>Emilio finds himself standing on the bank of the Amazon River. His compass indicates that water</td>
<td>Strand 4 Standard 8 ESS.9.4.1</td>
<td>Content Standard D K-4 The Surface of the earth</td>
</tr>
</tbody>
</table>
| 14 | Miss Alayne, a first grade teacher, takes her students on a field trip to the museum. Billy, a particularly precocious student, asks if dinosaurs and humans lived at the same time. Is this possible? | Strand 4  
Standard 8  
Analyze fossil record evidence about plants and animals that lived long ago | Content Standard D  
5-8  
Fossils provide important evidence of how life and environmental conditions have changed.  
9-12  
Origin and evolution of the earth system. | •Ault, 1982  
•Beaty, 2004  
•Libarkin & Anderson, 2005  
•Libarkin et al., 2005  
•Philips, 1991  
•Rice, 2005  
•Schoon & Boone, 1998 |

<table>
<thead>
<tr>
<th>Questions 15 - 20 Climate, weather, and atmosphere</th>
<th>Arkansas Frameworks</th>
<th>NSES (National Science Education Standards)</th>
<th>Research in Literature</th>
</tr>
</thead>
</table>
| 15 | David wins a trip to Antarctica. He wants to learn more about the environment he will encounter. Which of the following books would be the most helpful? | Strand 4  
Standard 8  
ESS.8.7.4  
Investigate the effect that oceans have on | Content Standard D  
5-8  
Global patterns of atmospheric movement influence local weather... |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th>climate</th>
<th>9-12</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ESS.8.7.11</td>
<td>Global climate is determined by energy transfer...</td>
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<td></td>
<td></td>
<td>Describe and map climates of major Earth regions</td>
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<tr>
<td>16</td>
<td>During which of the following processes in the water cycle do water molecules absorb energy?</td>
<td>Strand 4 Standard 8 ESS.8.4.7 Describe the processes of the water cycle ESS.8.7.16 Conduct investigations demonstrating the water cycle</td>
<td>Content Standard D 9-12 Earth systems have internal and external sources of energy...</td>
<td>&quot;Bar, 1989&quot; &quot;Ben-zvi-Assarf &amp; Orion, 2005;&quot; &quot;NTS, 2006&quot; &quot;Philips, 1991&quot;</td>
</tr>
<tr>
<td>17</td>
<td>In science class Marjorie and Dan were asked to fill a plastic milk jug with water. Approximately four centimeters from the bottom they punctured the milk jug with a pencil. They placed three holes vertically, one centimeter apart, directly above the first hole. Which hole will water stream out the farthest?</td>
<td>Strand 4 Standard 8 ESS.8.7.1 Describe the composition and physical characteristics of the atmosphere</td>
<td>Content Standard D 5-8 The atmosphere has different properties at different elevations.</td>
<td>&quot;Giese, 1987&quot;</td>
</tr>
<tr>
<td>18</td>
<td>Danny, an Eagle Scout of 25 years, claims he can predict the occurrence of a very cold winter.</td>
<td>Strand 4 Standard 8 ESS.8.7.7</td>
<td>Content Standard D K-4 Weather changes from</td>
<td>&quot;Lambert, 2006&quot; &quot;Philips, 1991&quot; &quot;Schoon, 1992 &amp; 1995&quot;</td>
</tr>
<tr>
<td>Is this possible?</td>
<td>Predict weather conditions</td>
<td>day to day and over the seasons.</td>
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<tr>
<td>19 The map below from Channel 29/40 KHOG shows a low pressure cell with accompanying fronts. Based on this map, which of the following statements are true?</td>
<td>Strand 4 \nStrand 8 \nESS.8.7.7 Predict weather conditions</td>
<td>Content Standard D K-4 Weather changes from day to day and over the seasons.</td>
<td>• Lambert, 2006 \n• NTS, 2006</td>
<td></td>
</tr>
<tr>
<td>20 George lives in Phoenix, Arizona. Martha lives in Tampa, Florida. One afternoon they both washed their laundry and hung it out to dry. It was a sunny day of 75 degrees Fahrenheit in both places. Whose laundry will dry first?</td>
<td>Strand 4 \nStrand 9 \nESS.9.3.1 Analyze the effect of wind and water on the Earth’s surface</td>
<td>Content Standard D K-4 Weather changes from day to day and over the seasons. Weather can be described by measurable quantities</td>
<td>• Bar, 1989 \n• Lambert, 2006</td>
<td></td>
</tr>
</tbody>
</table>
Appendix G:

ACES-Q II-R HOC
I am Katherine Leslie, a doctoral candidate at the University of Arkansas. I am conducting research using a questionnaire to learn more about alternative conceptions in Earth science held by preservice teachers. Your participation will help ensure the validity of my instrument. Completion of this instrument will take approximately 15 minutes and poses no risk to you, the participant. Participation is completely voluntary; there is no penalty for refusal to participate. By completing this form you are implying your consent to participate in this study. Data gathered using this form are completely anonymous. If you have questions regarding this study please do not hesitate to contact me or my faculty advisor, Dr. Mike Wavering, (wavering@uark.edu or 479-575-4283). For questions or concerns about your rights as a research participant, please contact Ro Windwalker, the University’s Compliance Coordinator (irb@uark.edu or 479-575-2208). Thank you for your participation.

For this study, Earth science is defined as any of several of the geologic sciences that are concerned with the origin, structure, and physical phenomena of the Earth, including the Earth as a body in space. For the purpose of this study the researcher has divided the topic of Earth science into four distinct constructs. Operational definitions for each construct are listed below:

**Solar System:** the area of Earth science directly concerned with the Earth as a member of the solar system, Earth's place in space, and relationships with other bodies in space.

**Earth’s History:** the area of Earth science that focuses on the origin of the Earth, how rocks provide a history the Earth, and paleontology.

**Earth’s Systems:** an area of Earth science directly concerned with water cycle, rock cycle, the atmosphere and the hydrosphere.

**Climate:** the area of Earth science that focuses on the study of weather, weather over time, or climate, and the impact these have on Earth.
Please rate how well each item relates to each construct. You will do this in the first four columns following the question. These columns are marked: Solar System, Earth’s History, Earth Systems, & Climate. It is important that you use the operational definitions listed previously as the basis for your ratings and not your own definitions or other definitions for the items listed. The rating scale is described below:

“1” An item is a clear measure of the construct, according to the operational definition.
“0” An item is an unclear measure of the construct, according to the operational definition. The item may be somewhat related to the construct or a slight measure of the construct, but not a clear or clean measure of the construct.
“-1” An item is clearly not a measure of the construct, according to the operational definition.

The sixth column asks you to indicate what particular grade levels this question is appropriate for. Please indicate the appropriate grade level for each question using one of the following: K-4, 5-8, or 9-12.

The seventh column asks you to indicate if you believe teacher candidates hold misconceptions with regard to each individual question. Indicate (Y) for yes, teacher candidates do have misconceptions in this area of Earth science or (N) for no, teacher candidates do not have misconceptions in this area of Earth science.
### Judges’ Ratings Table of Specifications

<table>
<thead>
<tr>
<th>Questions on Instrument</th>
<th>Solar System</th>
<th>Earth’s History</th>
<th>Earth Systems</th>
<th>Climate</th>
<th>Indicate Grade Level (K-4, 5-8, or 9-12)</th>
<th>Possible Alternative Conceptions (Y or N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Desmond measures his shadow at noon for several months. He notices that as the year progresses his shadow lengthens and then shortens. Desmond realizes that he might be able to correlate the season based on the length of his shadow. What season is it in figure B?</td>
<td></td>
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<td>2. Ursula, Desmond’s sister, decides to measure her shadow every two hours for one day. At what point or points is Ursula’s shadow the longest?</td>
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<td>3. Bob notices that regardless of what phase the moon seems to be in, he always seems to see the same side of the moon. He wonders if this could possibly be true. True or False? Observers on Earth never see the far side or the back of the lunar surface.</td>
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<tr>
<td>5. According to the diagram below, what season is Arkansas experiencing in position C?</td>
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<tr>
<td>6. Imagine that there is a hole through the Earth. Bubba stands at the hole and drops a bowling ball into the hole. Where will the bowling ball stop?</td>
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<td>Questions on Instrument</td>
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<td>7. Which of the following man-made structures is most likely to be damaged by acid rain? (Mt. Rushmore, Tombstone, Slate Roof)</td>
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<td>8. Stephen attempted to break into the library by cutting through the glass window using information he learned in geology class. He finally gave up and ran away after the alarms were triggered. The university police found scratches on the window and traces of a mineral on the ground by the window. Using the Mohs Hardness scale, which of the following minerals could it have been?</td>
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<td>9. Suzy is walking along the banks of the Richland Creek. This area is known to be rich in fossils of trilobites, crinoids, and other seafaring creatures. Suzy bends to retrieve a particularly fascinating rock containing several impressions of crinoids. What kind of rock is Suzy holding?</td>
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</tr>
<tr>
<td>10. Marta has traveled extensively. Her favorite places to visit are sandy beaches around the world. One afternoon while drying in the warm sun of Gulf Shores, Alabama, Marta reflects on the saltiness of the Gulf waters. If her memory serves her well, are the Gulf waters saltier than the waters surrounding Hawaii?</td>
<td></td>
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</tr>
</tbody>
</table>
### Judges' Ratings Table of Specifications

<table>
<thead>
<tr>
<th>Questions on Instrument</th>
<th>Solar System</th>
<th>Earth's History</th>
<th>Earth Systems</th>
<th>Climate</th>
<th>Indicate Grade Level</th>
<th>Possible Alternative Conceptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. As a child, Nancy remembers playing in the run-off channels around Fayetteville, Arkansas. Despite the drought of the past few years, Nancy feels she cannot allow her children to play in the run-off because there seems to be much more water in the channel after a rain since the city has developed and drowned in the past 20 years. Is Nancy being overly cautious?</td>
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<tr>
<td>12. Jim and Calli both live on the Atlantic Seaboard. However, Jim lives 350 miles north of Calli. Is it really possible for Jim to experience tidal ranges over 50 feet in depth while Calli, only 350 miles south, experiences tidal ranges of less than ten feet?</td>
<td></td>
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<tr>
<td>13. Emilio finds himself standing on the bank of the Amazon River. His compass indicates that the water is flowing west to east. Is his compass malfunction</td>
<td></td>
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<tr>
<td>14. Miss Alayne, a first grade teacher, takes her students on a field trip to the museum. Billy, a particularly precocious student, asks if dinosaurs and humans lived at the same time. Is this possible?</td>
<td></td>
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<tr>
<td>15. David wins a trip to Antarctica. He wants to learn more about the environment he will encounter. Which one of the following library books would be the most helpful? (Deserts of the World, Explore the Tundra, Discover the Aquatic)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Questions on Instrument</td>
<td>Solar System</td>
<td>Earth’s History</td>
<td>Earth Systems</td>
<td>Climate</td>
<td>Indicate Grade Level</td>
<td>Possible Alternative Conceptions</td>
</tr>
<tr>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>16. During which of the following processes in the water cycle do water molecules absorb energy?</td>
<td>(1, 0, or -1)</td>
<td></td>
<td></td>
<td></td>
<td>(K-4, 5-8, or 9-12)</td>
<td></td>
</tr>
<tr>
<td>17. In science class Marjorie and Dan were asked to fill a plastic milk jug with water. Approximately four centimeters from the bottom, they punctured the milk jug with a pencil. They placed three more holes, vertically, one centimeter apart, directly above the first hole. Which hole will water stream out farthest?</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. Danny, an Eagle Scout of 25 years, claims he can predict the occurrence of a very cold winter. Is this possible?</td>
<td></td>
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<tr>
<td>19. The map to your right from Channel 40/29 KHOG shows a low pressure cell with accompanying fronts. Based on this map, which of the following statements are true?</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>20. George lives in Phoenix, Arizona. Martha lives in Tampa, Florida. One afternoon they both washed their laundry and hung it out to dry. It was a sunny day of 75 degrees Fahrenheit in both places. Whose laundry will dry first?</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Thank you for your time and expertise!
Appendix H:

ACES-Q II-R

Alternative Conceptions In Earth Science ~ A Questionnaire

Data Sheet
Ex: Answer 1 2 3 4 Sure? 5 4 3 2 1 Alternate Response___________
Response a b c d Sense? 5 4 3 2 1 ____________

1. Answer 1 2 3 4 Sure? 5 4 3 2 1 Alternate Response___________
Response a b c d Sense? 5 4 3 2 1 ____________

2. Answer 1 2 3 4 Sure? 5 4 3 2 1 Alternate Response___________
Response a b c d Sense? 5 4 3 2 1 ____________

3. Answer 1 2 3 4 Sure? 5 4 3 2 1 Alternate Response___________
Response a b c d Sense? 5 4 3 2 1 ____________

4. Answer 1 2 3 4 Sure? 5 4 3 2 1 Alternate Response___________
Response a b c d Sense? 5 4 3 2 1 ____________

5. Answer 1 2 3 4 Sure? 5 4 3 2 1 Alternate Response___________
Response a b c d Sense? 5 4 3 2 1 ____________

6. Answer 1 2 3 4 Sure? 5 4 3 2 1 Alternate Response___________
Response a b c d Sense? 5 4 3 2 1 ____________

7. Answer 1 2 3 4 Sure? 5 4 3 2 1 Alternate Response___________
Response a b c d Sense? 5 4 3 2 1 ____________

8. Answer 1 2 3 4 Sure? 5 4 3 2 1 Alternate Response___________
Response a b c d Sense? 5 4 3 2 1 ____________

9. Answer 1 2 3 4 Sure? 5 4 3 2 1 Alternate Response___________
Response a b c d Sense? 5 4 3 2 1 ____________

10. Answer 1 2 3 4 Sure? 5 4 3 2 1 Alternate Response___________
Response a b c d Sense? 5 4 3 2 1 ____________

Next Page Please ➔
21. Briefly describe how you would teach the following earth science concept for the grade level of your choice. Be sure to include a description of any teaching strategies, activities, and/or materials you might use. **Topic: Solar Eclipse**

**Grade**

**Level:**

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

**Demographics:**

Age ____ Gender Female Male Undergraduate Degree ____________

**Certification Level**

High School Middle School Elementary School

**Area of Licensure**

Elementary Math Science English Social Studies

Foreign Language Speech and Drama

How many science courses did you complete as an undergraduate in the following content areas?

EARTH _____________ (i.e. Astronomy, Geology, etc.)

LIFE _______________ (i.e. Biology, Anatomy and Physiology, Botany etc)

PHYSICAL __________ (i.e. Physics and Human Affairs, etc.)

CHEMISTRY __________ (i.e. Chem I, Chem II, etc.)

**Highest degree of:**

**Female Parent:**

__ Elementary School
__ Some High School
__ High School
__ Some College
__ Bachelor’s Degree
__ Master’s and/or Doctorate

**Male Parent:**

__ Elementary School
__ Some High School
__ High School
__ Some College
__ Bachelor’s Degree
__ Master’s and/or Doctorate
Appendix I:

Alternate Answers and Responses

ACES-Q II-R
## Alternate Answers and Responses Provided on the ACES-Q II-R

<table>
<thead>
<tr>
<th>Question ID</th>
<th>ID (Score)</th>
<th>Alternate Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>56(7)</td>
<td>There’s not enough detail in the diagram.</td>
</tr>
<tr>
<td></td>
<td>44(13)</td>
<td>With only 2 choices and 4 seasons, it seems as though B could be several choices.</td>
</tr>
<tr>
<td></td>
<td>45(8)</td>
<td>Seasons are based on tilt Earth’s axis.</td>
</tr>
<tr>
<td>3</td>
<td>33(3)</td>
<td>The moon rotates around the earth in 29 days but the moon completes a rotation in less time.</td>
</tr>
<tr>
<td>5</td>
<td>33(3)</td>
<td>Modified B and D [Response choices] Earth is tilted and Arkansas is in the northern hemisphere and the n. h. [northern hemisphere] is closer to the sun at point c. Therefore must be the hottest. Likewise the southern hemisphere has its summer at A.</td>
</tr>
<tr>
<td></td>
<td>53(11)</td>
<td>Earth is tilted so sun’s rays are dispersed more in winter in lower hemisphere and more focused in n[orthern] hemis[phere] during summer.</td>
</tr>
<tr>
<td>6</td>
<td>33(3)</td>
<td>Everything is pulled towards the center of the earth; not the surface. The surface is the visible consequence.</td>
</tr>
<tr>
<td>7</td>
<td>33(3)</td>
<td>The more porous a rock the more likely it will be broken by acid rain.</td>
</tr>
<tr>
<td>9</td>
<td>31(11)</td>
<td>Fossils can only form in sedimentary rock.</td>
</tr>
<tr>
<td>11</td>
<td>8(11)</td>
<td>Half the moon is lit and the earth casts a shadow so it will be a quarter moon.</td>
</tr>
<tr>
<td>13</td>
<td>85(10)</td>
<td>Nile flows south to north, right?</td>
</tr>
<tr>
<td>14</td>
<td>33(3)</td>
<td>Some scientists say humans died; others say they hid in caves during the ice age.</td>
</tr>
<tr>
<td></td>
<td>35(3)</td>
<td>People are defined as what homo erectus, habilis, etc…</td>
</tr>
<tr>
<td></td>
<td>50(7)</td>
<td>Maybe not humans but some form of sapiens.</td>
</tr>
<tr>
<td></td>
<td>88(8)</td>
<td>Religion versus science.</td>
</tr>
<tr>
<td></td>
<td>51(12)</td>
<td>Anything is possible.</td>
</tr>
<tr>
<td>16</td>
<td>28(7)</td>
<td>All of the above [Answers and Responses]</td>
</tr>
<tr>
<td>17</td>
<td>33(3)</td>
<td>Streaming out farthest will be a [sic] because of gravity and horizontal push.</td>
</tr>
<tr>
<td></td>
<td>46(5)</td>
<td>The top height is greater.</td>
</tr>
<tr>
<td>18</td>
<td>33(3)</td>
<td>Anyone can predict anything. It can be proven write or wrong by science.</td>
</tr>
<tr>
<td></td>
<td>44(13)</td>
<td>He can not [sic] be completely sure, but more sure this way.</td>
</tr>
<tr>
<td>29</td>
<td>29(15)</td>
<td>Scientists follow ocean currents and can use El Nino and La Nina.</td>
</tr>
</tbody>
</table>
Vita

Katherine Anna Mangione was born in Buffalo, New York on November 23, 1969. She attended grammar school and high school in Eureka Springs, Arkansas where she graduated in 1987. In 1991 she earned a Bachelor’s of Arts in Elementary Education from Hendrix College in Conway, Arkansas. She graduated in 1996 from the University of Central Arkansas, Conway where she earned a Master’s of Science in Education in Gifted and Talented Education. She earned a Doctor of Philosophy degree in Curriculum and Instruction from The University of Arkansas, Fayetteville in 2011. Katherine taught elementary school and pre-school for five years in rural and suburban Arkansas and for five years in inner-city Saint Louis, Missouri. She has been teaching undergraduates and graduates for the past ten years.

During her graduate work at the University of Arkansas Katherine served as a graduate teaching assistant and an adjunct faculty member. There she taught science and math methods courses for elementary teachers, classroom management, and children’s literature. Additionally Katherine worked for the Center for Math and Science and the N.A.S.A. Educators Resource Center as the StarLab presenter for public schools in Northwest Arkansas. Currently, she is an Assistant Professor of Elementary and Early Childhood education at the University of Central Missouri, Warrensburg where she continues teaching science methods courses, classroom management, and children’s literature courses for elementary teachers.