Changing Perceptions of Science in Undergraduate Students: A Mixed Methods Case Study

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CHANGING PERCEPTIONS OF SCIENCE IN UNDERGRADUATE STUDENTS:
A MIXED METHODS CASE STUDY

by

Cindy S. Larson-Miller

A DISSERTATION

Presented to the Faculty of
The Graduate College at the University of Nebraska
In Partial Fulfillment of Requirements
For the Degree of Doctor of Philosophy

Major: Educational Studies
(Teaching, Curriculum, and Learning)

Under the Supervision of Professor Ronald J. Bonnstetter

Lincoln, Nebraska
August 2011
The purpose of this bounded single-case study was to explore the understanding of the nature and process of science for undergraduate students at the University of Nebraska-Lincoln (UNL). The study investigated one professor’s methodology to explicitly teach undergraduate students about the nature and process of science, and documented their understanding and perception of science, both pre- and post-course.

Using a mixed method approach, data were collected to provide a better understanding of teaching the nature and process of science. Three main types of data were analyzed: the process of science (TPOS) assessment; survey questions, and the module curriculum.

Participating students completed The Process of Science (TPOS) assessment and open-ended survey questions pre- and post-intervention. The intervention in the study was the teaching of a process of science module developed by the instructor involved in the case study. Using a split-plot analysis of variance (ANOVA) in the pre- and post-module data, comparisons were drawn for the TPOS assessment and the survey questions. Evidence showed a statistically significant improvement in the pre- and post-scores for both assessments.
The process of science module was also analyzed and found to be an educationally-sound curriculum when based on the foundation and philosophy of Bloom’s Taxonomy. Students appreciated the module and the change that it caused in their perceptions of science.
Dedication

I dedicate this work to my three daughters, Lizbeth, Sophia, and Margaret. Throughout this process, I have asked myself why finishing this degree is so important. What I have realized is that aside from the personal accomplishment, it is important to me that my girls see that a woman can accomplish anything she decides that she can accomplish. Being the last of three daughters, I once asked my Dad if he had wanted me to be a boy when I was born. His wise, and I believe honest, answer was “I just always figured that a girl can do anything a boy can do”. I was raised according to this philosophy and I hope that I am passing it down to my three wise and strong daughters. May you never find an obstacle you aren’t able to overcome.
Acknowledgements

I would first like to thank my advisor Dr. Ronald Bonnstetter for his unceasing encouragement to learn and grow and persist. Without him, I would not be half the educator that I am.

I would also like to thank the other members of my committee – Dr. Larry Dlugosh, Dr. Dave Gosselin, and Dr. Jim Walter. Your continued support of my professional work is greatly appreciated.

A special thank you is needed to Dr. Dave Gosselin who allowed me to delve into his teaching curriculum to complete this project.

Thank you to Chaorong Wu with the UNL NEAR Center. It was like you knew what I was thinking and solved my statistics problems without hesitation.

Thanks to my family who constantly support me in whatever I am doing. My husband, Jon, is my greatest advocate. Thank you for sacrificing all these years and allowing me the space to grow. A special thanks to my mom and dad, Kay and Everett, who gave me the gift of education, metaphorically and literally. Thank you to my daughters, who survived my educational pursuits and were so helpful through the writing of this dissertation.

I have come to understand that the writing of a dissertation is not a one-person pursuit. Without the contribution of these and so many other people in my life, I could not–would not, have finished this work. I thank you all.
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Chapter One
Introduction to the Study

Statement of the Problem

Since the 1900’s, scholars have been warning of the danger of reducing science to a set of facts; and focusing on the content without the process (Steinkuehler & Duncan, 2008). In 1905 Henri Poincare stated, "Science is built up of facts, as a house is built of stones; but an accumulation of facts is no more science than a heap of stones is a house" (cited in Gould, 2001, p. 141). In 1993 the American Association for the Advancement of Science (AAAS) called for the United States to stress the development of science literacy among American students:

As the world becomes increasingly scientific and technological, our future grows more dependent on how wisely humans use science and technology. And that, in turn, depends on the effectiveness of the education we receive. With the exploding impact of science and technology on every aspect of our lives, especially on personal and political decisions that sustain our economy and democracy, we cannot afford an illiterate society.

And yet, according to Miller (2004), only one in five Americans is scientifically literate. The Third International Mathematics and Science Study (TIMSS) adds to our information about American students’ science literacy showing us that USA test scores of middle school science students have virtually stayed the same or decreased over the last 12 years (US Department of Education, 2007). Obviously, we are not making great strides toward developing science literacy.

The question lingers then as to what educators can do in their classrooms to improve science literacy in the United States. To begin, we must explore the nature and process of science, what science is, how science is practiced, and how students learn science.
Purpose of the Study

The purpose of this case study was to explore the understanding of the nature and process of science for undergraduate students at the University of Nebraska-Lincoln (UNL). The study investigated one professor’s methodology to teach undergraduate students about the nature and process of science, and documented their perception of science, both pre- and post-course.

According to Yin (2009, kindle location 343), a “case study is used in many situations, to contribute to our knowledge of individual, group, organizational, social, political, and related phenomena.” The intent of this research was to contribute to the knowledge surrounding understanding the nature and process of science. Yin rationalizes the use of a single-case study when “the case represents an extreme case or a unique case” (2009, kindle location 1208). Dr. Gosselin’s undergraduate course is one such unique case in that the explicit teaching of the nature and process of science is, from my experience, uncommon at the undergraduate level.

Research Questions and Instrumentation

The purpose of this mixed methods case study was to investigate a group of undergraduate students’ understanding of the nature and process of science in the context in which it was learned, a college course setting. Both quantitative and qualitative research methods were used separately, maintained separately, and integrated in the final analysis. According to Creswell and Plano Clark, “The use of quantitative and qualitative approaches in combination provides a better understanding of research problems than either approach alone” (2007, p. 18).
**Central Research Question.** How does explicitly teaching the process of science affect undergraduate students’ perceptions and understanding of the nature and process of science?

**Subquestions.**

1. How can educators explicitly teach the process of science?
2. What themes emerge in undergraduate students’ perceptions of science?
3. What misconceptions emerge in undergraduate students’ understanding of the nature and process of science?

**Instrumentation.** The research questions were addressed using an instrument developed by Dr. Anthony Carpi at John Jay College, New York City, called the Process of Science Assessment (TPOS—Appendix A). This instrument was designed to measure student understanding of the process of science in five key concept areas:

- Scientists use multiple research methods to study the natural world.
- Scientific knowledge evolves with new evidence and perspectives.
- Scientific theories are testable explanations supported by multiple lines of evidence.
- The community of science engages in debate and mitigates individual human errors.
- Science is valuable to individuals and society; students will appreciate the value of science and a scientific way of thinking.

The measure was administered pre- and post-course, in both online and face-face sections of the course and included both quantitative and qualitative components.
Face and content validity were established in Carpi’s original research with the TPOS instrument. Face validity results from Carpi’s participant panel in 2008 steered the development of subsequent versions of the instrument (personal communication, March 1, 2011). In 2009, Carpi convened a panel of experts in the field of the nature and process of science to determine if the measure addressed the content it was designed to measure, content validity. Again, this process resulted in a revised version which is the one used in this study. Reliability was calculated in this study using the current data set as previous reliability could not be obtained. Our sample generated a Cronbach’s Alpha of .589 for the face-to-face section and .539 for the online section. Without data from the assessment’s prior trials, the researcher assumes the low alpha is in part due to the relatively small sample included in the study.

Reflective Process of Science (RPOS) survey questions (Appendix B) explored the students’ perception of science. Students responded, pre- and post-treatment, to the questions in a written format. These questions were coded and analyzed quantitatively. In addition, the RPOS survey questions were investigated for themes related to the research subquestions.

A curriculum analysis of the teaching module explored the teaching methods of the participating educator in terms of the nature and process of science.

The reason for collecting both quantitative and qualitative forms of data was to bring together the strengths of both forms of research to give a descriptive interpretation of the results. Further, Creswell defines a case study as using “detailed, in-depth data collection involving multiple sources of information” (2007, p. 73). The design of this
study attempted to capture the essence of the case study through multiple data sets and thorough analysis.

Case Setting

The involved case was University of Nebraska-Lincoln (UNL) undergraduate course, NRES 108: Earth’s Natural Resource Systems taught by Dr. David Gosselin (Appendix C). A full course syllabus is available in Appendix D.

Data were collected from two sections of this course. There were sixty-three (63) students involved in the study from the Fall 2010 online (39) and face-to-face sections (24). Four students’ data were incomplete thus these students were removed from the study providing a final n of fifty-nine (59).

The researcher and Dr. Gosselin worked together on multiple projects outside of the current study. Working together as a team allowed the researcher access to the instructor for almost constant questioning and collaboration.

Definition of Terms

The following set of definitions is offered as an attempt to build a common understanding of how the terms are used within the extent of the study.

Bounded single-case study—A case study is an in-depth exploration of a bounded system, a case separated out from others based on time, place, or other physical boundary (Yin, 2009). In this study, the boundary is created by the time and place of the course offering.

Inquiry—Inquiry involves but is not limited to making observations; posing questions; examining resources for prior studies; planning investigations; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and
communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations (Olson & Loucks-Horsley, 2000, p. 13). In summary, inquiry is intimately connected to scientific questions—students must inquire using what they already know and the inquiry process must add to their knowledge (Olson & Loucks-Horsley, 2000, p. 13).

Closed items—Closed items limit respondents' possible answers to the survey. Participants choose from pre-existing set answers; such as yes/no, true/false, or multiple choice. The most common of the ranking scale questions is called the Likert scale question, in which participants select a response that best fits to what extent they agree ("I strongly agree, I somewhat agree, I have no opinion, I somewhat disagree, I strongly disagree") with the given statement (Colorado State University, 2011).

Open-ended items—Open-ended items do not give respondents answers to choose from. Instead, questions are asked such that participants need to explain their answers in their own words or diagram (Colorado State University, 2011).

Nature of science—The nature of science is a multifaceted concept. It includes aspects of history, sociology, and philosophy of science, and has variously been defined as science epistemology, the characteristics of scientific knowledge, and science as a way of knowing (Bell, 2009, para. 4). With no simple definition available, science educators have developed a set of key concepts that are essential understanding the nature of science. These include; tentativeness, empirical evidence, observation and inference, scientific laws and theories, scientific methods, creativity, objectivity and subjectivity (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002).
Process of science—The process of science refers to the steps and actions used by scientists to explore and interpret their findings (Carpi & Egger, 2009b). While this term and the proceeding term (Nature of Science) are often used interchangeably in the literature, this investigation will use the combined term “nature and process of science” to show the distinct differences between the two terms and acknowledge their interconnectedness.

Science—According to Bell (2009) science is composed of three main aspects: science as a body of knowledge, the methods and processes, and a way of knowing about the world. In addition, science can be seen as the modern art of creating stories that explain observations of the natural world, and that could be useful for predicting, and possibly even controlling, nature (Bickmore & Grandy, 2007).

Science-literate citizens—The American Association for the Advancement of Science (AAAS) defines a science-literate person as one that is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes. (para. 10)

Theory—In science, a theory is a documented and thorough set of ideas that is based on large amounts of data collected over a span of time. These ideas generally explain a natural phenomenon. Scientific theories can be tested and refined by additional research, and they allow scientists to make predictions (Carpi & Egger, 2009a). This definition is often confused with the common language use of the term theory meaning an educated guess or a hunch.
Assumptions

Students were enrolled in the science course mainly as fulfillment of a requirement in completing their undergraduate degree. It is assumed that students reflected on their experiences with honesty, integrity, and clarity.

One of the variables in the study was the delivery method of the two sections involved. Students in the face-face section of the course were given class time to complete the pre-assessments. They completed the post-assessments as part of their graded coursework. Students in the online section were expected to complete the assessments given the same importance as the face-to-face students did within the classroom.

TPOS (pre- and post-) was evaluated solely on a completion basis; it was not a graded assignment. The RPOS survey questions administered pre-module were evaluated as a completion grade whereas the post-module RPOS survey questions were evaluated as a graded assignment. Students were not aware of this difference in grading weight prior to completing the assessments. Therefore, the assumption was made that the same importance was placed on the completion of all the assessments.

Limitations of the Study

One primary limitation of the case study design is that it is only applicable to the population being studied. One cannot generalize the findings of the case study to the larger population (Yin, 2009). For this reason, the insights gained from this study can be used to generalize to the theory of teaching the nature and process of science and not for statistical generalization.
The limitations of the concurrent data collection model include the difficulty comparing the results of two analyses using data of different forms. It is possible that one form of data might introduce bias that would confound the results from the other form of data collected from the same participants and the researcher may be unclear about how to resolve the discrepancies that arise. This method may also result in unequal evidence within the study (Creswell & Plano Clark, 2007).

The students involved in this study were undergraduate students, who were most likely enrolled in more than one course at a time. Because of this fact, it is difficult to ascertain that any change seen in the pre/post results are the results of this and only this professor’s treatment.

Further, the TPOS assessment was administered pre- and post-course, not post-module. It is possible that the other modules within the course also influenced students’ understanding of the nature and process of science.

**Significance of the Study**

Examining student understanding of the process of science, and perceptions of science answers questions about how to design curriculum to enhance and promote science learning. This study may help educators answer the question of what effect these aspects have on student achievement in science. If this study indicates that understanding the process of science positively impacts their perception of science, similar curricula modifications might be considered by educators around the world. Showing that it is possible to positively affect undergraduate students’ perspectives of science in an online format could contribute to the growing literature in distance education.
College faculty may benefit by examining the use and impact of explicitly teaching the process of science in their online courses. The study may also be of interest and benefit to science educators and students.
Chapter Two

Review of Literature

Restatement of the Problem

It is an age-old problem, for over 100 years science educators have been encouraged to teach science as an inquiry process, being careful not to diminish the process to a set of facts for memorization. In the last 20 years numerous advances have been made to increase the scientific literacy of American students. However, the 2007 TIMSS study shows that USA test scores of middle school science students have virtually stayed the same or decreased over the last 12 years (U.S. Department of Education, 2007). This study does not show a nation making improvements in scientific literacy. Of course, there are multiple factors to consider in this problem, curriculum decisions, teaching methodologies, and student motivation to name a few.

The question that remains through all of the factors is what can educators do in their classrooms to improve science literacy in the United States? To begin, we must explore the nature and process of science, what science is, how science is practiced, and how students learn science.

What is Science?

Everyone uses the word “science” and it means something unique to each person. The problem is when we are trying to communicate on a scale of commonality this definition can be as different as the people who hold it. The media attempts to persuade us with scientific evidence, churches are worried about science interfering with their congregations’ faith system, and teachers are trying to develop scientifically literate
citizens. For the purpose of this discussion, I offer the following definition from Bickmore and Grandy (2007, p.1) as our point of commonality:

*Science is the modern art of creating stories that explain observations of the natural world and that could be useful for predicting, and possibly even controlling, nature.*

Notice the use of the term *stories* in the previous definition. Scientific explanations are constantly changing, at any time new discoveries can be made that change the way we previously saw or thought about the natural world. “The universe is a very complicated place, and it is very likely that any explanation that humans come up with will be, at best, an approximation of the truth” (Bickmore & Grandy, 2007, p. 2). Scientists can only offer stories of that best-effort truth.

There are rules to follow however, that make the definition easier to speak of in a common language. According to Bickmore and Grandy (2007), these rules include:

- Scientific stories are crafted to explain observations, but the observations that are used as a basis for these must be reproducible.
- Scientists prefer stories that can predict things that were not included in the observations used to create those explanations in the first place.
- Scientific stories should be subject to an infinitely repeating process of evaluation meant to generate more and more useful stories.
- Scientific explanations do not appeal to the supernatural. Only naturalistic explanations are allowed.
• Any scientific explanation involving events in the past must square with the principle of “Uniformitarianism”—the assumption that past events can be explained in terms of the “natural laws” that apply today.

• Scientists assume that nature is simple enough for human minds to understand.

• Scientific explanations should not contradict other, established scientific explanations, unless absolutely necessary.

Think of the concept of science as a sphere. At the core of the sphere are well-tested theories; at the edges are speculations and more questions waiting to be tested. Scientists of all types are always expanding their theories, seeking more explanations, and making more connections (Quinn, 2009).

The Nature and Process of Science

One thing is very clear when it comes to the actual way in which science is conducted: the linear model of “The Scientific Method,” that most of us learned in middle school science class is just too simple to be effectively used in science (see Figure 1). The trajectory of scientific discoveries that lead to recognized stories/theories are much more complicated. Often, scientists repeat steps, go back and forth between steps, and in general, follow a process that makes sense for the given inquiry, see Figure 2 (Harwood, 2004).

However, this point is almost moot, because the overarching misconception that students hold is that science is just a bunch of facts, that there is no process to it at all (Science Education Resource Center, 2009). Also, there are many points of the process of science that students just don’t know—they are missing conceptions (Science
Education Resource Center, 2009). Science education often focuses on correcting students’ misconceptions about science and its content. The fact remains that students simply lack the knowledge of what science is and is not. It is so important that we deliberately teach our students about this process of questioning, investigating,
examining, communicating, and back and forth so that they might start to move away from the many misconceptions they hold and grow into a deeper understanding of science as a process as well as the content itself. According to the Science Education Resource Center (2009), there are five major categories of misconceptions that students have for the nature and process of science. These include, but are not limited to:

- the scientific method;
- the nature of uncertainty and change in scientific knowledge;
- the community of science and the role it plays;
- the nature of scientific theories; and
- who can do science.

Motivation and the Nature and Process of Science

“I’m not good at science.” “Science is hard.” “Science is for boys.” We have all heard science students utter these phrases. Research conducted by Lombozo, Thanukos, and Weisberg (2008) suggests that at the foundation of the problem with science and learners is the weak connection between their attitudes and motivation to learning science and their engagement with the content. Teaching students what science is and is not, can help break down these attitudinal and motivational barriers. Students need to experience a variety of scientific ideas and experiments and not just science content out of context. They need to directly discuss the nature and process of science to move beyond their simplified and perhaps intimidating view of science. Teacher use of creativity, innovation, and discovery in science might make it more exciting for students to learn the content (Lombozo et al., 2008).
**Mindsets.** While the idea of mindsets does not specifically relate to the focus of the current study, it is important to understand that to engage any science learner, we must consider the learner as a whole. If this is not done, no science curriculum, no matter how rich it is, is going to be successful in meeting the needs of students. Students in Dr. Gosselin’s undergraduate course complete a simplistic pre-course mindset assessment. However, the mindset assessment was not selected to be a part of this study due to the nature of the assessment being naive and the lack of a complete data set.

Barber, a prominent sociologist, once said, “I don’t divide the world into the weak and the strong, or the successes and the failures . . . I divide the world into learners and nonlearners.” What does it mean to be a nonlearner? Dweck, author of *Mindset: The Psychology of Success*, contends that every baby is born to learn. Babies tackle the most difficult and frightening tasks of a lifetime, learning to walk for example. There is no more vulnerable position than being on the brink of walking or not walking. Infants never decide it is too difficult to try or not worth the effort. They aren’t worried about being embarrassed or not succeeding. They just keep getting up when they fall down. Some people, however, do choose to be a nonlearner later in life. Dweck tells us that “they become afraid of not being smart” (2006, p. 16). If this is true, then we, as educators, must provide all students with a learning environment that provides safety for learning, room for making mistakes, and opportunities for challenge.

The concept of mindsets stems from the earlier ideas of: locus of control theory introduced by Rotter in the 1950s; Weiner’s attribution theory in the late 1970s; and learned helplessness explained by Feldman in the 1980s (Brooks, 2009). Today, Brooks
defines the term mindset as a set of ideas, beliefs, attitudes, skills, and assumptions, all of which guide our behavior (Brooks, 2009).

“By the time students reach their middle school years, they already have a mindset about who they are and what they can or cannot accomplish” (Theobald, 2005, p. 6). This is an unfortunate statement about people who are barely 12 years-old.

Dweck (2006) asserts that there are two types of mindsets. First, a fixed mindset is one in which you believe that your qualities are carved in stone. Further, a person with a fixed mindset believes they have a fixed amount of intelligence, a specific personality, and a certain moral character. The second type of mindset is a growth mindset in which the individual believes that his or her basic qualities can grow and change through effort. In short, this person believes that anyone can be anything. Isn’t this the foundational statement of America’s schools? Shouldn’t all educators believe that anyone can do anything?

Dweck (2007) contends that educators commonly hold two beliefs that can actually hold our students back from success.

1. Praising students’ intelligence builds their confidence and motivation to learn.
2. Students’ inherent intelligence is the major cause of their achievement in school.

In her research, Dweck has found that the first statement is simply false and the second statement can be harmful to students, even those who are most competent. Why? Because in both situations, the teachers guiding beliefs are tacitly communicating the message that student effort does not make a difference.
The way educators praise students can go a long way in nurturing a growth mindset. In one study, Mueller and Dweck (1998) asked fifth grade students to work on a set of problems. They had the teacher praise some of them for their intelligence (“You must be smart at these problems”) and others for their effort (“You must have worked hard on these problems”). The researchers found that praise for intelligence tended to put children in a fixed mindset and praise for effort tended to put children in a growth mindset. Dweck calls the latter form of praise “process praise” (2007). Examples of process praise are (p. 37):

- I like the way you tried all kinds of strategies on that math problem until you finally got it.
- You stayed at your desk, kept up your concentration, and kept working. That’s great!
- All right, that was too easy for you. Let’s do something more challenging that you can learn from.

In essence, teachers are unwittingly perpetuating the creation of a fixed mindset in their students. The danger is that a student will eventually accept the belief that her intelligence is what it is and no amount of effort is going to change it, so why bother. Alternatively, a student can become so worried about showing how smart they are that they avoid tasks that might challenge them. In contrast, we want to nurture growth mindsets in our children so they understand that effort builds intelligence, shapes personalities, and develops moral character.

Current research in psychology and neuroscience supports the concept of developing a growth mindset. Doidge (2007) explains the term “neuroplasticity” as the
idea that the brain can change structure and function even into adulthood, through the individual’s effort, senses, thinking and imagining. If an individual commits to an action, encounters experiences that support that action, and imagines that he can achieve it, he can. Our brains have amazing plasticity. We can change our mindset.

It is very clear that the mindset of the teacher is a crucial component in the process of developing growth mindsets in students. To be effective, and to promote mindsets of learning and achievement amongst their students, Theobald’s (2005) suggestions include:

- Each student can learn.
- Teachers are responsible for providing an environment where students are safe to make mistakes and learn from those mistakes.
- Everyone needs positive feedback once in a while.
- Teachers need to provide opportunities for students to build a positive self-concept.

**One Curriculum-based Solution: Layered Curriculum™.** Educators attempt many things to motivate kids, technology, cooperative learning groups; hands-on, minds-on activities; attempts at scientific inquiry; and many more. However, none of these came close to creating the utopian, free and safe environment that would allow students to explore and learn to their greatest potential. The Layered Curriculum™ approach (Nunley, 2004) may come closest to providing such an environment. This approach is not used in the case involved in this study. However, the involved instructor does use the philosophy of Bloom’s Taxonomy in which Layered Curriculum™ is grounded. It is this
foundation that spurs the researcher to offer Layered Curriculum™ in this literature review.

Layered Curriculum™ is one way in which educators might seek to fully engage students in the science curriculum and motivate them to set higher goals for themselves. Using this method of structuring curriculum, one is able to create levels of learning that move students up the ladder of Bloom’s Taxonomy (Figure 3). Layer C activities provide students with opportunities to gain content knowledge and begin to build understanding within the concept.

Source: http://faculty.chass.ncsu.edu/slatta/hi216/images/gifs/blm.gif

*Figure 3.* Bloom’s taxonomy.

Layer B activities are where you would find your more traditional hands-on activities; those that help students apply and analyze what they are learning. And finally, Layer A takes students to the level of evaluation and creativity that we expect to see in scientific inquiry. Unfortunately, while this is where real learning and deep understanding takes place, this is the step that usually gets left out in the “hurry and cover the material” mentality that teachers are often swept into by the district curriculum demands. This is also the step that those students who need more time to succeed rarely are able to explore with their teacher. Without creating this deep connection, science remains irrelevant, and
students remain disengaged. Through disengagement, middle school students tend to turn away from science experiences. In contrast, Layered Curriculum™ allows students to:

- work at their own pace;
- put forth the effort that is appropriate for them;
- choose the activities that interest them;
- experience novelty on a daily basis;
- spend individual time with the instructor;
- be accountable for their own learning; and
- be creative!

When students disengage from the curriculum they often make choices that become behavior and management concerns in the classroom. The fundamental principle of William Glasser’s (1998), *Choice Theory*, is that concerning student behavior and engagement, students, first and foremost, must have their biological needs met.

The issue of meeting biological needs is crucial in motivating students to learn. It is true if students are scared, tired, hungry, thirsty, or have to go to the bathroom, they cannot and will not learn. Teachers must build a knowing relationship with their students so that they can be aware of signs and/or changes in students that signal that these needs are not being met. A study done by Korol and Gold (1998) showed that eating a moderate amount of glucose, a piece of fruit for example, raised the performance and accuracy of memory, attention, and motor function in adult learners. While this study has not been repeated in younger learners, we know that the brain needs oxygen and glucose to operate efficiently. And the more challenging the task, the more fuel (glucose) the
brain will require (Sousa, 2006). Take a walk through a middle school on any given day, you will find many students, and teachers, who did not eat enough fuel for breakfast and who are not drinking enough water to support efficient brain activity. With regard to water, Sousa tells us that low amounts of water in the blood diminish the efficiency of the neuron signals in the brain (2006). It is safe to say that humans cannot learn if their physical needs are not met.

Once physical needs have been met, and the curriculum is structured for optimum learning, then students can focus on student goal-setting. For centuries it has been taught that human behavior is a result of some stimulus that is external to self, for example, consider Pavlov’s dogs, or Skinner’s rats. Because of the weight placed on these and other behavioral conditioning theories prevalent in the 1950’s, educators are trained to use external motivators to encourage behavior in students (Sullo, 2007). Sullo further emphasizes’ that when educators do this, they send a clear message, even if it's unintentional, that if it were not for the reward offered, what is being taught may not be worth learning. Obviously, this is not the primary goal most teachers are seeking out of reward systems. Conversely, students can learn to find their own internal motivations, and set goals that mean something to them, that are worth exerting effort to achieve. Teachers should not set the goals for students–instead they should identify objectives for learning and encourage students to set their own goals for how to meet those objectives. “Goal setting is imperative to student motivation because where there is no vision, there is no purpose and where there is no purpose, there is no stimulation to act” (Springs & Kritsonis, 2008, p. 4).
Rita Smilkstein (2002) writes that humans have an innate and natural motivation to learn. Medina (2008) asserts that we were born to be problem-solvers. The process of neuroplasticity, in which brains are continually restructuring based on input, characterizes the human brain as having the ability to learn and change throughout the adult lifespan (Doidge, 2007; Sousa, 2006). The desire to learn is inherent and natural. It is perhaps true that we teach children to be nonlearners. And, it is the undeniable task of educators to nurture students to their full potential.

Developing an accurate and thorough understanding of the nature and process of science in students has long been a goal of science educators (Lederman, 1992). Lederman’s (1992) review of the literature shows that even though this goal is so obvious, K–12 students do not attain the necessary understandings of the nature and process of science. He goes on to say that the research indicates that K–12 teachers must understand the nature and process of science in order to teach it successfully (Lederman, 1992).

Assessing student understanding of the nature and process of science continues to be an area of needed investigation. In 2002, Lederman et al. developed an open-ended instrument called the Views of Nature of Science Questionnaire (VNOS). This instrument sought to provide a more meaningful assessment of learners’ nature of science views than the previous forced-choice assessments were providing. The results of these studies and follow-up interviews support a high confidence level in the validity of the VNOS for assessing the NOS understandings of a wide variety of respondents (Lederman et al., 2002, p. 517).
In a later study of pre-service elementary teachers, done by Matkins and Bell (2007, p. 150) it was found that “prior to the instruction provided by the researchers, the participants’ views of the nature of science were clearly inconsistent with those reflected in current science education reform documents.” Participant responses in the post-instruction phase of the study showed their ideas changed substantially. The preservice elementary teachers in this study “used their understanding of the science process skills as a bridge to understanding the more abstract aspects of the nature of science” (p. 157). In summary, the explicit teaching of the process of science appeared to have a positive effect on the participants understanding of the nature of the science in a face-to-face learning environment. The goal of this study was to see if the same results could be found in Dr. Gosselin’s online and face-to-face sections of his undergraduate course.
Chapter Three
Methodology

Purpose of the Study

The purpose of this case study was to explore the understanding of the nature and process of science for undergraduate students at UNL. Assessments were selected by the instructor that allowed students to demonstrate their understanding and experiences with science prior to the course and following the course. A curriculum module was developed by the instructor that allowed students to experience the nature and process of science using Bloom’s Taxonomy as a model to move them towards higher order thinking. The curriculum module was also introduced to students as a way to engage them in the content and increase their motivation to do well in the course.

The study will investigate one professor’s methodology to teaching undergraduate students about the nature and process of science, and document their perception of science, both pre- and post-course in both online and face-to-face environments.

Research Questions and Instrumentation

The purpose of this mixed methods case study was to investigate a bound group of undergraduate students’ understanding of the nature and process of science in the context in which it was learned, a college course setting. Both quantitative and qualitative research methods were used separately, maintained separately, and integrated in the final analysis. According to Creswell and Plano Clark, “The use of quantitative and qualitative approaches in combination provides a better understanding of research problems than either approach alone” (2007, p. 18).
**Central Research Question.** How does explicitly teaching the process of science affect undergraduate students’ perceptions and understanding of the nature and process of science?

**Subquestions.**

1. How can educators explicitly teach the process of science?
2. What themes emerge in undergraduate students’ perceptions of science?
3. What misconceptions emerge in undergraduate students’ understanding of the nature and process of science?

**Instrumentation.** The research questions were addressed using an instrument developed by Carpi called the Process of Science Assessment (TPOS—Appendix A). This instrument was designed to measure student understanding of the process of science. The measure was administered pre- and post-course, in both online and face-to-face sections of the course and included both quantitative and qualitative components within the questions (see Table 1).

RPOS survey questions (Appendix B) explored the students’ perception of science. Students responded, pre- and post-treatment, to the questions in a written format. These questions were coded and analyzed quantitatively. In addition, the survey questions were investigated for themes related to the research subquestions (see Table 1).

A curriculum analysis of the teaching module explored the teaching methods of the participating educator in terms of the nature and process of science (see Table 1).
Table 1

**Study Instrumentation**

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Collected</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPOS</td>
<td>Pre-treatment</td>
<td>Quantitative—Closed Items</td>
</tr>
<tr>
<td></td>
<td>Post-treatment</td>
<td>Qualitative—Open-ended Items</td>
</tr>
<tr>
<td>RPOS Survey Questions</td>
<td>Pre-treatment</td>
<td>Quantitative—Rubric Scoring</td>
</tr>
<tr>
<td></td>
<td>Post-treatment</td>
<td>Qualitative—Emergent Themes</td>
</tr>
<tr>
<td>Curriculum Analysis</td>
<td>Post-course</td>
<td>Qualitative Analysis—Emergent Themes</td>
</tr>
</tbody>
</table>

The reason for collecting both quantitative and qualitative forms of data was to bring together the strengths of both forms of research to give a descriptive interpretation of the results.

**Research Design**

This bounded single-case study employed a convergent mixed-methods design. In this design the researcher combined the strengths of quantitative and qualitative methods of inquiry while also compensating for the known weaknesses of each approach (Creswell & Plano Clark, 2007). In gathering data, equal emphasis was given to quantitative and qualitative data sets. Both forms of data were collected separately, maintained separately during the study, and then integrated in the interpretation of the final results (Creswell, 2003).

In Dr. Gosselin’s online and face-to-face course, NRES 108: Earth’s Natural Resource Systems, he has developed and executed a process of science module (Appendix E) in which he strives to give his students a better understanding of the nature and process of science. The three week teaching module was the treatment of this study.
Prior to beginning the process of science module, students in NRES 108: Earth’s Natural Resource Systems were given an assessment developed by Carpi called the Process of Science Assessment (TPOS, Appendix A). According to Carpi (personal communication, March 1, 2011), this closed item instrument was designed to measure student understanding of the process of science. Other assessments of process understanding have been composed of mostly open-ended items. The TPOS was created as an attempt at creating a measure that is less time-intensive to score. Students were encouraged to answer the questions thoughtfully and without looking up any information.

Also pre-module, students answered the RPOS survey questions (Appendix B) in a written format. Again, students were encouraged to answer the questions thoughtfully and thoroughly and without looking up any information.

Students then proceeded through the process of science module as it was designed for the course curriculum. Upon finishing the module, students revisited and revised their answers to the reflective survey questions (Appendix B).

At the end of the 16-week course, participating students were again given the TPOS assessment. Table 2 outlines the timeline in which the study progressed and the corresponding data collection.
Table 2

Study Timeline

<table>
<thead>
<tr>
<th>Time</th>
<th>Task</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning of course</td>
<td>Pre-assessments</td>
<td>TPOS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RPOS Survey Questions</td>
</tr>
<tr>
<td>Week One</td>
<td>Treatment: Process of Science Module</td>
<td></td>
</tr>
<tr>
<td>Week Three</td>
<td>Post-assessments</td>
<td>RPOS Survey Questions</td>
</tr>
<tr>
<td>Week Sixteen: End of course</td>
<td>Post-assessment: Curriculum Analysis</td>
<td>TPOS</td>
</tr>
</tbody>
</table>

Quantitative data. The research questions were addressed by collecting quantitative data using the Process of Science Assessment (TPOS—Appendix A), designed to measure student understanding of the process of science. Administered pre- and post-course, the measure was scored according to the prescribed instructions from the developer (Appendix A). A sample scoring guide is included in Table 3.
Table 3

*Sample TPOS Quantitative Scoring Guide*

**Item**
To understand the effects of human activities on global climate change a group of researchers has developed a computer program that attempts to predict how factors such as carbon dioxide emissions, volcanic eruptions, ocean circulation, and sea ice can influence the temperature of Earth's atmosphere. Using this information, they then make and test predictions about how changes in one factor can lead to changes in the effects of other factors. They present their findings before a group of their peers stating that their models demonstrate a link between carbon dioxide emissions and climate change.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree or Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>(It is not scientific research)</td>
<td></td>
<td></td>
<td></td>
<td>(It is a good example of scientific research)</td>
</tr>
<tr>
<td>a)</td>
<td>b)</td>
<td>c)</td>
<td>d)</td>
<td>e)</td>
</tr>
</tbody>
</table>

Please explain your answer of why this is, or is not, a good example of scientific research:

**Scoring Guide**
Read student explanation to make sure the justification matches the selected answer

A, B, or C = 0 points
D = 1 point
E = 2 points

RPOS survey questions (Appendix B) explored the students’ perception of science. Students responded, pre- and post-treatment, to the questions in a written format in both the online and face-face sections of the course. These questions were coded and analyzed quantitatively on a zero-two (0-2) scale. A score of zero (0) represents a naïve response, showing little or no understanding of the concept explored in the question. A score of one (1) represents a transitional response, showing a growing but limited understanding of the concept. A score of two (2) represents an informed response, showing an accurate and thorough response to the question. A sample rubric for the survey questions is included in Table 4 (see Appendix B for the entire rubric).
Table 4

*Sample Rubric for RPOS Survey Questions*

<table>
<thead>
<tr>
<th>Question 1: What is Science?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Student’s Score</strong></td>
</tr>
<tr>
<td>Naïve 0 points</td>
</tr>
<tr>
<td>Transitional 1 point</td>
</tr>
</tbody>
</table>
| Informed 2 points | Student response includes:  
| | • Key aspects that describe what makes science unique from other ways of thinking and understanding.  
| | • Need for creativity and collaboration. |

Inter-rater reliability was established between three raters who were involved in the project. All three raters were involved in the creation of the rubrics and were trained in using the rubric to evaluate the survey questions. Initially, raters were given fifteen sets of student responses. The first trial to establish inter-rater reliability resulted in a Cronbach’s Alpha of 68.4%. Determining that this rate of agreement was unacceptable, raters reviewed and revised the rubrics to tighten up possible interpretations. In the second attempt, raters were given fifteen additional sets of student responses. In the second trial, inter-rater reliability was found to be 95.9% using Cronbach’s Alpha.

**Qualitative data.** In addition to the quantitative scoring of the TPOS closed items, the open-ended items were analyzed qualitatively. An example of rubric for the open-ended items is included in Table 5 (see Appendix A for the entire rubric).
Table 5

Sample TPOS Qualitative Scoring Guide

<table>
<thead>
<tr>
<th>Item</th>
<th>Description of score based on analysis of student’s responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student’s Score</td>
<td></td>
</tr>
<tr>
<td>New high-resolution radar images of the Arctic Ocean show a dark spot under the polar ice that some scientists have hypothesized could be a yet undiscovered land mass. If you were asked to lead a follow up research study into this question, what specific steps would you take to studying this possibility?</td>
<td></td>
</tr>
<tr>
<td>Unclear</td>
<td></td>
</tr>
<tr>
<td>Naïve</td>
<td>Unintelligible responses or no indication of scientific approach</td>
</tr>
<tr>
<td>Transitional</td>
<td>Indication of need to objectively collect data, need to verify findings, unclear on possible approaches to follow-up investigations</td>
</tr>
<tr>
<td>Informed</td>
<td></td>
</tr>
<tr>
<td>Student response includes:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Acknowledgement of scientific method to answering question</td>
</tr>
<tr>
<td></td>
<td>Need to collect and independently verify data</td>
</tr>
<tr>
<td></td>
<td>Need to investigate possible factors that can produce “dark spot” on radar images</td>
</tr>
<tr>
<td></td>
<td>Clear understanding of data collected as a result of method proposed</td>
</tr>
</tbody>
</table>

The student RPOS survey questions (Appendix B) were also analyzed qualitatively. These questions were collected in written format in both the online and face-face sections of the course. The responses were coded using the MAXQDA, software for qualitative data analysis, program (2010) and identified significant emergent themes in each response. Emerging themes also serve to address the subquestions of the study.

A curriculum analysis of the teaching module explored the teaching methods of the participating educator in terms of the nature and process of science. The curriculum was coded according to Bloom’s Taxonomy in each activity. The reason for collecting
both forms of data was to bring together the strengths of both forms of research to give a
descriptive interpretation of the results.

**Case Setting and Population**

The involved case was University of Nebraska-Lincoln (UNL) undergraduate
course, NRES 108: Earth’s Natural Resource Systems. The researcher collected data
from two sections of this course. There were sixty-three (63) students involved in the
study from the Fall 2010 online (39) and face-to-face sections (24). Four students’ data
were incomplete thus these students were removed from the study providing a final n of
fifty-nine (59).

NRES 108: Earth’s Natural Resource Systems is an undergraduate course
available to UNL freshman through senior students as well as eligible students in the
advanced scholars program, a program that offers online courses to qualified high school
juniors and seniors. While no demographic data were collected for the population, Dr.
Gosselin maintains that the majority of the students in these sections are junior and senior
elementary and middle school education majors who put off taking a science class
because they don’t particularly like science. As upperclassmen, they now need a science
course and turn to NRES 108: Earth’s Natural Resource Systems to fulfill the
requirement (personal communication, April 8, 2011).

**Research Permission and Ethical Consideration**

Throughout this research ethical guidelines were followed. Permission from the
Institutional Review Board (IRB) was requested and received (Appendix I) in April of
2011. The researcher was added as an investigator of an existing project, Assessing
Skills of the 21st Century, and allowed to add the current study to the existing protocol. The principal investigator of the existing project is Sara Cooper.

Anonymity and confidentiality are important ethical considerations. Participant names were stripped from the data and replaced with numbers. The location of the study was not revealed. Participants were informed that while summary data would be disseminated to the professional community, their individual responses would remain anonymous.
Chapter Four

Results and Analysis

Review of Methodology

Using case study for this research project allowed for close examination of the explicit teaching of the nature and process of science. The case allowed for documentation of how one instructor implemented the teaching of the nature and process of science with his students. In The Art of the Case Study, Stake writes that (sometimes) “We will have a research question, a puzzlement, a need for general understanding, and feel that we may get insight in the question by studying a particular case” (1995, p. 3). That was precisely the reason case study was employed in this research project. The researcher sought to understand how one might explicitly teach the nature and process of science in an undergraduate college classroom by closely observing the work of one instructor.

As with any case study, data had to be collected to provide a better understanding of teaching the nature and process of science. Three main types of data were analyzed: the process of science (TPOS) assessment; reflective process of science (RPOS) survey questions, and the module curriculum. The data provided an opportunity to look closely at how an instructor may explicitly teach the nature and process of science with undergraduate college students.

TPOS Assessment

Students in NRES 108: Earth’s Natural Resource Systems completed the twenty-five (25) item TPOS assessment (Appendix A) pre- and post-treatment. Twenty-two (22) of these questions were closed items that were quantitatively coded in accordance with
the scoring guidelines developed by Dr. Carpi (Appendix A). The three remaining open-ended items were evaluated and analyzed separately.

Using a split-plot analysis of variance (ANOVA) in the pre- and post-module data, comparisons were drawn for the TPOS responses. To calculate a total score of the item responses, the mean score was determined first as not all students answered all of the TPOS items. Then, the calculated total scores were compared. Figure 4 shows this comparison. While both sections of the course showed a statistically significant improvement (p=.002) in the TPOS scores post-module, the face-to-face section did show a greater improvement than the online section, though this difference was not statistically significant (p=.064).

![Figure 4. TPOS pre-post comparison.](image)

Within the ANOVA design a comparison is said to be significant if the p-value (probability) is less than .05 (Gravetter & Wallnau, 2006). The p-value derived from the pre-post TPOS scores determined a .002 probability that the change seen in the pre- and post-module TPOS scores was due to random chance. This is evidence that the teaching
of the process of science module did have a positive effect on the students’ understanding of the nature and process of science. Further, the data showed there was a negligible difference in the effect on the face-to-face students compared to the online students.

Further exploration of the total closed item TPOS scores for individual students showed that 63% of students showed an improvement of +1.0 or more in their total score post-module. 16% showed no change in their score. And, 21% of the students showed a decrease of -1.0 or more in their total score.

There are several possible reasons for the relatively high percentage of students who showed no change or for whom the score decreased. First, upon looking at individual scores item-by-item it was found that many of the students scored high (2) both in the pre-assessment item and in the post-assessment item. This score translates as no change in the score however there wasn’t a higher code to show improvement from a score of 2 in the pre-assessment. This lack of variance in the assessment should not be translated as a lack of student growth in understanding. The student’s understanding may have grown, but, the assessment as it was coded simply could not measure the growth.

Second, many of the items that did not show a change in score were Likert scale items that were answered as; strongly disagree, disagree, neither agree or disagree, agree, or strongly agree. It is very possible that the process of science module enhanced student understanding slightly but not enough to cause the student to jump from “agree” to “strongly agree” for example. Again, this resultant should not necessarily be translated into a lack of student growth in understanding.
Finally, these data showed that student scores remained the same or decreased in several questions that had an open-ended, written counterpart item. Using the rubrics provided by the developer (See Table 5), the open-ended items were analyzed as further explanation for the lack of change and/or decrease in student scores.

Three results were possible within the written TPOS data. Students’ responses either: (a) showed improvement, (b) stayed the same, or (c) decreased in complexity of understanding from the pre-module data to the post-module data. Among those results, subcategories emerged. Figure 5 shows the resultant categories observed and the relative number of times that the categories appeared in the data set.

![Figure 5. TPOS qualitative comparison.](image-url)
Recall that in the quantitative analysis of the TPOS closed item scores, 63% of students showed an improvement, 16% showed no change, and, 21% of the students showed a decrease in their total score. The following narrative is offered as an attempt to use the qualitative data to explain the quantitative data.

*Improved*—Reading through the written responses that followed the closed items, it became evident that many of the student responses showed growth from the pre-module data to the post-module data. Using the rubric, the pre-responses earned a naïve or transitional score. Then, the pre-responses showed a higher level of understanding moving the score to either transitional or informed as appropriate. An example of this category is provided in Table 6 where the student response went from naïve to transitional. Examples from the online (D) and face-to-face (F) sections are labeled either Pre- or Post-D or Pre- or Post-F respectively.

Table 6

**TPOS Open-ended Improved Written Response**

<table>
<thead>
<tr>
<th>Question: Do all scientific investigations have to follow these steps: create a hypothesis, collect data, analyze data, and form conclusion? Explain your answer.</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Student’s Score</td>
<td></td>
</tr>
<tr>
<td>Naïve</td>
<td>Yes, all scientific investigations have to follow those steps because if any of them are left out, or occur in a different order, it is likely that the hypothesis, data, and/or conclusion is incomplete. All steps must be present, but they may occur in a slow, planned out manner, or in a fast-paced, new discovery-driven fashion, but no matter how fast or slow they happen, all good scientific investigations include these steps in the given order. (Pre-D)</td>
</tr>
<tr>
<td>Transitional</td>
<td>No, all scientific investigations do not have to follow those steps because the scientific process is not linear. While the linear scientific method is one way to do this, it is not the only way to conduct scientific investigations. (Post-D)</td>
</tr>
</tbody>
</table>

*Slightly Improved*—In quite a few cases, but fewer than the improved group, the student’s writing did improve in complexity or the way they were thinking about the
concept but it wasn’t enough of a change to warrant moving their score up to the next level on the rubric. An example of this category is provided in Table 7 where the student response went from naïve to an improved, yet still naïve answer.

Table 7

TPOS Open-ended Slightly Improved Written Response

<table>
<thead>
<tr>
<th>Question: Do all scientific investigations have to follow these steps: create a hypothesis, collect data, analyze data, and form conclusion? Explain your answer.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student’s Score</td>
</tr>
<tr>
<td>Naive</td>
</tr>
<tr>
<td>Yes, I think it is important for scientific investigations to follow these steps because the second step feeds off of the first, etc. (Pre-F)</td>
</tr>
<tr>
<td>Naive +</td>
</tr>
<tr>
<td>Not all scientific investigations have to follow the 5 steps in the process. It is important for scientists to understand all the different types of methods so that they can know which one to use and when. (Post-F)</td>
</tr>
</tbody>
</table>

Started high and stayed high—These categories were noted when students pre-module written response was quite good, earning an informed score. Their post-module response was also in the informed level. Therefore, these students were unable to show growth by virtue of the assessment scoring.

Started low and stayed low—Students in this category started the module with a low scoring written response and did not improve on their score in the post-module data. It is probable that these students were not highly engaged in the module material and were not motivated to improve or show their improvement in their written responses.

Decreased—It is important to note that there were only two times that a decrease in score was found among this subset of the open-ended TPOS data. An example of this
category is provided in Table 8 where the student response went from an informed to a transitional answer.

Table 8

*TPOS Open-ended Decreased Written Response*

<table>
<thead>
<tr>
<th>Student’s Score</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Informed</td>
<td>I believe this is a good example of a scientific investigation. In this experiment, the scientists are trying to solve a problem. They want to understand the effects of human activities on global climate change. They attempt to predict how different factors such as carbon dioxide emissions, volcanic eruptions, etc. influence the temperature of Earth’s atmosphere. Since they create a hypothesis, test, and gather information, an investigation is taking place. They investigate the links between their findings and climate change. (Pre-D)</td>
</tr>
<tr>
<td>Transitional</td>
<td>Since they make predictions and then collect data to see a change, I believe this is a good investigation. It could be better if they physically able to proof it correct without relying on the validity of a computer system. (Post-D)</td>
</tr>
</tbody>
</table>

**Future Use.** Using the TPOS in an educational research project in the future would require a revision of the coding and scoring systems that were developed with the assessment. The items included in the assessment are quality items that accurately measure what students understand about the nature and process of science. However, the lack of variance in the codes was a problem with seeing the whole picture of how students’ understanding grew. In addition, the researcher recommends that in prior use of TPOS, students not have access to their pre-module answers so that they are unable to
copy and paste their first answer in for their post-module response. This occurred several times within the data and caused a loss of information about the student’s understanding of the nature and process of science.

RPOS Survey Questions

Students in NRES 108: Earth’s Natural Resource Systems answered five survey questions (Appendix B) both pre- and post-treatment, in order to demonstrate their understanding of the nature and process of science. These questions were coded and analyzed quantitatively on a zero-two (0-2) scale in accordance with the rubric developed by the researcher and Dr. Gosselin (Appendix B).

Again using a split-plot ANOVA design of pre- and post-module data, comparisons were drawn for the survey responses. Figure 6 shows this comparison. Both sections of the course showed a statistically significant improvement (p=.000) in the survey question scores post-module, the face-to-face section did show a greater improvement than the online section, this difference is statistically significant as well (p=.007).

![Figure 6. RPOS Survey questions pre-post comparison.](image-url)
In this test, the probability that the increase in scores from pre- to post-data was due to random chance is calculated to be .000. Evidence is clear that the process of science module had a substantial and positive effect on the students understanding of the nature and process of science. Also for this set of data, the face-to-face students’ scores were more dramatically affected by the treatment than the online students’ scores. In this case the difference was significant (p= .007). It is likely that the face-to-face interactions with the instructor led the students’ to write more clearly articulated answers and with more specific examples which led to higher scores in the post-module responses.

Looking at the RPOS survey response quantitative scores for individual students showed that 86% of students showed an improvement of +1.0 or more in their total score post-module. 14% showed no change in their score. And, 0% of the calculated students showed a decrease of -1.0 or more in their total score.

Investigating the 14% of students with no change in their score uncovered that all of the involved students started with a low total score and ended with a low total score. This evidence indicated that these students probably lacked engagement in the course and were not motivated to improve or show their improvement in their understanding of the nature and process of science. In addition, all of these survey questions were open-ended items that were coded according to the prescribed rubric however the nature of the open-ended question does lend itself to subjectivity in scoring and may affect results.

In addition to the quantitative scoring, the RPOS survey questions were qualitatively investigated for themes related to the research subquestions. The themes that naturally emerged from the data fell into three main categories: nature and process of
science related comments; attitudinal comments; and comments that unveiled misconceptions held by the student. Within each main category, subthemes emerged. Descriptions of the codes and exemplars can be found in Table 9. Exemplars from the online (D) and face-to-face (F) sections are labeled either Pre- or Post-D or Pre- or Post-F respectively.

Table 9

*Code Descriptions and Exemplars*

<table>
<thead>
<tr>
<th>Code</th>
<th>Description of Code Comments include:</th>
<th>Exemplar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process of Science</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Creativity-Curiosity</td>
<td>Given words used specifically or alluded to within the comment</td>
<td>“The process of science starts with a natural curiosity or question about something in the natural world.” (Pre-D)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>“Most of all science is about creating understanding. It is about curiosity, which leads to asking questions and engaging oneself into an investigation.” (Post-F)</td>
</tr>
<tr>
<td>Storytelling</td>
<td>Given word used specifically or mention of the story-telling article from the module</td>
<td>“In Science as Storytelling: Version 4.2, they define science as ‘the modern art of creating stories that explain observations of the natural world, and that could be useful for predicting, and possibly even controlling, nature.’ Their idea of ‘storytelling’ in science suggests that scientific explanation isn’t a set thing because it can always be changed with the evolution of science. The goal of science is to get close to the ‘truth’ which means that we must in fact tell stories based on scientific inquiry in order to strive for this goal.” (Post-D)</td>
</tr>
</tbody>
</table>

Table 9 continues
<table>
<thead>
<tr>
<th>Code</th>
<th>Description of Code</th>
<th>Exemplar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citizen-Community</td>
<td>Mention of the need for scientists to communicate with general citizens and/or community as a whole</td>
<td>“There are scientific studies that are published in journals and other sources of media that are shared with the rest of the world.” (Pre-F)  “One thing scientists do need to work on is how they communicate with the public. I find it very confusing to understand some of the scientific happenings that are in the media or in school. It is a form of communication but they need to learn how to communicate better so more people can understand.” (Post-F)</td>
</tr>
<tr>
<td>Inquiry</td>
<td>Given word used specifically or mention of the inquiry article from the module</td>
<td>“We influence science because we drive the inquiry, the discovery, and the dissemination of new information.” (Pre-D)  “In class we made an observation and then used the scientific inquiry model of questioning rather than the scientific method, it brought out the more realistic way of going about studies or experiments. There is not a set path in which you have to follow in science.” (Post-F)</td>
</tr>
<tr>
<td>Rules</td>
<td>Mention of the general rules of science explored with the module. Examples include but not limited to, reproducibility, predictability, uniformitarianism.</td>
<td>“I think it is important that scientists perform their experiments over and over again to minimize error and make sure their findings are correct.” (Pre-D)  “The stories and explanations have to follow certain rules to be considered scientific. These rules are reproducibility, predictive power, prospects for improvement, naturalism, uniformitarianism, simplicity, and harmony.” (Post-D)</td>
</tr>
<tr>
<td>Attitudinal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive-Past</td>
<td>Description or mention of positive science experiences or feelings from their past, prior to the course</td>
<td>“I like science. It has always been an interesting subject to me. I love to learn how things work, and that is what all my science classes have basically been about so far. It is sometimes challenging, but usually once I figure something out, it creates a hundred more questions on the subject.” (Pre-D)</td>
</tr>
<tr>
<td>Positive-Course</td>
<td>Description or mention of positive science experiences or feelings directly related or attributed to the course</td>
<td>“I am hoping that this science course will change my mindset.” (Pre-D)  “My thoughts about science have changed after examining what science means to a classroom full of mostly education majors. We have discussed the idea that science does not have to mean doing research and this it is not always focused around experiments. After class discussion, I have become more aware in how often we use science in our daily lives.” (Post-F)</td>
</tr>
<tr>
<td>Code</td>
<td>Description of Code Comments include:</td>
<td>Exemplar</td>
</tr>
<tr>
<td>-----------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Negative-Past</td>
<td>Description or mention of negative science experiences or feelings from their past, prior to the course</td>
<td>“I have realized that in Elementary Education we have to fill a lot more science requirements than I originally thought we would. I was not exactly thrilled about this because I know that I have not had as high of scores in science as I have other subjects growing up.” (Pre-D)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>“I believe that I usually do not like science, because it feels dry, unexciting, and uninteresting. Sometimes, I would almost start to become interested in a topic, but within a short period of time, I would find myself snap back to the present as I remember all of the facts that must be memorized for the upcoming test. Then, I put my brain back into ‘cram’ mode and focus once again on studying information” (Pre-D)</td>
</tr>
<tr>
<td>Negative-Course</td>
<td>Description or mention of negative science experiences or feelings directly related or attributed to the course</td>
<td>“When we started this class, I had a slight understanding of what science is and tried to come into this class with an open mind. Although lesson two did seem a bit long and redundant at times, I appreciate the articles and saw growth in my own understanding of science.” (Post-D)</td>
</tr>
<tr>
<td>Misconceptions</td>
<td></td>
<td>“Science is done by observing, collecting data, making a theory, and testing out your observation.” (Pre-F)</td>
</tr>
<tr>
<td>Theory</td>
<td>Given term used according to layman’s definition, “a hunch” or guess, unsubstantiated by evidence</td>
<td>“Theories are widely accepted explanations of the natural world, but are apt to be changed.” (Post-D)</td>
</tr>
<tr>
<td>Scientific Method</td>
<td>Description of science limited to the linear scientific method</td>
<td>“The most important term that was taught to me over and over was the scientific theory and how to use it in your experiments. (It is) done through educated guesses, collection of data, analyzing data, finally conclusion of data.” (Pre-F)</td>
</tr>
</tbody>
</table>

The codes themselves tell a story within the case study. Some codes were present in the pre-data as well as the post-data, such as creativity and curiosity (See Figure 7). Others were only present in the post-data, like storytelling. Still others were present in both data sets but dramatically decreased in the post-data, as in both cases of misconceptions.
The following is an attempt to tell the story of each code as it unfolded in the pre- and post-data.

*Creativity-curiosity*—These codes were noted when students included the term(s) specifically or alluded to the idea that science is about being creative or curious. While there is no distinctive difference in the number of codes seen in this category pre-post, it is important to note that in the post-data students more often than not included the aspect of scientific creativity and/or curiosity within their discussion of scientific inquiry. In educational terms, the post-data usage of the terms displays a richer understanding of the terms creativity, curiosity, and inquiry. For example, from the post-data:

> Science is the process through which we conduct inquiry into the natural world. As a discipline, science is concerned only with the natural world, and the things we can learn from what we observe in it. It is a form of study framed by rules and accepted processes, but despite the governing factors, science can result from a spur-of-the-moment curiosity or develop naturally from other pursuits.
**Storytelling**—Probably most noticeable from this category is the fact that it was absolutely absent from the pre-data. Not one student mentioned that science tells a story prior to their participation in the module. Post-module, thirty-one (31) different students used this term to describe the nature and process of science. Twenty-nine of those responses came from the online students, which is not surprising as science as storytelling was a key component of Dr. Gosselin’s online module. The storytelling article was not introduced in the face-to-face course, however two students from that section did relate science to storytelling in their post responses. It is interesting to recount the large number of students who found this to be a novel and/or refreshing way to think about science.

I always thought that science was boring. I hated doing lab write-ups and science reports, because I found them boring to read. I recently learned that science doesn’t have to be boring. Those papers and lab write-ups can be written in story form. Not only will these papers be more interesting, they are helping the writer to make sense of their experiences. Science doesn’t have to be taught straight out of a textbook, science is taught by experiencing authentic situations.

**Citizen communication**—In the pre-data very few students directly mentioned the need for scientists to be able to communicate with the average citizen with the community. Most students mentioned that scientists must communicate with each other but it wasn’t until the post-data that students included the importance of scientists communicating with the community-at-large. Within the process of science module, students learn that communication is one of the key aspects of science. The increase in these comments in the post-data was positive evidence that students took away a greater understanding of the role of communication in science.

**Inquiry**—Mention of the word *inquiry* was almost non-existent in the pre-data. Several students alluded to the concept of inquiry but most did not use the term until
experiencing the concept through the process of science module. One post-data example stood out.

I was always told that there was a set of steps (the scientific process) that we needed to follow to do science. I have since learned that to do science we engage ourselves in a series of activities. They can be completed in any order. These activities are known as the activity model or inquiry method. The ten activities are asking questions, making observations, defining problems, formulating questions, investigating the known, articulating the expectation, carrying out a study, examining the results, reflecting on the findings, and communication with others. This is basically the scientific process, however it allows for more flexibility. Last of all science is done by following natural curiosity. The more curious and excited you are about science, the easier it is to learn and teach.

Rules—In the pre-data, students did mention the rules of science. Usually, they did so without mention of the rules specifically, just that there were rules to follow in science. Not only were the post-data comments regarding the rules of science more prevalent, they were also more specific.

Science is done by rules, or actions that define it. For one, Science must have reproducibility. In other words, and experiment must be done to prove an observation, then identical experiments must be able to be performed. These experiments must have the same outcome as the first one. This way, someone cannot just make a random claim. Science also have predictive power. Hypotheses or 'if..then' statements must be able to be made. Science also have prospects for improvement. It must be able to be built upon with additional stories, or additional facts and findings. Science is also limited to the natural world. Supernatural explanations of things are not considered scientific. Science must also have uniformitarianism, or it must happen in some regular fashion or according to some natural laws.

Positive-past—It was surprising how many pre-data comments there were about students’ past positive science experiences. The researcher assumed the pre-data comments would be predominantly negative and that was not the case. In fact, in the pre-data there were thirty-six (36) positive comments about student past science experiences.

Positive-course—The positive course comments were the most prevalent comment coded for within all the pre- and post-data. There were seventy-two (72) coded
comments that directly attributed an improved perception of science to NRES 108: Earth’s Natural Resource Systems. It is important to note that these comments were made within the first three weeks of the course. The only content the students had interacted with at that point was the process of science module. This fact provides further evidence that the process of science module itself affected students’ perception of science. The following is an exemplar:

Before this class I had a totally different concept of what science is, but now I have changed my mind completely. I used to think science was experimenting and following the scientific method. Now, I think science is the process of discovering the natural world, how it works and how it got to be the way it is. Science can be done in a variety of ways such as observing, collecting data, experimenting and asking questions. Until recently, there was a scientific method that was used to do science but now there are new models of doing science that aren't exact and listed. This new model is helpful because it is flexible and can be used in any way; it does not have to be in a certain order.

Negative-past—As stated previously, the researcher assumed the comments about negative past science experiences would appear more often than they did in the pre-data. It is encouraging to see that the number of negative past comments decreases significantly in the post-data. Perhaps the experience in NRES 108: Earth’s Natural Resource Systems had a deleting effect on these experiential memories. A lot of the comments were similar to this, Science can be interesting but it is very confusing for me and I do not like it at all.

Negative-course—This category is included only because it was so notable that there was only one negative comment about the course in all the pre- and post-data. In fact, the comment that was coded as a negative course comment is not purely negative. It is included below:

When we started this class, I had a slight understanding of what science is and tried to come into this class with an open mind. Although lesson two did seem a
bit long and redundant at times, I appreciate the articles and saw growth in my own understanding of science.

Theory misconception—The term theory is often misused amongst the general public when discussing science. People will say, as our student did “scientists use hypothesis to create what they think is going to happen and test their theory” when it would be more accurate to use the word prediction in that example. In science, a theory is a documented and thorough set of ideas that is based on large amounts of data collected over a span of time. Twelve students misused the term theory in the pre-data, while it was only found four times in the post-data.

Scientific method misconception—Dr. Gosselin expressed that if the students learned nothing more than that science does not have to follow the linear scientific method then he would be happy (personal communication, April 8, 2011). For this reason, the data were examined to determine how prevalent this misconception was among his students. The code for scientific method misconception appeared twenty-two (22) times in the pre-data and only four times in the post-data. Dr. Gosselin fulfilled his goal of moving student thinking away from the linear scientific method towards an inquiry way of thinking, as is evident in the following post-data comment:

The process of science has always been taught to me by using the scientific method. You always follow those same five steps and you are doing some sort of science. However, in class on Monday I learned that the scientific method isn’t the only way “to do science”. You can do science in a lot of different ways. The scientific method is probably the most commonly used in elementary schools but it probably isn’t the best. The activity model for inquiry is the best way to get science done. Many scientists have helped with this model and the model has a lot of advantages. The biggest advantage in my opinion is it isn’t a set model. The scientific method says you have to follow the five steps in order. The model for inquiry allows a scientist to go back and test research numerous times. When scientists are allowed to test their research numerous times it allows for new information to be discovered.
The quantitative and qualitative analyses of the survey questions led to an unexpected observation regarding the length of the responses themselves. It was noticeable that the post-module responses were much longer than the pre-module responses. Upon conducting an analysis of the word count of each response, it was found that the average word count of the post-module responses was approximately double that of the average pre-module word count, 730 compared to 366, respectively. This indicates that in both sections, students wrote down more information about the questions after participating in the process of science module than they did before the module.

**Future Use.** Similar to the suggestions made for the TPOS, the lack of variance in the coding system did not provide the whole picture that was there to be gleaned from the survey question responses. While this lack is accounted for in the mixed-method design of the study, the coding system used for the survey questions could be improved upon to show greater variance in the pre- and post-responses. In addition, question three should be reworded to more accurately ask the student what the instructor wants to know. A suggested change follows:

Existing Question: What are some of the key words and terms that are important to science?

Revised Question: Provide explanations for at least three key terms that are important to science?

**Curriculum Analysis**

Throughout the entire course, Dr. Gosselin sought to motivate his undergraduate students to higher levels of thinking and problem solving (personal communication, April 8, 2011). Based on this premise, the process of science module curriculum was analyzed on a comparison with the revised Bloom’s Taxonomy (See Figure 3). Each activity
within the module was carefully examined to determine what level the individual activity was developing. The following verbs were used as indicators of each level of thinking (Educational Origami, 2011):

Create: Design, build, construct, plan, produce, devise
Evaluate: Check, judge, critique, experiment, test, detect
Analyze: Compare, organize, research, deconstruct, outline, attribute
Apply: Do, carry out, use, run, implement
Understand: Interpret, summarize, explain, classify, infer, compare
Remember: Recall, list, retrieve, find, name, recognize, identify, describe

Figure 8 depicts the number of times a specific task within each module activity attempted to meet the noted level of Bloom’s Taxonomy. The total number of tasks present at each level is represented numerically at the bottom of Figure 8. It is important to note that the activities fell into multiple levels on the taxonomy as they had multiple tasks within each activity.
<table>
<thead>
<tr>
<th>Title of Module Activity</th>
<th>Remember</th>
<th>Understand</th>
<th>Apply</th>
<th>Analyze</th>
<th>Evaluate</th>
<th>Create</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feelings and Perceptions about Science Reflective Questions</td>
<td></td>
<td>•</td>
<td></td>
<td></td>
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<tr>
<td>Science as Story-Telling</td>
<td></td>
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<tr>
<td>Activity Model for Scientific Inquiry</td>
<td></td>
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<tr>
<td>Death to Dinos and Rhinos</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Bringing it All Together: Models for How Science Works</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>•</td>
</tr>
<tr>
<td>Content Mastery Assignment: Reflective Writing - Nature and Process of Science</td>
<td>•</td>
<td>•</td>
<td></td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task Total</td>
<td>3</td>
<td>13</td>
<td>8</td>
<td>13</td>
<td>12</td>
<td>5</td>
</tr>
</tbody>
</table>

Figure 8. Module activity matrix.

Revisiting the graphic presented earlier of Bloom’s Taxonomy (Figure 3) provides an understanding of the hierarchy present in the model. The model implies that mastery of one level is needed in order to move on and master the next level (Krathwohl, 2002). Within Dr. Gosselin’s curriculum, the remembering level activities are present and the least prominent, with understanding, analyzing, and evaluating levels being almost equally represented and more prominent. This evidence supports his effort to offer curriculum that encourages students to reach the higher level thinking skills and not stop at the lower levels.

It makes sense that the creating level activities would be the less common within the curriculum as those activities are generally culminating, synthesis type of activities.
that take more time and effort than other activities. Dr. Gosselin’s module curriculum fits
the model in this respect and appears to meet his goal of engaging students in higher level
thinking tasks.

In addition, the amount and quality of the positive course attitudinal comments in
the RPOS survey questions reinforce the idea that Dr. Gosselin’s module kept the
students engaged in learning and offered them a positive science experience.

**Future Use.** As with any piece of curriculum, it would be beneficial for the
instructor to review the activities and the outcomes to determine what if anything should
be changed for future use. One thing stood out as missing from the students’ written
work and that is the concept of peer review and the important role that it plays in science.
If this curriculum were used again in the future it would be a good idea to add emphasis
to this key idea.

Also, with the popularity of the science as storytelling among the student responses, it
is recommended that Dr. Gosselin incorporate the article by Bickmore and Grandy into
the face-to-face curriculum as he did with the current online curriculum.

**Summary**

Using a mixed-methods approach to analyze the data leads to the conclusion that
the teaching of the process of science module did have a significant effect on the
students’ understanding of the nature and process of science. Students exited the course
with an improved understanding of the five key concepts of science that the TPOS
investigates: (a) multiple research methods, (b) growth with new evidence and
perspectives, (c) theories as testable and supported explanations, (d) role of scientific
debate, and (e) scientific value to individuals and society. In addition, they finished the
module being able to more clearly articulate their ideas on what science is; how science is done; key terms in science; and humans’ role in science. Dr. Gosselin’s process of science module is an educationally-sound curriculum when based on the foundation and philosophy of Bloom’s Taxonomy. Students appreciated the module and the change that it caused in their perceptions of science.
Chapter Five
Conclusions and Recommendations

Conclusions

The importance of educating students in the nature and process of science is stressed by multiple organizations including the American Association for the Advancement of Science (AAAS), the National Science Education Standards, state science standards, and local school districts around the country. However, the information regarding how to effectively educate students in the nature and process of science is still developing. The current study investigated one instructor’s methodology in explicitly teaching the nature and process of science and assessing his student’s growth in understanding. The sample included (N=59) undergraduate students at the University of Nebraska-Lincoln with results that reflect a successful integration of an effective curriculum module.

The central research question explored in the case study was: How does explicitly teaching the process of science affect undergraduate students’ perceptions and understanding of the nature and process of science? This chapter is concerned with addressing the central question and the subquestions to summarize the findings for the study and to make recommendations for educational practice and future studies.

Central research question. The current study provides evidence that explicitly teaching the process of science does have a positive effect on students’ understanding of the nature and process of science. The TPOS quantitative data confirmed significant (p=.002) improvement in NRES 108: Earth’s Natural Resource Systems students’ understanding of the nature and process of science. While this statistic is good news for the educator involved in the case study, it is important to note that the scores for
individual students reflected that 16% of the students showed no change in their score and 21% of the students showed a decrease of -1.0 or more in their total score. These are numbers that needed to be investigated further.

In the extended investigation, a mixed-methods analysis of the data provided evidence that the students who either: (a) showed no change, or (b) a decrease in the quantitative scores, by and large, showed increases in the complexity of their writing or the way they were thinking about the question. This evidence gives credibility to analyzing data qualitatively and quantitatively to see the whole story of the question unfold.

Regarding the other assessment used in the study, the open-ended reflective process of science (RPOS) survey questions, the pre- and post-data showed that the process of science module did have a positive effect (p=.000) on the answers that the students were able to provide. Not only did the quantitative scores improve in the pre-post analysis, but the qualitative codes were richer and more prevalent in the post-module responses than they were in the pre-module responses. The accuracy of student comments improved post-module with more students writing about the different facets of the nature and process of science including scientific storytelling, inquiry methods, specific examples of inquiry experiences, and the rules of science inquiry. Their positive course attitudinal responses showed an overall improvement in their perception of science. And, perhaps most importantly, the amount of misconceptions that occurred in the post-module responses was dramatically reduced from the amount in the pre-module responses.
Subquestion one. How can educators explicitly teach the process of science?

The amount of curriculum resources for teaching the nature and process of science are developing a regular basis as educators and scientists answer the calls from school districts and state departments of education across the country. One way to address the question is through the use of Layered Curriculum™ wherein students are allowed choices to remain engaged in the science curriculum. In addition to the use of choice to engage students, Layered Curriculum™ is designed using the concept of hierarchical levels of thinking in Bloom’s Taxonomy.

Dr. Gosselin’s process of science module was a successful model of how to build a curriculum based on Bloom’s taxonomy. The use of varying levels of activities with a large portion of the activities falling into the higher levels of analyzing and evaluating tasks kept the students engaged and actively participating throughout the module. Perhaps most importantly, the students left the module with a positive perception of what science is and how science is done as was evident in the abundance of positive comments students offered for the course experience.

Subquestion two. What themes emerge in undergraduate students’ perceptions of science?

The main themes that emerged from these data regarding students’ perception of science were the ideas of creativity and curiosity in science, the use of stories to talk about science, the importance of scientists communicating with the larger community, the importance of inquiry in science, and the rules of science.

Students used the terms creativity and curiosity to describe science in the pre-module data almost as often as they did in the post-module data. The difference is in how
they used the terms. The pre-module responses provided flat usage of the words, without context. In the post-module data students were able to use creativity as part of the inquiry method where scientists can be open to exploration and allow themselves to be curious when it comes to questioning the natural world. Post-module students used the term inquiry to mean a movement through many steps of a larger, non-linear method of science that allows for fluidity in scientific investigations.

Science as storytelling was a concept that was absent in the pre-module data. Students were surprised that science can tell a story to explain natural phenomena. Seeing science as a story rather than dry text allows the student to immerse themselves in the content and scientific experiences.

One of the prescribed rules of science is that science must be communicated. In the pre-data students wrote about the communication of science as something that did not involve them as citizens. Communication was something that scientists did with and for each other. Post-module, students were able to express that scientists have a responsibility to be able and willing to share their findings with the scientific community and the community at large. With respect to the rules of science, pre-module responses lack the mentioned of the rules other than to say that scientists must follow the scientific method (more on that in the next subquestion). Post-module responses were more articulate in the spelling out that science must show reproducibility, predictive power, prospects for improvement, naturalism, uniformitarianism, simplicity, and harmony. Not one of these terms was present in the pre-module responses.

Subquestion three. What misconceptions emerge in undergraduate students’ understanding of the nature and process of science?
The major misconceptions noted with the study data were related to the use of the term “theory” in science and the importance of following the linear scientific method. In common language, the term *theory* is used to mean an idea that is unsubstantiated, a hunch, a guess. Many of the students in the current study used the term in this way in their pre-module responses. The decrease in the misuse of this term in the post-module responses is evidence that students’ understanding of the term changed as they explored the nature and process of science in the module.

**Recommendations**

**Recommendations for educational practice.** First and foremost, it is recommended that educators use a method of explicitly teaching the nature and process of science in their classrooms. If we are to address the concern of the AAAS, science standards, and the overarching goal of creating scientifically literate citizens, the education must start in our schools. The curriculum designed by Dr. Dave Gosselin would be an excellent resource for teachers wanting to design their own nature and process of science curriculum. Based on the positive response the instructor in this study received from students regarding the novel idea of using storytelling to describe science, it is recommended that educators look at this idea as a way of introducing the unit of the nature and process of science.

This study follows students through the exploration of one module within Dr. Gosselin’s NRES 108: Earth’s Natural Resource Systems course. The module, as the study intervention, represented approximately three weeks of the total course curriculum. It is important to note that Dr. Gosselin incorporates the same ideas of the nature and process of science throughout the entire sixteen (16) week course (personal
communication, April 8, 2011). This philosophy is recommended to other educators as a way to create consistency and engagement throughout the entire course.

As discussed in the literature review for this study, the mindset of the student plays a crucial part in determining how willing to learn the student is upon entering the classroom. It is recommended that educators assess their students’ mindsets and, using Dweck’s methodologies, strive to develop growth mindsets in individual students. Dr. Gosselin used one form of assessment for this task. It is recommended that he use the mindset assessment provided by Dweck (2006) to gain results that can be more readily analyzed.

It is also recommended science educators explore Layered Curriculum™ as a potential method as a way to engage students in science experiences and give them opportunities to explore science at the higher levels of Bloom’s Taxonomy.

While the results were positive for this single-case study, the results are not generalizable to all students in all classrooms. An educator needs to look at this and ask if there is something he or she could be doing in his or her own classroom that would address their curricular needs. It is recommended that educators do their own form of action research to make determinations about what their students are able to do and what they gain from the curriculum currently in place.

**Recommendations for future studies.** There is a need for future studies in the area of teaching the nature and process of science. Further research could be done using the current study as a jumping off point; it would be interesting to describe the data from the point of online delivery compared to face-to-face delivery. The current data provide
A longitudinal study could also be done using the same instruments and methodology as the current study. One could look at the lasting effects of the teaching module to determine if students maintain the positive effects on their perception and understanding of the nature and process of science at intervals of time following participation in the treatment.

Another way to assess student learning and understanding is through the use of oral dialogue (Jakobsson, 2009). A study similar to the current study but using oral dialogue as a measurement either instead of or in addition to the TPOS and RPOS survey questions would add to the developing knowledge of teaching the nature and process of science. This would be a natural fit in a Layered Curriculum™ classroom as much of the assessment in a layered class is verbal and practical. This study would look at what students can do and how they do it instead of what they know.

And lastly, the research on developing growth mindsets is new and exciting in educational research. Using what we know of engaging students in science, an interesting study could be designed to look at the mindsets of students at the beginning of the school year and follow the potential changes in their mindsets as they progress through the course.

The current study using Dr. Gosselin’s NRES 108: Earth’s Natural Resource Systems course at the University of Nebraska-Lincoln took an initial look at the possibilities that exist in understanding the teaching and learning of the nature and
process of science. The researcher is proud to have been a part of this study and intends to pursue further research in the field.
References


Appendix A

The Process of Science (TPOS) Assessment Instrument and Scoring Instructions
1.1 The North American Gray Wolf is federally listed as an endangered species. A small population of these wolves was recently introduced into a region of northern Minnesota, and a group of environmental scientists is interested in monitoring how the transplanted population fares. They have tracked the wolves’ movements, including the distance traveled daily. In addition, they occasionally go to observe the wolves when they are nearby, and make notes of their behavior and eating habits. After several months they announce that the wolf population is thriving and wolves are expanding their habitat in the state.

How strongly would you agree that this represents an example of a scientific investigation (please check one)?

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree or Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>A)</td>
<td>B)</td>
<td>C)</td>
<td>D)</td>
<td>E)</td>
</tr>
</tbody>
</table>

1.1.1. Please explain your answer of why this is, or is not, a good example of a scientific investigation:

______________________________________________________________________________________
______________________________________________________________________________________

1.2 To understand the effects of human activities on global climate change a group of scientists has developed a computer program that attempts to predict how factors such as carbon dioxide emissions, volcanic eruptions, ocean circulation, and sea ice can influence the temperature of Earth's atmosphere. Using this information, they then make and test predictions about how changes in one factor can lead to changes in the effects of other factors. They present their findings before a group of their peers stating that their models demonstrate a link between carbon dioxide emissions and climate change.

How strongly would you agree that this represents an example of a scientific investigation (please check one)?

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
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<td></td>
</tr>
<tr>
<td>A)</td>
<td>B)</td>
<td>C)</td>
<td>D)</td>
<td>E)</td>
</tr>
</tbody>
</table>

1.2.1. Please explain your answer of why this is, or is not, a good example of a scientific investigation:

______________________________________________________________________________________
______________________________________________________________________________________

1.3 Several scientists are traveling on a ship in Alaskan coastal waters to examine possible oil exploration sites. During a visit to Prince William Sound, a number of them witness a glacier that is “calving,” or dropping huge pieces of ice from its face as it advances into the sea. They spend part of their day on deck searching for drilling sites, and part below deck processing data. During the times that they are on deck, one scientist notes additional glaciers calving. During their post cruise debriefing, this scientist states that his observation of the calving glaciers is proof that global warming is occurring.
How strongly would you agree that this represents an example of a scientific investigation (please check one)?

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree or Disagree</th>
<th>Agree</th>
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</tr>
</thead>
<tbody>
<tr>
<td>(It is not a scientific investigation)</td>
<td></td>
<td></td>
<td></td>
<td>(It is a good example of a scientific investigation)</td>
</tr>
<tr>
<td>A)</td>
<td>B)</td>
<td>C)</td>
<td>D)</td>
<td>E)</td>
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</tbody>
</table>

1.3.1. Please explain your answer of why this is, or is not, a good example of a scientific investigation:

______________________________________________________________________________________
______________________________________________________________________________________
______________________________________________________________________________________
____________________________________________

1.4 Scientists associated with the NASA SETI project collect radio signals from outer space in an effort to search for possible signals from intelligent life forms on a planet other than earth. These signals are collected with large radio telescopes that systematically scan the entire sky over 24-hour intervals. Because of the large amount of data collected and background noise in the universe, they need a large amount of computing power to analyze their data. They ask the public to use their home computers to help them analyze the data when they are not in use. After the first year of operation, the lead scientists with the project announce that they have identified a radio signal from a new pulsar in the constellation of Vulpecula that was previously undetected.

How strongly would you agree that this represents an example of a scientific investigation (please check one)?

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree or Disagree</th>
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<td></td>
<td>(It is a good example of a scientific investigation)</td>
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<td>A)</td>
<td>B)</td>
<td>C)</td>
<td>D)</td>
<td>E)</td>
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</table>

1.4.1. Please explain your answer of why this is, or is not, a good example of a scientific investigation:

______________________________________________________________________________________
______________________________________________________________________________________
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1.5 Do all scientific investigations have to follow these steps: create a hypothesis, collect data, analyze data, and form conclusion? Explain your answer.

______________________________________________________________________________________
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1.6 New high-resolution radar images of the Arctic Ocean show a signal anomaly under the polar ice that some scientists have hypothesized could be a yet undiscovered land mass. If you were asked to lead a scientific investigation into this question, what specific steps would you take to study this possibility?

______________________________________________________________________________________
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2.1 Prior to the 1960s, male scientists depicted the social structure of some primate species as being led by single dominant males. Female scientists in the 1970s, however, demonstrated the critical role of females in determining social structure in primates. This is an example of how:

A. Personal views and biases do not influence scientific interpretations.
B. Scientific understanding evolves with new and different perspectives.
C. Observations can be upheld with experimental evidence.
D. Scientific research is unaffected by new techniques or evidence.
E. The behavior of primates has changed over the years.

2.2 Recent data collected by the Mars Landers suggest that liquid water existed on the surface of the planet far more recently than previously thought, and liquid water may still exist below the surface of the planet. This research suggests that:

A. Previous scientists made mistakes in how they interpreted the data available to them.
B. Scientists can never be certain of any new discoveries.
C. Scientific interpretations changes as new techniques and evidence become available.
D. The technology that scientists used in the past was not reliable.
E. Scientists rarely change their views based upon preconceived notions.

2.3 The Hawaiian Islands are a chain of volcanoes that are formed by magma rising up through the Earth’s crust from deep in the mantle, a type of volcano called a hot spot. Scientists used to think that these hot spots were stationary for tens of millions of years while the tectonic plates moved over them, but in the late 1990’s, some scientists proposed that the hot spots can also move, and now most agree with this explanation. Which of the following statements best describes how these different scientific explanations are related?

A. The explanation that hot spots move is wrong because it contradicts the earlier explanation.
B. Each explanation is equally likely, and simply represents a difference of opinion between scientists.
C. Neither explanation can be supported because scientists cannot make observations over millions of years.
D. The explanation that hot spots move is more accurate because it is based on data not available before the late 1990’s.
E. More data are needed to determine which explanation is correct.

3.1 A scientific theory:

A. __ is settled and cannot be disproved.
B. __ is the most reasonable guess that scientists can make until they can collect better data.
C. __ can become a law when enough data are gathered.
D. __ is a comprehensive explanation based on careful analysis of data.
E. __ is the same as a hypothesis.
3.2 If a scientific theory is based on many different kinds of data, then:
A. __ the theory is not yet precise enough and must be revised.
B. __ different theories are needed to explain all of the different data.
C. __ it will eventually become a law.
D. __ it is considered well-supported.
E. __ it is considered true and correct.

3.3 For a theory to be scientific, it must:
A. __ make sense to a wide range of people.
B. __ be voted on by a scientific society.
C. __ be predictive.
D. __ be published in a journal.
E. __ be supported by experiments.

3.4 The theory of evolution by natural selection is a good example of a scientific theory because:
A. __ it is supported by multiple lines of evidence.
B. __ the majority of scientists accept it.
C. __ the theory has remained the same since Darwin posed it in 1859.
D. __ it is an educated guess being investigated by scientists.
E. __ it is one of many different ideas on the subject of organism change.

4.1 Scientists sometimes disagree and debate over how results are interpreted. Which of the following most accurately describes such disagreements?
A. They indicate that data interpretation is of questionable value.
B. They are a key part of the scientific process.
C. They determine whose research will be funded.
D. They are eventually resolved by scientific societies.
E. They suggest that scientists made mistakes in their research methods.

4.2 The main point of replicating studies in science is to:
A. __ verify that equipment is working properly.
B. __ convince non-scientists.
C. __ prove a theory is true.
D. __ reduce error.
E. __ prove that one is a good scientist.

4.3 A research paper by several scientists was published in Nature (a prestigious science journal). One year later, other scientists in the same discipline discovered mistakes in the procedures used and alerted the authors. The authors agreed that they had made mistakes and could no longer be confident in their results. They asked Nature to retract their paper, or remove it from publication. Which of the following statements best describes this situation?
A. The authors committed fraud and should be punished.
B. The authors simply made a mistake; there is no need to retract the paper.
C. The mistakes should have been caught earlier by the journal editor.
D. The community of science often catches mistakes that individuals might miss.
E. The scientists who found the mistakes were just being picky.

4.4 Scientists agree that 250 million years ago, nearly 90% of all species alive at that time went extinct. However, scientists disagree about what caused this mass extinction. Why do you think they disagree even though they all have the same information?
<table>
<thead>
<tr>
<th></th>
<th>A) Strongly Disagree</th>
<th>B) Disagree</th>
<th>C) Neither Disagree nor Agree</th>
<th>D) Agree</th>
<th>E) Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1. Knowing how science works helps me better understand everyday life.</td>
<td></td>
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<tr>
<td>5.2. Students who do not major/concentrate in science should not have to take science courses.</td>
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<td>5.3. Only scientific experts are qualified to make scientific judgments.</td>
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<td>5.4. When scientific results conflict with my personal experience, I follow my experience in making choices.</td>
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<td>5.5. It is important to understand how society interprets scientific evidence.</td>
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<td>5.6. Scientific uncertainty is sometimes misrepresented by non-scientists to achieve political ends.</td>
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<td>5.7. Scientific knowledge is constantly changing, so there is no point in learning about it.</td>
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<tr>
<td>5.8. The most important part of learning science is understanding the formulas, terms, and facts already uncovered.</td>
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</table>
TPOS Scoring Instructions

Key Concept #1
Scientists use multiple research methods to study the natural world.

Underlying misconception:
• There is only one way to conduct scientific investigations.

1.1 The North American Gray Wolf is federally listed as an endangered species. A small population of these wolves was recently introduced into a region of northern Minnesota, and a group of environmental scientists is interested in monitoring how the transplanted population fares. They have tracked the wolves’ movements, including the distance traveled daily. In addition, they occasionally go to observe the wolves when they are nearby, and make notes of their behavior and eating habits. After several months they announce that the wolf population is thriving and wolves are expanding their habitat in the state.

How strongly would you agree that this represents an example of scientific research?
Suggested grading – 1 pt for agree, 2 pts for strongly agree

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
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<tr>
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1.1.1. Please explain your answer of why this is, or is not, a good example of scientific research:
___________________________________________________________________________

1.2 To understand the effects of human activities on global climate change a group of researchers has developed a computer program that attempts to predict how factors such as carbon dioxide emissions, volcanic eruptions, ocean circulation, and sea ice can influence the temperature of Earth’s atmosphere. Using this information, they then make and test predictions about how changes in one factor can lead to changes in the effects of other factors. They present their findings before a group of their peers stating that their models demonstrate a link between carbon dioxide emissions and climate change.

How strongly would you agree that this represents an example of scientific research?
Suggested grading – 1 pt for agree, 2 pts for strongly agree

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<td>e)</td>
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1.2.1. Please explain your answer of why this is, or is not, a good example of scientific research:
___________________________________________________________________________

1.3 Several scientists are traveling on a ship in Alaskan coastal waters to examine possible oil exploration sites. During a visit to Prince William Sound, a number of them witness a glacier that is “calving,” or dropping huge pieces of ice from its face as it advances into the sea. Over the course of the day, they keep track of the number of calving glaciers whenever they are on deck for to examine drilling sites. During their
post cruise debriefing, one of the scientists sends presents his observations to the group as proof that global warming is occurring.

How strongly would you agree that this represents an example of scientific research?

Suggested grading – 1 pt for disagree, 2 pts for strongly disagree

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
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1.3.1 Please explain your answer of why this is, or is not, a good example of scientific research:
___________________________________________________________________________

1.4 Scientists associated with the NASA SETI project collect radio signals from outer space in an effort to search for possible signals from intelligent life forms on a planet other than earth. Because of the large amount of background radio frequency noise in the universe, they need a large amount of computing power to analyze their data. They ask the public to use their home computers to help them analyze the data when they are not in use. After the first year of operation, the lead scientists with the project announce that they have not identified any signals from intelligent life forms; however, they have identified a new pulsar in the constellation of Vulpecula.

How strongly would you agree that this represents an example of scientific research?

Suggested grading – 1 pt for agree, 2 pts for strongly agree

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</tbody>
</table>

1.4.1 Please explain your answer of why this is, or is not, a good example of scientific research:
___________________________________________________________________________

Open ended explanations to be scored using matrix below, an informed answer would include the following:

<table>
<thead>
<tr>
<th>Student’s Score</th>
<th>Description of score based on analysis of student’s responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naïve</td>
<td>Unintelligible responses or no understanding of why they selected the choice they did</td>
</tr>
<tr>
<td>Transitional</td>
<td>Some statement of objectivity in data analysis, no indication of incorrect method in answer.</td>
</tr>
</tbody>
</table>
| Informed        | Student response includes:  
  o Understanding of the need for reasonable objectivity in data collection. |
1.7 Do all scientific investigations have to follow these steps: create a hypothesis, collect data, analyze data, and form conclusion? Explain your answer.

___________________________________________________________________________
___________________________________________________________________________
___________________________________________________________________________
___________________________________________________________________________
___________________________________________________________________________

Answer to be scored using matrix below, an informed answer would include the following:

1.8 New high-resolution radar images of the Arctic Ocean show a dark spot under the polar ice that some scientists have hypothesized could be a yet undiscovered land mass. If you were asked to lead a follow-up research study into this question, what specific steps would you take to studying this possibility?

___________________________________________________________________________
___________________________________________________________________________
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Answer to be scored using matrix below, an informed answer would include the following:

<table>
<thead>
<tr>
<th>Student’s Score</th>
<th>Description of score based on analysis of student’s responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unclear</td>
<td>Unintelligible responses or no indication of scientific approach</td>
</tr>
<tr>
<td>Naïve</td>
<td>Indication of need to objectively collect data, need to verify findings, unclear on possible approaches to follow-up investigations</td>
</tr>
<tr>
<td>Transitional</td>
<td>Student response includes:</td>
</tr>
<tr>
<td></td>
<td>o Acknowledgement of scientific method to answering question</td>
</tr>
<tr>
<td></td>
<td>o Need to collect and independently verify data</td>
</tr>
<tr>
<td></td>
<td>o Need to investigate possible factors that can produce “dark spot” on radar images</td>
</tr>
<tr>
<td></td>
<td>o Clear understanding of data collected as a result of method proposed.</td>
</tr>
</tbody>
</table>

Key Concept #2

Scientific knowledge evolves with new evidence and perspectives.

Underlying misconception:
- Scientific knowledge is fixed and unchanging.

2.1 Prior to the 1960s, male scientists depicted the social structure of some primate species as being led by single dominant males. Female scientists in the 1970s, however, demonstrated the critical role of females in determining social structure in primates. This is an example of how:

A. Personal views and biases do not influence scientific interpretations.
B. Scientific understanding evolves with new and different perspectives.
C. Observations can be upheld with experimental evidence.
D. Scientific research is unaffected by new techniques or evidence.
E. The behavior of primates has changed over the years.

Suggested grading – 2 pts for B

2.2 Recent data collected by the Mars Landers suggest that liquid water existed on the surface of the
planet far more recently than previously thought, and liquid water may still exist below the surface of the planet. This research suggests that:

A. Previous scientists made mistakes in how they interpreted the data available to them.
B. Scientists can never be certain of any new discoveries.
C. Scientific information changes as new techniques and evidence become available.
D. The technology that scientists used in the past was not reliable.
E. Scientists rarely change their views based upon preconceived notions.

Suggested grading – 2 pts for C, 1 pt for A

2.3. The Hawaiian Islands are a chain of volcanoes that are formed by magma rising up through the Earth’s crust from deep in the mantle, a type of volcano called a hot spot. Scientists used to think that these hot spots were stationary for tens of millions of years while the tectonic plates moved over them, but in the late 1990’s, some scientists proposed that the hot spots can also move. Which of the following statements best describes how these different scientific explanations are related?

A. The explanation that hot spots move is wrong because it contradicts the earlier explanation.
B. Each explanation is equally likely, and simply represents a difference of opinion between scientists.
C. Neither explanation can be proven because scientists cannot make observations over millions of years.
D. The explanation that hot spots move is more accurate because it is based on data not available before the late 1990’s.
E. More data are needed to determine which explanation is correct.

Suggested grading – 2 pts for D, 1 pt for E

Key Concept #3
Scientific theories are testable explanations supported by multiple lines of evidence.

Underlying misconceptions:
* The everyday use of “theory” is the same as the scientific use of “theory.”
* A theory is just a guess or casual conjecture.
* Theories graduate into laws, then don’t change: the everyday use of “theory” is the same as scientific use of “theory.”

3.1 A scientific theory:

F. __ is settled and cannot be disproved.
G. __ is the most reasonable guess that scientists can make until they can collect better data.
H. __ can become a law when enough data are gathered.
I. __ is a comprehensive explanation based on data.
J. __ is the same as a hypothesis.

Suggested grading – 2 pts for D

3.2 If a scientific theory is based on many different kinds of data, then

F. __ the theory is not yet precise enough and must be revised.
G. __ different theories are needed to explain all of the different data.
H. __ it will eventually become a law.
I. __ it is considered well-supported.
J. __ it is considered true and correct.

Suggested grading – 2 pts for D, 1 pt for E

3.3 For a theory to be scientific, it must

F. __ make sense to a wide range of people.
G. __ be voted on by a scientific society.
H. __ be predictive.
I. __ be published in a journal.
J. __ be supported by experiments.

Suggested grading – 2 pts for C, 1 pt for A

3.4 The theory of evolution by natural selection is a good example of a scientific theory because:
F. __ it is supported by multiple lines of evidence.
G. __ scientists accept it.
H. __ the theory has remained the same since Darwin posed it in 1859.
I. __ it is an educated guess being investigated by scientists.
J. __ it is one of many different ideas on the subject of organism change.

Suggested grading – 2 pts for A, 1 pt for B or D

Key Concept #4
The community of science engages in debate and mitigates individual human errors.

Underlying misconceptions: Scientific debate is a sign of confusion and disarray.

4.1 Scientists sometimes disagree and debate over how results are interpreted. Which of the following most accurately describes such disagreements?
F. __ They indicate that data interpretation is of questionable value.
G. __ They are a key part of the scientific process.
H. __ They determine whose research will be funded.
I. __ They are eventually resolved by scientific societies.
J. __ They suggest that scientists made mistakes in their research methods.

Suggested grading – 2 pts for B

4.2 The main point of replicating studies in science is to:
F. __ Verify that equipment is working properly.
G. __ Convince non-scientists.
H. __ Prove a theory is true.
I. __ Reduce error.
J. __ Prove that one is a good scientist.

Suggested grading – 2 pt for D, 1 pt for A or possibly E?

4.3 A research paper by several scientists was published in Nature (a prestigious science journal). One year later, other scientists in the same discipline discovered mistakes in the procedures used and alerted the authors. The authors agreed that they had made mistakes and could no longer be confident in their results. They asked Nature to retract their paper, or remove it from publication. Which of the following statements best describes this situation?
F. __ The authors committed fraud and should be punished.
G. __ The authors simply made a mistake; there is no need to retract the paper.
H. __ The mistakes should have been caught earlier by the journal editor.
I. __ The community of science often catches mistakes that individuals might miss.
J. __ The scientists who found the mistakes were just being picky.

Suggested grading – 2 pt for D, 1pt for C

4.4. Scientists agree that 250 million years ago, nearly 90% of all species alive at that time went extinct. However, scientists disagree about what caused this mass extinction. Why do you think they disagree even though they all have the same information?
Answer to be scored using matrix below, an informed answer would include the following: Scientists’ theoretical commitments, beliefs, previous knowledge, training/specialization, experiences, and expectations actually influence their work. Scientists’ observations (and investigations) are always motivated and guided by, and acquire meaning in reference to questions or problems. These questions or problems, in turn, are derived from within certain theoretical perspectives (i.e., they are theory-laden).

<table>
<thead>
<tr>
<th>Disagreement</th>
<th>Description of score based on analysis of student’s responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unclear</td>
<td>Unintelligible responses or no evidence</td>
</tr>
<tr>
<td>Naïve</td>
<td>States that scientists disagree only because they have different opinions, or like to argue – no apparent appreciation for the benefits of disagreement and debate</td>
</tr>
<tr>
<td>Transitional</td>
<td>Insufficient description such as only “because they have different beliefs” or “they don’t know everything”</td>
</tr>
<tr>
<td>Informed</td>
<td>Student response refers to at least one of the following: o Influence from education, training, and background knowledge o Influence from personal experiences and observations o Data can be interpreted in multiple ways o (For the exceptional earth scientist): Less evidence the further you go back in time – easier to have multiple interpretations</td>
</tr>
</tbody>
</table>

**Key Concept #5**

*Science is valuable to individuals and society; students will appreciate the value of science and a scientific way of thinking.*

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Disagree nor Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1. Knowing how science works helps me better understand everyday life.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.2. Students who do not major/concentrate in science should not have to take science courses.</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>5.3. Only scientific experts are qualified to make scientific judgments.</td>
<td></td>
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</tr>
<tr>
<td>5.4. When scientific results conflict with my personal experience, I follow my experience in making choices.</td>
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<td></td>
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</tr>
<tr>
<td>5.5. It is important to understand how society interprets scientific evidence.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.6. Scientific uncertainty is sometimes misrepresented by non-scientists to achieve political ends.</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>5.7. Scientific knowledge is constantly changing, so there is no point in learning</td>
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<tr>
<td>--------------------------------</td>
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<td></td>
</tr>
<tr>
<td>about it.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.8. The most important part of learning science is understanding the formulas, terms, and facts already uncovered.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix B

Reflective Process of Science (RPOS) Survey Questions and Scoring Rubric
Based on your experiences with science, address the following questions:

A. What is science?

B. How is science done?

   (What is your understanding of the process of science?)

C. What are some of the key words and terms that are important to science?

D. How do humans influence science?

E. How is communication used in science?

### Question 1: What is Science?

<table>
<thead>
<tr>
<th>Student’s Score</th>
<th>Description of score based on analysis of learner’s responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naïve 0 points</td>
<td>Unintelligible response or no understanding of science explained or understanding is based on a faulty conceptual model (incorrect information).</td>
</tr>
<tr>
<td>Transitional 1 point</td>
<td>Some statement of what science is to them. Misconceptions may be present.</td>
</tr>
</tbody>
</table>
| Informed 2 points | Student response includes:  
  - Key aspects that describe what makes science unique from other ways of thinking and understanding.  
  - Must allude to or specifically mention creativity and collaboration. |

### Question 2: How is science done? (What is your understanding of the process of science?)

<table>
<thead>
<tr>
<th>Student’s Score</th>
<th>Description of score based on analysis of learner’s responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naïve 0 points</td>
<td>Unintelligible response or no understanding of the process of science explained. Understanding is based on a faulty conceptual model.</td>
</tr>
<tr>
<td>Transitional 1 point</td>
<td>Limited understanding of the process of science. Misconceptions may be present.</td>
</tr>
</tbody>
</table>
| Informed 2 points | Student response includes:  
  - Understanding of the need for reasonable objectivity in data collection.  
  - Understanding of methods used to collect and interpret data beyond the linear scientific method.  
  - Understanding of the process used to interpret data and make reasonable conclusions using data analysis. |
**Question 3:** What are some of the key words and terms that are important to science?

<table>
<thead>
<tr>
<th>Student’s Score</th>
<th>Description of score based on analysis of learner’s responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naïve 0 points</td>
<td>Unintelligible response or no understanding of key terms presented. Understanding is based on a faulty conceptual model. Terms listed, but no definitions given.</td>
</tr>
<tr>
<td>Transitional 1 point</td>
<td>Limited understanding of at least 2 key terms with definitions. Misconceptions may be present. Definitions may be found within &quot;How is science done?&quot; section.</td>
</tr>
</tbody>
</table>
| Informed 2 points | Student response includes:  
  - Definitions of at least 3 key terms in context of how they are used in science.  
  - Terms may include three of more of the following: inference, experiment, observation, explanation, theory, and/or hypothesis, or similar terminology. Definitions may be found within "How is science done?" section. |

**Question 4:** How do humans influence science?

<table>
<thead>
<tr>
<th>Student’s Score</th>
<th>Description of score based on analysis of learner’s responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naïve 0 points</td>
<td>Unintelligible response or no understanding of how humans influence science. Understanding is based on a faulty conceptual model (incorrect information).</td>
</tr>
<tr>
<td>Transitional 1 point</td>
<td>Limited understanding of how humans influence science. Misconceptions may be present.</td>
</tr>
</tbody>
</table>
| Informed 2 points | Student response includes:  
  - Science is a human endeavor.  
  - How culture (worldview, politics, religion, etc) plays a role in the practice of science.  
  - Specific examples or evidence. |

**Question 5:** How is communication used in science?

<table>
<thead>
<tr>
<th>Student’s Score</th>
<th>Description of score based on analysis of learner’s responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naïve 0 points</td>
<td>Unintelligible response or no understanding of communication in science. Understanding is based on a faulty conceptual model (incorrect information).</td>
</tr>
<tr>
<td>Transitional 1 point</td>
<td>Limited understanding of how communication is used in science. Understanding is limited to inter-scientist communication. Misconceptions may be present.</td>
</tr>
</tbody>
</table>
| Informed 2 points | Student response includes:  
  - Description of the role of communication in science.  
  - Understanding of the importance of informal and formal (peer review) communication between scientists. (peer review MUST be mentioned or alluded to)  
  - Understanding of the importance of public outreach and education. |
### Question 1: What is Science?

<table>
<thead>
<tr>
<th>Student’s Score</th>
<th>Description of score based on analysis of learner’s responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naïve 0 points</td>
<td>Unintelligible response or no understanding of science explained. Understanding is based on a faulty conceptual model.</td>
</tr>
<tr>
<td>Transitional 1 point</td>
<td>Some statement of what science is to them. Misconceptions may be present.</td>
</tr>
</tbody>
</table>
| Informed 2 points | Student response includes:  
  o Key aspects that describe what makes science unique from other ways of thinking and understanding.  
  o Need for creativity and collaboration. |

### Question 2: How is science done? (What is your understanding of the process of science?)

<table>
<thead>
<tr>
<th>Student’s Score</th>
<th>Description of score based on analysis of learner’s responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naïve 0 points</td>
<td>Unintelligible response or no understanding of the process of science explained. Understanding is based on a faulty conceptual model.</td>
</tr>
<tr>
<td>Transitional 1 point</td>
<td>Limited understanding of the process of science. Misconceptions may be present.</td>
</tr>
</tbody>
</table>

### Question 3: What are some of the key words and terms that are important to science?

<table>
<thead>
<tr>
<th>Student’s Score</th>
<th>Description of score based on analysis of learner’s responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naïve 0 points</td>
<td>Unintelligible response or no understanding of key terms presented. Understanding is based on a faulty conceptual model.</td>
</tr>
<tr>
<td>Transitional 1 point</td>
<td>Limited understanding of key terms. Misconceptions may be present.</td>
</tr>
</tbody>
</table>
| Informed 2 points | Student response includes:  
  o Definitions of key terms in context of how they are used in science.  
  o Terms may include three of more of the following: inference, experiment, observation, explanation, theory, and/or hypothesis. |

### Question 4: How do humans influence science?

<table>
<thead>
<tr>
<th>Student’s Score</th>
<th>Description of score based on analysis of learner’s responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naïve 0 points</td>
<td>Unintelligible response or no understanding of how humans influence science. Understanding is based on a faulty conceptual model.</td>
</tr>
<tr>
<td>Transitional 1 point</td>
<td>Limited understanding of how humans influence science. Misconceptions may be present.</td>
</tr>
</tbody>
</table>
| Informed 2 points | Student response includes:  
  o Science is a human endeavor.  
  o How culture (worldview, politics, religion, etc) plays a role in the practice
Question 5: How is communication used in science?

<table>
<thead>
<tr>
<th>Student’s Score</th>
<th>Description of score based on analysis of learner’s responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naïve 0 points</td>
<td>Unintelligible response or no understanding of communication in science. Understanding is based on a faulty conceptual model.</td>
</tr>
<tr>
<td>Transitional 1 point</td>
<td>Limited understanding of how communication is used in science. Understanding is limited to inter-scientist communication. Misconceptions may be present.</td>
</tr>
</tbody>
</table>
| Informed 2 points | Student response includes:  
  o Description of the role of communication in science.  
  o Understanding of the importance of informal and formal (peer review) communication between scientists.  
  o Understanding of the importance of public outreach and education.  
  o Specific examples or evidence. |
Appendix C

Biographical Sketch: David Gosselin
David C. Gosselin, Ph.D., is a professor and Director of Environmental Studies at the University of Nebraska-Lincoln. He has served as the director of the Nebraska Earth Systems Education Network since its inception in 1993. For his work with NESEN, he was recognized by the Nebraska Association of Teachers of Science in 1999 with their Catalyst Award, which is presented in appreciation for dedicated service to science education. He teaches Earth’s Natural Resource Systems, a course whose primary audience is future elementary educators. His record of grants, contracts, and publication record documents his ability to complete projects on-time and with impact. He is committed to teacher professional development in the area of Earth Systems Science and his interest in using technology to accomplish this task. Dr. Gosselin earned his Ph.D. in geology at the South Dakota School of Mines and Technology. His current scientific research interests are in using geochemistry to understand groundwater systems and examining the occurrence and distribution of arsenic and uranium in public water supplies. He is an author on more than 100 refereed articles, abstracts, technical reports, maps, and book chapters related to topics including: remote sensing, igneous and metamorphic rocks, meteorites, lunar materials, ground water chemistry and geology, and science education.

**Education:**

<table>
<thead>
<tr>
<th>Degree</th>
<th>Year</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.A. Geology</td>
<td>1982</td>
<td>University of St. Thomas, St. Paul, MN</td>
</tr>
<tr>
<td>Ph.D. Geology</td>
<td>1987</td>
<td>South Dakota School of Mines and Technology, Rapid City, SD</td>
</tr>
</tbody>
</table>

**Professional Experience:**

<table>
<thead>
<tr>
<th>Position</th>
<th>Period</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postdoctoral Trainee</td>
<td>1988 - 1989</td>
<td>Battelle-PNL, Richland, WA</td>
</tr>
<tr>
<td>Assistant Professor, CSD</td>
<td>1989 - 1995</td>
<td>University of Nebraska-Lincoln</td>
</tr>
<tr>
<td>Associate Professor, SNR</td>
<td>1995 - 2003</td>
<td>University of Nebraska-Lincoln</td>
</tr>
<tr>
<td>Professor, SNR</td>
<td>2003 - present</td>
<td>University of Nebraska-Lincoln</td>
</tr>
<tr>
<td>Associate Director SNR</td>
<td>2004 – 2007</td>
<td>University of Nebraska-Lincoln</td>
</tr>
<tr>
<td>Director, NESEN</td>
<td>1993 – Present</td>
<td>University of Nebraska-Lincoln</td>
</tr>
<tr>
<td>Director, Environmental Studies</td>
<td>2008 – present</td>
<td>University of Nebraska-Lincoln</td>
</tr>
</tbody>
</table>

**Education-Related Honors:**

1999 Catalyst Award, Nebraska Association of Teachers of Science.

**Past Grants Related to Climate Change and Earth Systems Education**

- Nebraska Department of Education Math and Science Partnership, co-P.I. R.J. Bonnstetter, and S. Person-Pandil (ESU 3), 2004 - 2005. $60,916
- National Science Foundation, “Integration of Earth System Science Research and Education: Involving Teachers in Scientific Research and Scientists in Inquiry-Based Learning,” co-PI, Ron Bonstetter, UNL Teachers College 2000 to 2002. $74,204

Teacher Professional Development Program
in Support of Earth Science in the Community (EarthComm), American Geological
Institute, June 1999 to June 2000. $57,851

Professional Development Training for Earth Science and the Community (EarthComm)-A Pilot Project, American Geological Institute, June 1998 to May 1999. $40,000

Process-oriented Environmental Change Education:
A Model for Connecting Research to the Classroom, co-PI Steve Meyer, UNL School of Natural Resource Sciences, National Institute of Global and Environmental Change July 1996 to 1999. $119,000

Enhancing K-12 Drought-Related Educational Activities and Materials, National Drought Mitigation Center, July 1997 to June 1998. $11,828

Nebraska Earth Science Education Network:
Enhancing the NASA, University, and Pre-College Science Teacher Connection with Electronic Communication NASA, co-PI, Dale Finkelson, UNL Information Services, March 1994 to February 1997. $200,000

Publications Related to Earth Systems Science Education:


Appendix D

Course Syllabus
Course Introduction

In this class, you will develop an understanding of the Earth's natural resource systems using a systems approach. This course will provide opportunities for you to start making connections between a variety of disciplines and concepts.

It is critical that you understand the dependence of all people on both renewable and non-renewable resources and the potential consequences that human activities have on global processes and the availability of natural resources. This class will employ a systems approach to understanding natural resource systems that recognizes that everything is connected to everything else (ECEE). Using this approach, natural resources are considered part of a larger system that allows us to deal more responsibly and rationally with local, regional and global issues. In addition, this approach recognizes that humans are dependent on, impact the distribution of, and influence natural resource systems. This course will emphasize earth, water and soil resources. This course will provide a general understanding of the processes that relate to the interaction of the atmosphere, hydrosphere and, geosphere and biosphere.

For the future educators in this class, many of the activities that we will do in this class may be able to be used directly in an elementary, middle school or high school classrooms. All activities are designed to challenge you as learners. All the concepts in this class can be related to both the K-12 National and Nebraska science education standards. It is important to recognize that this is a science class and not a methods class.

My role in this class is to provide you with opportunities to learn about the Earth and to challenge you as learners so that you can understand and apply basic Earth system science concepts to your own community. Everyone can be successful in this class, but it is up to you. I am always available for help.

Learning Objectives

By the end of the course, you will:

1. This will meet ACE student learning outcome 4 in which the student will use scientific methods and knowledge of the natural and physical world to address problems through inquiry, interpretation, analysis, and the making of inferences from data, to determine whether conclusions or solutions are reasonable.
2. Describe and explain the basic interactions between the hydrosphere, geosphere, atmosphere, and biosphere.
3. Acknowledge and work with individuals who have different perspectives about natural resources.
4. Demonstrate an understanding of the properties, occurrence and distribution of water and soil.
5. Demonstrate an understanding of rocks and minerals as fundamental resources for humans and scientists who study the Earth.
6. Explain the basic chemical and physical processes that control the distribution of geologic resources from the Earth including metals and energy.
7. Explain the social and economic issues that control the availability of mineral and energy resources.
8. Collect basic data required for the analysis of natural resource systems.
10. Understand the dependence of all people on both renewable and non-renewable resources.
11. Describe the impact of humans as stewards, managers and components of natural resources systems.

---

**Professional Behavior**

Professional behavior determines the way others view you. This includes professional colleagues, parents, students, instructors, teaching colleagues view you.

Professional behavior includes, but is not limited to:

- Being responsible
- Maintaining an excellent attendance record
- Showing initiative
- Developing rapport with other professionals and with those you interact with such as students
- Maintaining flexibility
- Being prepared
- Maintaining confidentiality
- Demonstrating ability to meet deadlines

These behaviors, along with other considerations, are important attributes of quality employees and professionals. You will be challenged to succeed if you do not have these characteristics.

Modified from: PROTOCOL, POLICIES, AND PROFESSIONAL REQUIREMENTS CI 495C or WLED 495C, The Pennsylvanian State University.

---

**Calendar**

The calendar will be updated periodically as we move through the modules. Please check it regularly for new/revised due dates on assignments.

<table>
<thead>
<tr>
<th>Lesson</th>
<th>Activity</th>
<th>Completion Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module 1</td>
<td>1. Introductions, Expectations, and Questions</td>
<td>1.1: Introduce Yourself</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.2: Your Expectations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.3: Questions, Questions, and More</td>
</tr>
<tr>
<td>Module 2</td>
<td>What do I know?</td>
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<td>-----------------------</td>
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<tr>
<td></td>
<td>4: Natural Resources and Civilization</td>
<td>Sept 20</td>
</tr>
<tr>
<td></td>
<td>4.1: Cost of Natural Resources</td>
<td>Sept 20</td>
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<tr>
<td></td>
<td>4.3: What Energy Do I Use?</td>
<td>Sept 20</td>
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<tr>
<td></td>
<td>4.4: Natural Resources: Developing a Common Language</td>
<td>Sept 20</td>
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<tr>
<td></td>
<td>4.5: Sustainability and Ecological Footprints: What are they and who cares?</td>
<td>Sept 20</td>
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<tr>
<td></td>
<td>5: Earth's Spherical Systems</td>
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<td></td>
<td>5.1: Overview of Earth System Concepts</td>
<td>Sept 27</td>
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<tr>
<td></td>
<td>5.2: Earth's Life Support Systems: An Introduction</td>
<td>Sept 27</td>
</tr>
<tr>
<td></td>
<td>5.3: Watch NASA CONNECTS - Earth Systems</td>
<td>Sept 27</td>
</tr>
<tr>
<td></td>
<td>5.4: ECEE Discussion</td>
<td>Sept 27</td>
</tr>
<tr>
<td>What Did I Learn: Mastery of Content Activity: Module 2 &amp; Concept Map Update</td>
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<tr>
<td><strong>Module 3</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>What Do I Know?</strong></td>
<td>Oct 11</td>
<td></td>
</tr>
<tr>
<td>6: Water - Our Most Valuable Resource</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.2: Your Water Supply</td>
<td>Oct 11</td>
<td></td>
</tr>
<tr>
<td>6.3: Water Language Journey</td>
<td>Oct 11</td>
<td></td>
</tr>
<tr>
<td>7: Surface Water Resources;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.1: Geography of U.S. Rivers</td>
<td>Oct 18</td>
<td></td>
</tr>
<tr>
<td>7.2: Rivers and Hydrographs</td>
<td>Oct 18</td>
<td></td>
</tr>
<tr>
<td>8: Groundwater Resources</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.1: Geology, Groundwater and the Two P Words</td>
<td>Oct 18</td>
<td></td>
</tr>
<tr>
<td>8.2: A Groundwater Journey Essay</td>
<td>Oct 18</td>
<td></td>
</tr>
<tr>
<td>What Did I Learn: Content Mastery Activity: Module 3</td>
<td>Oct 25</td>
<td></td>
</tr>
<tr>
<td>8.2: A Groundwater Journey Essay</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Module 4</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>What Do I Know?</strong></td>
<td>Nov 1</td>
<td></td>
</tr>
<tr>
<td>9: Observing Geological Resources in Your World</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.1: Going on a Walk-About to Observe Your World</td>
<td>Nov 1</td>
<td></td>
</tr>
<tr>
<td>9.2: Process of Science @ VisionLearning</td>
<td>Nov 1</td>
<td></td>
</tr>
<tr>
<td>10: Rock and Mineral Resources and the Human Endeavor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.1: Strategic Minerals: Past, Present, and Future</td>
<td>Nov 8</td>
<td></td>
</tr>
<tr>
<td>11: Elements, Rocks, Minerals and their Relationships</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.1: Mystery Mineral Game and Investigation Lab</td>
<td>Nov 15</td>
<td></td>
</tr>
<tr>
<td>11.2: Rock Research</td>
<td>Nov 15</td>
<td></td>
</tr>
<tr>
<td>11.3: Going Venn with the Rocks</td>
<td>Nov 15</td>
<td></td>
</tr>
</tbody>
</table>
### Structure and Method

Structure: NRES 108 is a three-credit graduate level, Internet-based, computer-delivered, distance learning course. It is delivered online via Blackboard. The "course" is structured around the following modules:

Module 1. Welcome to Earth's Natural Resource Systems

Module 2. Natural Resources: Linking Science, Society, and Systems

Module 3. Water Resource Systems

Module 4. Rock and Mineral Resource Systems

Module 5. Soil Resource Systems
Each Module includes:

- Learning objectives and an introduction that highlights these objectives
- Module organization and topics to be covered

**Methods:** A variety of learning strategies will be used and include, but not be limited to: group cooperative strategies in which the individuals and group will be held accountable through peer evaluation; group discussions will provide students the opportunity to think about and integrate course content through free writing and focused questions; on-line content essays; and field exercises.

---

**Grading**

This course is designed to help you learn more about Earth's natural resources and as such, the focus is on learning, not grades. Your grade in this course will be based on your ability to **master course content** along with **active participation** and the **on-time, quality completion** of the grading elements in this course, not the accumulation of points. These elements include: assignments, activities, discussions, assessment tools, or other items to which the facilitators assign a due date. See the generalized rubrics that will be used to assess the quality completion of assignments (activities), discussions, and projects.

**Discussion**

Active participation in the discussion board is an important part of this course. Your individual discussion board participation will be assessed primarily on the **quality** of your contributions (See rubric). Irrelevant, redundant or unresponsive comments are discouraged. More specifically, we will be examining individual contributions based on the following criteria:

- The extent to which comments/questions relate to the current discussion.
- The extent to which the comment/question moves the discussion forward.
- The extent to which the comment/question is related to course content (e.g., assigned readings, activities, and assignments), or your own personal experience.
- The extent to which your reasoning is consistent and logical.
- The extent to which your comment/question brings a fresh analytic perspective and/or increased insight to the discussion.

Course facilitators will comment selectively and may post a final comment on the group discussion board.

**Group Work**

We may use some group activities during this course including data and information collection. The data and information collected may be used in other phases of the class so it is imperative that you participate. If you have difficulties within your group, please let the instructor know and steps will be taken to resolve the issue. Groups are challenging in an online environment, but we may give it a go.

**Data Collection, Presentations and Projects**

You will be asked to design a project in which you will be asked collect and interpret data on a natural resources question of interest to you. Project evaluation guidelines will be provided.
before the half-way mark of the semester. The goal of this project is for you to investigate something of interest to you and to use your new knowledge and skills.

**Content Mastery Assignments - Our primary tool for assessing your progress**

During each module, you will use one of several methods to demonstrate your mastery of the content. Instructors will provide feedback as appropriate and may ask you to revisit an assignment after additional guidance is given in order to receive full credit. If you do not respond to the feedback and suggestions, the original level of credit will be given. If you have a problem with a given deadline, please contact one of the instructors, otherwise if an assignment is not completed by its due date no credit will be given. **Note: You will not be allowed to resubmit, if you have not turned your materials in on time.**

**Grading Scale:**

Your success and that of the other course participants depends on your active, on-time participation. You can view your record by going to Evaluation on Blackboard and going to the Grade Center. These are under the course management segment of the course menu on the left. An "A" grade will be given if your record documents the quality completion of greater than 90% of the grade elements and meaningful completion of the course content questions. Documented mastery of 90% of the concepts will also be required.

A "B" grade will be given if your record documents the quality completion of 80 to 89% of the grade elements and meaningful completion of the course content questions. Documented mastery of 80 to 89% of the concepts will also be required.

A "C" grade will be given if your record documents the quality completion of 70 to 79% of the grade elements and meaningful completion of the course content questions. Documented mastery of 70 to 79% of the concepts will also be required.

A "D" grade will be given if your record documents the quality completion of 60 to 69% of the grade elements and meaningful completion of the course content questions. Documented mastery of 60 to 69% of the concepts will also be required.

An "F" grade will be given if your record documents the quality completion of less than 60% of the grade elements and meaningful completion of the course content questions. Documented mastery of less than 60% of the concepts will also be required.

If tasks that you do are not complete, you may be asked to revisit some aspect of the assignment, but issuing points and worrying about such things should not be a concern. Our goal is for you to be intrinsically motivated to learn the material and not need grades as a motivator or be concerned about grades to the point that it distracts from your learning. We want everyone to feel comfortable exposing your areas of need and willing to work until you have the required concept knowledge and understanding.

You are welcome to ask about your grade, but please trust us that the goal is learning and if you do what is asked you will be successful.

**Content Questions**

At the beginning and end of the course, each student must complete a series of content questions. The goal of this course is learning. To show that each of you have learned from the course, we have designed a data collection process that includes a set of content questions. The goal is to have you show your initial knowledge and then have you revisit and update your responses. This way you can see what learning has occurred and we can improve what
we do to help you learn those concepts that should have shown gains, but did not. Obviously this can not be accomplished if everyone does not enter useable data, at the times requested.

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**Student Conduct**

**Academic honesty:**

Academic honesty is essential to the existence and integrity of an academic institution. The responsibility for maintaining that integrity is shared by all members of the academic community. To further serve this end, the University supports a Student Code of Conduct which addresses the issue of academic dishonesty.

**Diversity:**

The University is committed to a pluralistic campus community through Affirmative Action and Equal Opportunity. We assure reasonable accommodation under the Americans with Disabilities Act.

**Ethics and Integrity:**

The instructor is committed to offering a course that maintains an atmosphere of ethical behavior, individual integrity, and equitable treatment of each person. Expression of ideas from various perspectives acknowledges the dignity of all class members.

**Students with Disabilities:**

Students with disabilities are encouraged to contact the instructor for a confidential discussion of their individual needs for academic accommodation. It is the policy of the University of Nebraska-Lincoln to provide flexible and individualized accommodation to students with documented disabilities that may affect their ability to fully participate in course activities or to meet course requirements. To receive accommodation services, students must be registered with the Services for Students with Disabilities (SSD) office, 132 Canfield Administration, 472-3787 voice or TTY.

Click [here](#) for a link to the "Academic Services Handbook."
Appendix E

Process of Science Module
Activity 1: Feelings and Perceptions about Science Reflective Questions (Appendix B)

Everyone in this class has had various experiences related to "science." As instructors, we are very interested in learning more about how you feel about them.

In an essay format or other format of your choice, please address the following and post in your learning log: Activity 1: Feelings and Perceptions about Science.

How do you feel about science? Do you like it? Dislike it?

What experiences have influenced your feelings?

Based on your experiences with science, address the following questions:

F. What is science?

G. How is science done?

(What is your understanding of the process of science?)

H. What are some of the key words and terms that are important to science?

I. How do humans influence science?

J. How is communication used in science?

Activity 2: Science as Story-Telling

In the previous activity, we asked you to think about your past experiences related to science, your perceptions of scientists, what is science, and how is it done.

Part 1 of this exercise will require you to read the attached essay called "Science As Storytelling."

After reading, this essay we would like you to write an essay in your learning log that explains the "rules" for telling a "scientific" story and what makes one story better than another. Be sure to consider some of the examples given from the history of science about how the "rules" are human inventions that scientists have decided upon for practical reasons, not because it has to be that way. There are very practical reasons for scientist to use these rules when they are going about their scientific work. As you think about these so-called "rules" comment on the extent to which you agree or disagree with them.
Part 2. Go to the Module 1 discussion board and reconsider your original response in your learning about about What is science and How is it done? Post your ideas, new thoughts and revisit at least one of the entries in the thread entitled, "What is science ...."

**Activity 3: Activity Model for Scientific Inquiry**

Part 1. Read the attached article, ""A New Model for Inquiry: Is the scientific method dead?" by William Harwood.


**Activity 4: Death to Dinos and Rhinos**

Read through the attached passages from Bill Bryson's "A Short History of Nearly Everything."

From "Bang!" chapter, p. 195 to 202, This piece tells the story that provides an explanation for the disappearance of the dinosaurs.

From "The Fire Below" chapter, p. 207 to 209. The piece tells the story of Nebraska's own, Mike Voorhies, and his finding an ancient rhinoceros skull that led him to the discovery of Ashfall Fossil Beds.

For each of these stories, use an events table or chronological map to document the activities in your learning log that these scientists went through during their investigations. As you consider all the events and activities involved in these two very important discoveries, consider, where appropriate by providing evidence, the role of technology, curiosity, surprising observations, and chance or serendipity played in these discoveries.

**Activity 5: Bringing it All Together: Models for How Science Works**

Explore this narrated PowerPoint. You will need to have the latest Flash plug-in to view the presentation.

*The powerpoint presentation is available upon request.

**Activity 6: Content Mastery Assignment: Reflective Writing - Nature and Process of Science**
In your learning log, *Labeled Reflective Writing: Nature and Process of Science*, please reflect on your understanding of the nature and process of science as you did in Activity 1.

In an essay format, please address the following:

How have your thoughts and feelings about science changed after going through these activities.

Be sure to address the following questions:

A. What is science?

B. How is science done?
   (What is your understanding of the process of science?)

C. What are some of the key words and terms that are important to science?

D. How do humans influence science?

E. How is communication used in science?

Note the rubric that will be used for your essay. I suggest that you have a section in your essay that specifically addresses each question. As noted by the last two rows of this rubric, use examples from course content to support your ideas and help the clarity of your writing. Use diagrams and pictures as appropriate.
Appendix F

Application of the Activity—Model for Scientific Inquiry
**Part 1.** Review the Activity Model application in Harwood’s paper for a college biology class example.

**Part 2.** Review the following example of the application of the activity model. The Event Table and Chronological Map illustrate an inquiry path that a geologist might take while investigating the way trees died in a forest. Modified from Harwood (2004) An Activity Model for Scientific Inquiry, The Science Teacher, p. 44-46.

**Event Table for Investigating Why Trees Died in a Forest.**

<table>
<thead>
<tr>
<th>Events during Investigation</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Discovered a forest of dead cedar trees</td>
<td>Observation</td>
</tr>
<tr>
<td>2. What could have killed so many trees over so wide an area?</td>
<td>Question</td>
</tr>
<tr>
<td>3. Examined knowledge of earthquakes, plate boundaries, coastline subsidence.</td>
<td>Investigating the known</td>
</tr>
<tr>
<td>4. Did trees die at the same time?</td>
<td>Defining the problem/Formulating Question</td>
</tr>
<tr>
<td>5. Expected carbon dating to answer the question</td>
<td>Articulated expectation</td>
</tr>
<tr>
<td>6. Took samples and dated them</td>
<td>Carried out the study</td>
</tr>
<tr>
<td>7. Found all trees died about 300 years ago</td>
<td>Examined the results</td>
</tr>
<tr>
<td>8. Was their death related to nearby volcanic activity or some kind of biologic plight?</td>
<td>Forming study question</td>
</tr>
<tr>
<td>9. Examined knowledge of potential insect infestation</td>
<td>Investigating the known</td>
</tr>
<tr>
<td>10. Talked to colleagues in the entomology department to clarify his understanding of the insect literature</td>
<td>Communicating with others</td>
</tr>
<tr>
<td>11. Mapping indicated no evidence for widespread volcanic deposits</td>
<td>Observing/Carrying out the study</td>
</tr>
<tr>
<td>12. Trees not burned and no evidence of insect infestation</td>
<td>Observing/Carrying out the study</td>
</tr>
<tr>
<td>13. Considered role of salt water</td>
<td>Reflecting on Findings/Questions</td>
</tr>
</tbody>
</table>

**The Investigation Continues**

**Activity - Model Key**

1. Questions
2. Observing
3. Defining the Problem
4. Formulating the Question
5. Investigating the Known
6. Articulating the Expectation
7. Carrying out the Study
8. Examining the Results
9. Reflecting on the Findings
10. Communicating with Others

Record your thoughts and ideas as to what you can communicate to others about the process of science.
Part 3. One of the most important things that we’d like you to take from this class is the knowledge of how science works, and the knowledge that you do “scientific inquiry” in your everyday life. You’ll find that this is a lot like CSI or Sherlock Holmes. Here is an example from your daily life. Read through the following description. Use a table OR a graph as was done in part 2 to analyze the activities used to investigate lights out. Include your analysis including an Events Table OR Chronological Map in your learning log. Hint: The chronological map can be done in Excel or you could draw it by hand and scan it if you so desire.

Lights Out!

You walk into your bedroom at night and flick the light switch and nothing happens. The light does not come on. As you are standing in the dark, you say to yourself, self, why did the light not turn on? You ponder this question for a moment or two. It dawns up you that well may be the power for the house is out. Of course, if the power was out, then I would expect the lights in other rooms not to come on. To investigate this prediction, I go to other rooms in the house and the lights come on when the switch is flicked. It turns out that the lights in other rooms came on when their switches were flicked. Your next idea is that the light bulb may be burned out. So you replace the bulb and when you flick the switch the light goes on. After smiling about your success, you hear the front door slam and your proceed to discover your father has just come home and you tell him the whole story of the process that you went through to solve the mystery of lights out in your room.

Events Table

<table>
<thead>
<tr>
<th>Events during Investigation</th>
<th>Activity</th>
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</thead>
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</table>
Part 4. Personal Application of the Activity Model. (Modified from: Scientific Observation Activity Pete Stelling, Western Washington University)

1. Go for a walk outside or anywhere you would like. I want you to make an observation that is related to some sort of process. It can be about any process, but the key to a decent observation is to be able to ask “why is it like that?” or “How does this happen?” *(Activity Model: Observing)*

   For instance, while sitting in the dentist chair yesterday I noticed a big curved scrape in the drywall on the wall in front of the chair, about 2 feet long, ¼ inch deep. See the drawing below.

2. Next, ask a probing question about your observation. This question will usually include the words “how” or “why.” *(Activity Model: Questioning)*

   “How did that scrape get there?”

   If you have trouble forming a decent question, you might want to consider a different observation.

3. Then, make *at least* three more observations (i.e., collect additional data or information) that help you address your question. *(Activity Model: Questioning/Carrying out the study)*

   “There are no other marks on the wall.”
   “The part of the chair that sticks out the most is the elbow on the rotating arm the light is attached to.”
   “The scrape is higher on the wall than any or part of the chair or other instrument in the room, including the elbow of the light arm.”
   “There is some drywall stuck to the back side of the elbow of the light arm, and it has some paint on it that is the same color as the paint on the wall” (I had to get up out of the chair and look around to find this data)

4. Once you have made several observations that help answer your question, go ahead and try to answer your question. The answer to your question is your hypothesis, and it should come in the form of a confident statement. *(Activity Model: Articulate the Expectation)*
“The scrape on the wall happened when they moved the chair into the office and the light arm rubbed against the wall.

Then you should justify your statement with your observations. *(Activity Model: Examining Results/Reflecting on Findings)*

The evidence I see for this is the paint and drywall stuck on the back of the elbow of the light arm, and that the light arm is not high enough for this to happen while it is sitting in its current position. Also, it only happened once because there is only one scrape. It must have happened when the chair was higher than it is now, and that would be when people were moving it into the office.”

5. Finally, develop at least additional explanations (or two additional hypotheses) based on your conclusions that attempt in increase your understanding of the process or the objects involved: *(Activity Model: Articulate the Expectation/Examining Results/Reflecting on Findings)*

“*It must be difficult to move a dental chair into position*”

“*These people really don’t care about what this place looks like since they haven’t fixed or painted the wall, they haven’t even hung a picture over the scrape, and the crud is still on the light arm.*”

6. Write it up. *(Activity Model: Communicating with others)* I know you have probably had to write lab reports before and those have been tedious. Think about writing what you have done as writing a story, similar to what you read earlier in this module. Tell us where you started and what conclusions you ended up with and how you go from point A, where you started, point B, where you ended. You should use formal language and grammar (no text-message speak). Your submission will be assessed on the appropriateness of your observations, the logic you used to answer your initial question, the quality of the additional hypotheses, and the overall quality of your writing.
Appendix G

Bringing it All Together: Models for How Science Works
Models and Science

A Model for the Process of Science: The Linear Method

Vocabulary Knowledge Needed
- Hypothesis
- Experiment
- Observation
- Theory
- Lines of Evidence

Click Here For Help from: "Science at Multiple Levels"

One Model for the Process of Science: The Linear Method

Another Model for the Process of Science: The Activity Model For Inquiry (AMI)

Another Model: The Nature Of Science Model

Important Characteristics of Science

- Science is complex and multidimensional.
- Science focuses exclusively on the natural world.
- Science is a way of learning about what is in the natural world, how it works, and how it got to be the way it is.

Important Characteristics of Science

- Scientists work in many different ways test ideas and explain observations.
- Accepted scientific ideas have been subjected to rigorous testing, but as new evidence is acquired and new perspectives emerge, these ideas can be revised.
- Science is a community endeavor and relies on a broad range of perspectives on scientific ideas.
Appendix H

Content Mastery Assignment: Reflective Writing—Assessment Rubric
<table>
<thead>
<tr>
<th></th>
<th>Excellent (3 points)</th>
<th>Needs Work (2 points)</th>
<th>Unacceptable (1 point)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Components of Nature and Process of Science are considered including</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Includes key aspects that describe what makes science unique from other ways of thinking and understanding</td>
<td>May include or suggest ideas that make science ideas, but not clearly or succinctly illustrated</td>
<td>No aspects of what makes science unique are included</td>
</tr>
<tr>
<td>What is Science?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How is science done?</td>
<td>Includes key &amp; critical elements to making science successful.</td>
<td>Includes important components to making science successful. May include a few inaccurate views or slightly misinformed ideas.</td>
<td>No aspects of how science is done are considered, or extremely inaccurate views.</td>
</tr>
<tr>
<td>What are some of the key words and terms that are important to science?</td>
<td>Include definitions of key terms in context of how they are used in science.</td>
<td>May use the appropriate terms, but not clearly defined or used in ways that imply a slight misunderstanding.</td>
<td>Completely inappropriate use of terms, or no key terms included.</td>
</tr>
<tr>
<td>How do humans influence science?</td>
<td>Indicates how humans play a role in making science successful (or not) over time. May include specific examples.</td>
<td>Includes some component of human influence, but not clearly defined or explained.</td>
<td>Does not indicate how humans play a role in science.</td>
</tr>
<tr>
<td>How is communication used in science?</td>
<td>Clearly describes the role of communication in science and provides specific examples.</td>
<td>Describes some aspect of communication, but not clearly defined or explained.</td>
<td>No aspect of communication considered.</td>
</tr>
<tr>
<td>Other components considered in grading</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Writing clarity</td>
<td>Clear and concise writing, well thought out and succinct.</td>
<td>Ideas are generally well laid out and clear, but may lack a clarity that clearly illustrates the ideas portrayed.</td>
<td>Very difficulty to understand and follow. Ideas not clearly defined or illustrated, which makes it difficult to understand the intent of the authors.</td>
</tr>
<tr>
<td>Specific Examples</td>
<td>Accurate examples from course content are clearly linked to the scientific ideas portrayed.</td>
<td>A few vague examples, or only one example that relates to the content provided.</td>
<td>No examples relating the NOS content to the geosciences, or examples are misinformed and inaccurate.</td>
</tr>
</tbody>
</table>
Appendix I

IRB Approval Letter
April 29, 2011

Sara Cooper  
Environmental Studies Program  
149B HARH, UNL, 68583-0941

David Gosselin  
School of Natural Resources  
150A HARH, UNL, 68583-0941

IRB Number: 20101011098EP  
Project ID: 11098  
Project Title: Assessing Skills for the 21st Century

Dear Sara:

The Institutional Review Board for the Protection of Human Subjects has completed its review of the Request for Change in Protocol submitted to the IRB. It has been approved to include de-identified data from an additional class; NRES 108.

We wish to remind you that the principal investigator is responsible for reporting to this Board any of the following events within 48 hours of the event:
* Any serious event (including on-site and off-site adverse events, injuries, side effects, deaths, or other problems) which in the opinion of the local investigator was unanticipated, involved risk to subjects or others, and was possibly related to the research procedures;
* Any serious accidental or unintentional change to the IRB-approved protocol that involves risk or has the potential to recur;
* Any publication in the literature, safety monitoring report, interim result or other finding that indicates an unexpected change to the risk/benefit ratio of the research;
* Any breach in confidentiality or compromise in data privacy related to the subject or others; or
* Any complaint of a subject that indicates an unanticipated risk or that cannot be resolved by the research staff.

This letter constitutes official notification of the approval of the protocol change. You are therefore authorized to implement this change accordingly.
If you have any questions, please contact the IRB office at 472-6965.

Sincerely,

William Thomas, Ph.D.

Chair for the IRB