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## Inquiry, Efficacy, and Science Education

Heather Christa Scott

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# INQUIRY, EFFICACY, AND SCIENCE EDUCATION

By

HEATHER CHRISTA SCOTT

(Under the direction of Missy Bennett)

## ABSTRACT

Developing learners who are equipped to think critically about the vast information circulating around them is essential in their preparation for a role in society today. The use of effective inquiry-based instruction is not a widespread practice among K-12 classrooms. Many secondary and post-secondary science instructors see the valuable link between students asking questions and the development of critical thinking. Inquiry-based instruction provides student opportunities to ask questions, design methods of investigation, gather information, and finally reach conclusions based on evidence. However, this instruction style is rarely used in the classroom, particularly in elementary classrooms. This study examines the relationships between inquiry-based instruction, science content knowledge and self-efficacy among pre-service elementary teachers.

Using a mixed method (Quan. /qual.) study, the researcher examined two Life/Earth science classes of elementary pre-service teachers using inquiry-based and traditional instruction. Each class completed pre-assessment instruments to measure initial content knowledge, self-efficacy in science teaching, and the number of prior

science courses. The first eight weeks of the semester during life science content, one class received inquiry-based instruction, while the other class received traditional instruction. At the midpoint of the semester, each class completed a posttest for life science content and a self-efficacy instrument modified to address efficacy in life science. Following this, a crossover method occurred for the remaining eight weeks of the semester during earth science content. The class that previously received inquiry instruction now received traditional instruction and the class that previously received traditional instruction, now received inquiry instruction. At the end of the semester, each class completed a posttest for earth science content and a self-efficacy instrument modified to address efficacy in earth science. ANCOVA, correlations, and independent t-tests were used to analyze the quantitative data. Focus group interviews of volunteers from each class were used to gather qualitative data on what pre-service teachers think about inquiry versus traditional instruction.

The results showed a significant difference in life science content between inquiry-based and traditional instruction. There was no significant difference between earth science content, efficacy or expected teaching outcome in life or earth science. Correlation results show a significant relationship between prior courses and life science content, and between the Post Life Content and Post Earth Content scores. The Post Life Efficacy subscale was also statistically related to the Life Outcome subscale and the Earth Efficacy subscale.

INDEX WORDS: Efficacy, Inquiry, Pre-service teacher, Science, Teacher Education,

INQUIRY, EFFICACY, AND SCIENCE EDUCATION

by

HEATHER CHRISTA SCOTT

B.S., University of Georgia, 1993

M.A., Texas Tech University, 1995

A Dissertation Submitted to the Graduate Faculty

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INQUIRY, EFFICACY AND SCIENCE EDUCATION

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HEATHER CHRISTA SCOTT

Major Professor: MISSY BENNETT  
Committee: BRYAN GRIFFIN  
JACK TESSIER  
JOHN WEAVER

Electronic Version Approved:

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## DEDICATION

This dissertation is dedicated to my family: Damien, Christian-Thomas, Emmaline, Mary-Elizabeth and my mother, Harriet. For without each and every one of you, this entire project would never have been completed. Thank you all for you help, support and encouragement along the way.

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## CHAPTER 1

### INTRODUCTION

Developing critical thinkers that are equipped to gather information, analyze it and make decisions for themselves and their roles in society is an important part of education today (Ornstein, 2006). Although many researchers and some teachers have demonstrated the effectiveness of using an inquiry-based approach to science education, this is not a widespread practice among K-12 classrooms. Can inquiry-based instruction in science increase efficacy and content knowledge through the development of critical thinking in pre-service teachers?

The value of a student-centered classroom benefits many people associated with the educational experience. Teachers find that a student-centered classroom is not only more engaging for the students, but also for themselves. As students become more engaged in the learning process their attitudes improve and the classroom atmosphere brightens. It is also gratifying to watch students begin making connections and scaffolding their own knowledge. The teachers have opportunities to take ownership of their classrooms once again, when developing their own lesson plans and their creativity heightens. Teachers are professionals, although the current public view of teachers rarely treats them as such. In 2010, Nelson, Palonsky and McCarthy addressed contemporary schools as places where teachers are expected to accomplish something more than force-feeding students memorized materials; instead they should expect education and critical thinking. However, these same authors also concede that “in schools remain strong efforts to censor and restrain educators in performance of

their profession” (Nelson, Palonsky, & McCarthy, 2010 p. 403). Where is the balance? When schools resort to following canned lessons that keep everyone on the same page on the same day, teachers also miss out. Anyone can fill the role of following a canned lesson that someone else developed. How would a teacher find job satisfaction in always being the follower in their own classroom?

Society benefits from student-centered classrooms, as creativity and motivation infiltrate the population as these students graduate and then move into the next phase of their lives. Inquiry-based instruction, which is student-centered, provides opportunities for students to also further their critical thinking skills. The value of teaching people to think critically should be apparent in the independence that can arise in a population. These people become contributing members of a society, being able to take information and discern its value for their future (Brown et.al., 2006; DiPasquale, Mason, & Kolkhorst, 2003; Janners, 1988; McComas, 2005).

Finally, the students themselves benefit from a student-centered classroom. As previously mentioned the first noticeable impact for students is the level of engagement that changes when students are no longer being dragged along a passive educational road, while someone feeds them knowledge. Their interest in the subject matter increases and spills over into other areas as well. In addition, their ability to think and interact with knowledge changes dramatically. Following the ideas of Bandura’s Social Learning Theory (1977), students who have successful experiences in school and in the learning process, are more likely to seek additional similar experiences. Even having intermittent failures, strengthens their resolution to seek alternative paths for success. Sadly, that process is rarely evident in most schools today.



As a teacher educator, I have opportunities to be in a variety of classrooms differing in both content and grade level for pre-service teacher observations. The apathy that pervades most classrooms today is very discouraging. Student teachers work hard to develop engaging, high level units with multiple teaching strategies that utilize inquiry. When they reach the classrooms however, they are often met with an unexpected battle. The classroom teacher is worried about deviating too far from the prescribed plan of direct instruction. They are required to satisfy some quotient of material by “T-Day” or Test day. Using a different teaching approach may vary that schedule, and they find that scary! The control over their job is certainly not theirs, deciding the depth and presentation method from the perspective of a highly qualified individual is gone. Instead, they encourage our students, the pre-service teachers, to stick to direct instruction; we lovingly refer to it as Death by Power Point. Most often what occurs is the student teaching unit is permitted only after all testing for the year is complete. This sends the signal to both the pre-service teacher and the students that the upcoming unit is extraneous.

The students are so exhausted with the rigor of instruction that is focused on the upcoming test that they have lost any desire to learn and be an active participant in the process. Interestingly, “multiple-choice questions are an unnatural problem-solving format incongruous with solving real-life problems. Rarely are life’s dilemmas delineated by four answers, one of which is guaranteed to be correct” (Nelson, Palonsky & McCarthy, 2010, p. 336). It is not surprising that the resistance to change also is heard from the students. They have become lazy learners. It is easy to show up to

class with no materials required, endure a lesson and leave, again – no homework required. They certainly have mastered achieving the goal set forth for them!

However, the excitement of discovery and seeking knowledge doesn't have to be as extinct as some fossilized remains, pushed to the back of a dusty shelf. There are some teachers who have decided that their gift is teaching, and teaching is what they were meant to do. They are no longer standing aside and waiting for someone else to tell them how to teach. Instead, they are using their own creativity and intelligence to catch the flame of excitement in their students. One of the ways they are doing this is through inquiry.

The history of inquiry in scientific discovery is absolutely fascinating when you see the way in which our knowledge base has multiplied exponentially. Science is a process that builds upon prior knowledge and continuously seeks new branches. Often the paths chosen do not lead to expected discoveries, but in fact completely unexpected outcomes. Many say serendipity and science go hand in hand. Take for example some of the top scientific discoveries of all time. Penicillin is attributed to Fleming, who in 1928 noticed a mold growing in his culture plate of *Staphylococcus* (Wennergren & Lagercrantz, 2007). The clear ring around the mold demonstrated inhibited bacterial growth. Even the development of saccharin, by Falhberg, was due to lack of good lab practice when he failed to wash his hands and tasted a sweet substance on the bread he was eating (de la Pena, 2010). However, these incredible scientific discoveries were not blind luck, but the scientists working with them had the imagination to foresee the real discovery within the accident! These demonstrations of science in action as a process make science real for students. In addition, by situating students in positions

where they see themselves in a discovery role, their interest and confidence in their ability to do science improves. Teachers can only make this happen when they also are confident in their ability to teach science.

## CHAPTER 2

### REVIEW OF RESEARCH AND RELATED LITERATURE

#### Introduction

Elementary science tends to focus on the processes of science and less on the specific content while secondary science focuses more on content knowledge and less on the process (Haefner & Zembal-Saul, 2004). However, Chiappetta (1997) encourages all science teachers to view science as inquiry, which is more of an ongoing process and an overall mindset with students in an active learning role, rather than to teach science *by* inquiry which views science as isolated events in the course of the day or “risks sending the message that science is simply a body of knowledge to be learned, while inquiry-based instruction potentially offers significant advantages for science education, by modeling scientific inquiry” (Cobern et al., 2010, p. 93). Developing students that are comfortable with science as inquiry produces critical thinking skills that carryover into all aspects of life (Brand & Moore, 2011).

#### History of Inquiry

John Dewey had a vision for educational change. His view of the traditional classroom limited children when the laboratory, the materials, and the tools for construction or creation, and space were lacking (Dewey, 2001). He saw the learning in traditional schools confined to “the acquisition of what is already incorporated in books and in the heads of the elders” (Dewey, 1938, p. 19). Instead Dewey envisioned a

school where students had opportunities to ask questions and seek knowledge, which would foster ownership in the learning process.

“There is, I think, no point in the philosophy of progressive education which is sounder than its emphasis upon the importance of the participation of the learner in the formation of the purposes which direct his activities in the learning process, just as there is no defect in traditional education greater than its failure to secure the active co-operation of the pupil in construction of the purposes involved in his studying” (Dewey, 1938, p. 67).

In the late 1950s and early 1960s, the term inquiry became more widely used and studied as a popular and valid element in science education. In fact James Rutherford stated that the science teaching profession held the consensus that “science should be taught as a process rather than as content” (Chiappetta, 1997, p. 23). Science as a process involves the use of a variety of methods referred to as the science process skills, to seek answers. These methods such as inference, prediction, observation, measurement, etc. can be used to prove or disprove a hypothesis. In Rutherford’s case, his hypothesis regarding the structure of the atom, was disproved, however, even disproving a hypothesis is a valuable part of the learning process if you can explain why this occurred. It leads to different paths of exploration that builds on the prior knowledge.

Rheinberger refers to the epistemic object of science as the thing that catches our interest, leading to further exploration of the unknown. “A research experiment is a device to bring forth something unknown – in fact, something which does not even exist in the form in which it is going to be produced” (Rheinberger, 1992, p.391). In

constructing the framework of an experiment, the reshaping of an assumption forms the activity itself. Furthermore, where some expectations may lead to a dead end, as many times in science, the roadblock shifts the study focus (Rheinberger, 1992).

In addition, there are others that have claimed the value of stepping out from the linear scientific method. Kuhn recognizes that the anomalies of science actually create the pivotal moments in science that lead to a significant jump in our understanding and knowledge (Weaver, 2005). Paul Feyerabend (1978) conducts an extensive exploration of the understanding of scientific practice as opposed to scientific method. His interpretation of Galileo's success and persistence of the telescope is more a result of trial and error through experience than through the mathematical theory. This use of inquiry and acquisition of scientific knowledge is very interesting when we reflect on the historical acclaim for Galileo regarding astronomical discoveries, particularly when we note that his telescope was first developed and tested through the use of "terrestrial vision" (Feyerabend, 1978, p.107). Clearly, the linear, stepwise approach of the scientific method was less significant in the discovery of our modern telescope than simply the result of serendipity.

As well, Rheinberger (1992) sees an experimental system as "the smallest functional unit of research, designed to give answers to questions which we are not yet able to clearly speak" (p. 309). It is this experimental system that pre-service teachers need to experience personally, to gain their own understanding of the inquiry process. As products of an educational system that has told them what to know, rarely do they realize the process of acquiring knowledge and value of experiencing roadblocks in the

quest for knowledge. Using inquiry encourages pre-service teachers to design methods for answering questions, which sometimes leads to more questions.

Another interesting way to think about scientific inquiry is that once one result is realized, it is hard to ever go back and describe the unknown without referring to the newly found knowledge. “How, above all, does one recapture the sense of a maze with no way out, the incessant quest for a solution, without referring to what later proved to be the solution in all its dazzling obviousness” (Rheinberger, 1992, p. 321). Pinar (2004) also refers to this view in curriculum inquiry and research, “wherein destinations are not necessarily known in advance” (p. 29).

### **Inquiry Today**

There are a variety of challenges that arise from incorporating scientific inquiry in the classroom. Teachers that begin implementing scientific inquiry state two primary concerns: 1) how to appropriately assess students’ learning outcomes following the use of inquiry, and 2) developing sufficient breadth of personal knowledge to handle student led instruction (Brand & Moore, 2011; Britzman, 1991; Buck et al., 2007). Since most university elementary education programs provide little content knowledge in science, having students in a position to question outside of a known body of knowledge can be very disconcerting. In order for these teachers to achieve success with the use of inquiry, they need to increase their scientific knowledge as part of their teacher education programs or later through professional development experiences (Brand & Moore, 2011; Buczynski & Hansen, 2010).

In addition, some argue that to carry out inquiry-based instruction is too time-consuming (Brand & Moore, 2011). The mandates placed upon schools and teachers today require strict adherence to a method that prepares students to consume quantities of information that can be retrieved at a later date and at a superficial level, such as for use in an end of course test. However, using an inquiry approach can provide variation in instruction and assessment. As Nelson, Palonsky and McCarthy (2010) state, "Parents should not worry about a teacher who does not rely on standardized tests; they should worry more about teachers who believe standardized tests measure the ways in which a child's mind works" (p. 343). This method of instruction rarely stretches students to develop higher order thinking skills beyond basic knowledge and comprehension (Buck, McIntyre Latta, Leslie-Pelecky, 2007; Lord, T. & Orkwiszewski, 2006).

Other teachers argue that the time consuming part of inquiry comes from the process of having students ask questions and design experimental outcomes that can answer these questions. Many times, this reason alone would cause teachers to avoid inquiry by staying in their comfort zone. Their students may ask questions that the teacher is not equipped to answer immediately. Rather than seizing that as a teachable moment, they panic (Britzman, 1991; Pratt, 2007; Smith, 2007). Teachers in any content area may feel ill at ease with the notion that details for lesson preparation are yet to be determined. The teacher feels that s/he should have all of the answers outlined in a detailed plan. Leaving room for student predictions, questions or exploration removes a lot of teacher control and steers the classroom toward a more student-driven perspective.



In order for students to view themselves in the role of a scientist, they need to have their own experiences to ask questions and seek answers. Part of that process is deciding the method to best answer such questions, and that method may not be the same for each class or even each student. McComas (2005) states that, "Too frequently the school laboratory is far removed from the recommendations of constructivist teaching and is at odds with the way scientists themselves investigate problems" (24-25). Students view science as a body of knowledge that someone else discovered, rather than learning the process of asking questions and seeking answers for themselves, activities that naturally occur along the continuum of inquiry learning (Janners, 1988; Milner, Templin, & Czerniak, 2011; Tretter & Jones, 2003).

Although secondary and post-secondary science instructors more easily see the valuable link between students asking questions and developing critical thinking, it is still rarely utilized in the classroom; even less so in the elementary classroom. Elementary teachers are placed in a crucial position to develop inquiry practice in students' early educational experience. However, how are teachers adequately prepared to teach in this way? The responsibility falls to the teacher educator programs.

Allowing pre-service teachers to experience learning science through an inquiry-based approach builds their self-confidence to teach in future classrooms utilizing these practices. Researchers such as Sanger (2006) found that when elementary teachers were taught chemistry content utilizing an inquiry approach, they learned chemistry content at least as well as a traditional approach and in some situations could actually explain it better. Likewise, Smith (2007) found that, "Creating learning environments

that support and encourage reasoning and students' dispositions and abilities to do mathematics and science requires educating teachers in similar environments" (563-564). Learning science content in a way that increases science content knowledge is valuable, but learning science content in a way that increases the ability for pre-service teachers to *teach* science content is even more valuable.

Studying relationships between science and other areas such as technology, politics, and medicine, makes people aware of changes in society. Intellectual curiosity allows individuals to educate themselves on a topic and make decisions that will impact their own lives and perhaps the lives of others. Now we see science education changing into something more real, an interconnected opportunity to observe the world around us – how it works and why, while also asking questions and recognizing the impact that each discovery can make.

### **Future of Inquiry**

When relationships between science and other areas demonstrate science as a process, this method of thinking will become transferrable to other areas by developing critical thinking in other facets of life. In many if not most schools, we will continue to face the challenge of making learning real for all students. Not just focusing on the elite or advanced, the special education or the regular education, but ALL students and helping them discover their interests and curiosities. Also, since science education is confined to the same restraints that are guiding the direction of learning for all content areas, the standardized test, educators must move beyond teaching to the test, but teaching for the sake of knowledge. When this occurs, students will no longer lose the

opportunity to learn how to think from sheer memorization of facts. Pinar referred to this phenomenon well when he stated, “Intelligence is made narrow, and thus undermined, when it is reduced to answers to other people’s questions, when it is only a means to achieve preordained goals” (Pinar, 2004, p. 29). Students need to begin asking their own questions.

As the national school reform movement continues, inquiry will slowly be included in school science programs, as many textbook companies have realized, and have joined the pursuit by producing curriculum that boasts inquiry. The State of Georgia has included science process skills as part of the Georgia Performance Standards for some time as the Characteristics of Science. These characteristics are two-fold including the Habits of Mind and the Nature of Science. It is a goal of the Georgia Performance Standards that Content, Habits of Mind, and Nature of Science be considered co-requisites. “Science consists of a way of thinking and investigating, as well as a growing body of knowledge about the natural world. To become literate in science, therefore, students need to acquire an understanding of both the Characteristics of Science and its Content. For each grade level, students should have opportunities within science to develop the use of these science process skills” (GPS, 2004, Science: K-5 Science, Para. 3).

The National Science Teachers’ Association provides a position statement regarding scientific inquiry. They state “scientific inquiry is a powerful way of understanding science content. Students learn how to ask questions and use evidence to answer them” (NSTA Website, 2012). Not only will elementary students develop greater understanding of science when learning this way, but when pre-service teachers

gain content through personal experience with inquiry, it will also build confidence in their ability to teach this way.

### **Summary**

Helping pre-service teachers reach a point where their science content knowledge and their self-efficacy to teach science is strong enough to utilize a variety of instructional practices in the classroom should really be at the core of teacher educator programs. The process for developing effective science teachers in elementary classrooms means bringing their content knowledge to a level of expertise suitable for teaching. Self-efficacy and attitudes towards science content are critical components of effective, confident teaching.

College courses that follow an inquiry approach to science have found that students have a better attitude about science and they are better equipped with critical thinking skills than when they receive other instruction (Lord & Orkwiszewski, 2006; Ornstein, 2006; Sanger, 2006; Tessier, 2010). Science majors or non-science majors at the post-secondary level have demonstrated benefits of receiving instruction through inquiry methods of instruction. A study conducted by Sanger (2006), involved chemistry content taught to education majors through inquiry-based instruction and taught to students in general chemistry through a traditional direct instruction method. The results of content knowledge at the end of each course suggests that use of inquiry-based instruction helped students learn chemistry content at least as well as traditional methods, and in some instances better. More of this type of instruction should be seen in our universities, and when teacher education programs diligently utilize inquiry in teacher education, the process of inquiry will be seen in our schools.

In addition, attitude and efficacy are correlated with inquiry instruction. In studies where inquiry has been utilized as the primary instructional method, student confidence increased (Lord & Orkwiszewski, 2006; Ornstein, 2006; Sanger, 2006; Tessier, 2010). For science methods instructors, pre-service teacher attitudes and confidence in the subject matter greatly enhances the students' abilities to convey information through instruction. There is a vast difference in an individual being able to answer objective questions over science content and the ability to explain in vivid detail how or why a process occurs. This is the type of instruction that pre-service teachers need in order to be comfortable in their own inquiry-based classrooms.

#### Theoretical Framework

Bandura's Theory of Social Learning (Bandura, 1977, Bleicher, 2004;) provides a theoretical framework that is helpful when considering a pre-service teacher's self-efficacy for teaching science. Bleicher (2004) refers to Bandura's theory, "People are motivated to perform an action if they believe the action will have a favorable result and that they are confident that they can perform that action successfully" (p. 384). In addition, Bandura (1977) discusses persistence in activities that feel threatening but are performed through relatively safe procedures, produce mastery and increase self-efficacy for the individual. Therefore, the goal of science education for pre-service elementary teachers is to not just enhance their content learning to a level that will allow them to pass an exam, but to establish a knowledge base for being an effective teacher. Taking pre-service teachers to the point of mastery, with content that has previously been perceived as threatening, strengthens these future teachers' ability to teach

science. Therefore, to look for a relationship among instructional method, content knowledge and science teaching self-efficacy is valuable for teacher education.

Table 1 illustrates the major studies conducted regarding the relationship among inquiry, content knowledge, and efficacy.

Table 1

*Major Studies Regarding the Relationships between Inquiry-based Instruction and Content Knowledge as well as Attitudes towards Science*

<b>STUDY</b>	<b>SAMPLE</b>	<b>LOCATION</b>	<b>OUTCOMES</b>
<b>Bleicher, R.E. (2004)</b> Revisiting <i>STEBI-B</i>	290 pre-service elementary teachers at the beginning of science methods courses.	California State University Channel Islands	A factor analysis established that the two subscales Personal Science Teaching Efficacy Belief (PSTE) and Science Teaching Outcome Expectancy (STOE) were homogenous. Two items exhibited cross-loading and were modified and re-administered. Revised items loaded more clearly and item-total correlations were stronger. Comparison of means with # of science courses taken had significant associations.
<b>Lord &amp; Orkwiszewski (2006)</b> , <i>Science Attitude Survey</i> , and an <i>Integrated Processing Skills test</i> , as a pre and posttest assessment.	100 College students enrolled in a <i>biology class for non-majors</i>	Indiana	T-test used to compare averages between control and experimental groups of <i>attitudes towards science</i> . (*Note: 2008 refutes reliability/validity of SAI-II). The pre/posttest assessment using the Science Attitude Survey and the Integrated Processing Skills test revealed the experimental group to have a better attitude about science, and that they are better equipped to think through science problems, than the control group
<b>Milner, Templin &amp; Czerniak (2011)</b>	67 students in four 5 <sup>th</sup> grade classes	Rural Midwest	Causal comparative study to describe the influence of constructivist factors on student motivation and learning in a regular classroom (behaviorist), classroom/laboratory (cognitivist), or laboratory (constructivist) as it moves students along the inquiry continuum. Students expressed value in each learning environment.
<b>Ornstein, A. (2006)</b>	21 pairs of classes, (705 sixth-twelfth grade students); classrooms with	California, Connecticut, Florida, New	Analyzed level of classroom inquiry and student attitudes. Initially student attitudes decreased in classrooms with more inquiry present; however individual samples showed

	hands-on laboratory activities and classrooms without hands-on laboratory activities and measuring student attitudes	York, Texas, & Vermont)	a stronger significance. The researchers identified several issues with this study, namely consistency with the level of hands-on instruction and student interpretation of quantity.
<b>Sanger, M. (2006)</b>	16 elementary teaching majors enrolled in a <i>physical science</i> inquiry-based course (one-semester). Content knowledge was compared to students in gen. chemistry. Views of teaching were compared to secondary science teaching majors enrolled in methods course.	Middle Tennessee State	Results from study suggest that use of inquiry-based instruction helped students learn chemistry content at least as well as traditional methods. Also use of real-world applications improved interest and confidence in teaching science. When interest and confidence in teaching science go up, it is tied to their content knowledge. Results suggest that the use of inquiry based instructional materials improves the elementary teaching majors' conceptions regarding the nature of science, and improves their interest, enthusiasm and confidence in teaching science concepts to future students.
<b>Smith, B. (2007)</b>	<i>Secondary Math and Science</i> combined <i>methods classes</i> , spent 4 weeks exploring inquiry-based lessons with an interdisciplinary approach.	City College New York	Methods students explored a problem using integrated and following an inquiry-based format. A content expert (geologist, etc.) was utilized to help them solve the problem. Content knowledge and depth of lesson preparation increased following this instructional method.
<b>Tessier, J. (2010)</b>	<i>General biology course for pre-service elementary teachers</i> (n=52, traditional and n=57, inquiry). Course met 2x for 50 min. lecture, and 1x for 2 hr. lab/week.	Central Connecticut State University	Pre/Post semester <i>surveys to investigate student attitudes about biology, science in general, and teaching science</i> ; past experiences with elementary science, what they felt was the best way to learn science, and enjoyment of the course, and whether or not they would use the exercises from the lab in their own classrooms. Results indicate a significant increase in students from the inquiry-based class would use exercises from the lab in their future classrooms. A significantly higher number of students indicated that experiments were the best way to learn science, in the inquiry-based class.



## **CHAPTER 3**

### **METHOD**

#### **Introduction**

Effective use of inquiry-based instruction is a glaring weakness in science education for today's schools. Although many researchers understand the value of inquiry in our quest for knowledge as a society, and even the value of inquiry to develop critical thinking in the youth of today, the use of inquiry-based instruction remains absent in our educational system. Since elementary school is a primary time to develop the basic skills for science as a process, this should be the focus of teacher education programs; to strengthen the confidence in pre-service elementary teachers to accept the challenge to bring inquiry-based instruction into the classroom (Brand & Moore, 2011; Haefner & Zembal-Saul, 2004; Pratt, 2007; Sanger, 2006; ,Smith, 2007; & Tessier, 2010).

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

The use of inquiry-based instruction in developing student content knowledge and critical thinking skills has seen a push by researchers and the National Science Teachers Association (NSTA, 2012) in recent years. However, teachers are reluctant to incorporate inquiry into their classrooms because of the lack of familiarity with the process. Elementary teachers in particular have a lack of confidence in teaching science on many levels, and using inquiry feels very uncontrolled and uncomfortable. In order for pre-service teachers to gain confidence in using new methods of instruction in their future classrooms, they need to have opportunities to learn through experiencing

the same processes that they will use for instruction in the future and reflecting on the personal experiences gained through such. By measuring the increase in content knowledge gained through two opposing methods of instruction and assessing pre-service teacher efficacy for the content knowledge as well as the potential for future classroom use, it was possible to determine the effect of inquiry-based and traditional instruction on elementary pre-service teachers (Sanger, 2006).

### **Significance of the Study**

The use of inquiry-based instruction has gradually gained ground in K-12 classrooms and the post-secondary arena. There are studies that have looked at the use of inquiry to increase content knowledge and there are studies that have looked at attitudes towards science with inquiry instruction (Ornstein, 2006; Sanger, 2006; Tessier, 2010). However, a gap exists with the use of inquiry instruction for pre-service elementary teachers and its impact on content knowledge and self-efficacy for teaching science.

It is important to realize the need for pre-service teacher science content to increase. During a university program of study, education majors completing science courses receive content in the method most often utilized in universities, which is direct instruction. Thus far, we have failed to see a successful carryover of science content into the elementary classroom with this traditional method. The Board of Regents of the University System of Georgia (2009) has mandated two additional science content classes for elementary majors to cover life, earth and physical science. However,

without altering the pedagogy, why would we see a significant change in the way that these future teachers teach science in their classrooms or retain content knowledge?

The culture in K-5 classrooms today does not embrace the use of inquiry-based instruction. Pre-service teachers do not have opportunities to build on their working knowledge of inquiry instruction, which leads to decreased efficacy in the classroom. When pre-service teachers have opportunities to learn in an immersed environment where inquiry instruction is carefully scaffolded and modeled, they are more likely to have the confidence to teach in such a way in the future. This enables them to carefully build their skills to work comfortably within the framework of inquiry (Brand & Moore, 2011; Haefner & Zembal-Saul, 2004; Pratt, 2007; Sanger, 2006; Smith, 2007; & Tessier, 2010).

For this researcher, science content classes for early childhood education majors were a predominant part of her teaching requirement. More importantly, it was her responsibility to ensure the confidence and ability to teach science for future generations of students from these pre-service teachers. This study helped to discern the best approach that both increases science content knowledge and self-efficacy for teaching science in pre-service teachers.

### **Research Questions**

The purpose of this study was to determine what relationships exist between inquiry-based instruction, science content knowledge and self-efficacy in pre-service elementary teachers.

The following research sub-questions guided this study:

1. What is the effectiveness of inquiry-based instruction versus traditional methods of instruction in increasing life science and earth science content knowledge for elementary pre-service teachers?
2. What is the effect of inquiry-based versus traditional instruction on self-efficacy for teaching science in elementary pre-service teachers?
3. What is the relationship between the number of prior science content courses, content knowledge, instructional method, and self-efficacy for teaching science in elementary pre-service teachers?
4. What do pre-service teachers think of inquiry-based versus traditional instructional methods?

### **Research Design**

The purpose of this mixed methods (Quan./Qual.) approach was to analyze the relationship between instructional method and content knowledge in two life/earth science courses for early childhood majors in a major university in Georgia. In addition, a self-efficacy instrument was utilized to determine how instructional methods affect pre-service teacher science teaching efficacy or confidence to teach science.

### **Population**

For the quantitative and qualitative data collection for this study, the population for this study was pre-service early childhood education majors. In order to address the current gap in empirical literature by identifying the relationship of instructional method with change in content knowledge and self-efficacy for teaching science, it was necessary for pre-service elementary teachers to be used as the population.

## **Sample and Sampling**

Purposeful sampling was used for this study, with the Integrated Science (ISCI) 2001, Life/Earth Science specifically designated as the course to explore this study. Two sections of this course were used in the study. Each course had 30 students enrolled. As this course was required for all early childhood majors, the students enrolled were early childhood education majors. Two content areas, life science and earth science, were utilized through the crossover design. Each content area had an experimental and a control aspect, between the two course sections. The researcher for the study was also the instructor for both sections of the course, and used the inquiry-based and traditional instruction. She had 11 years of teaching experience, five in secondary science education, and six in post-secondary science education. The piloting of the study the prior semester allowed the instructor to gauge time needed for setting up different labs and activities between the two courses. In addition, it allowed an opportunity to develop guided inquiry techniques to allow students maximum student centered opportunities.

## **Instruments**

Following Institutional Review Board approval, the content knowledge was measured using the final examinations for the course and administering it in a pre and posttest format. The pretest was administered at the beginning of the semester with life science and earth science questions. The test assessed understanding of basic concepts in both life and earth science. It consisted of a total of 55 questions, mostly free response or fill in the blank. The content validity of the examination was

established using the Georgia Performance science standards (GPS, 2004) and the Board of Regents of the University System of Georgia (2009) learning outcomes. See Appendix B for the list of examination questions and their associated learning outcomes or standards. The Georgia Performance Science standards (GPS, 2004) were used to guide the curriculum for the Integrated Science (ISCI) courses across the state, as the pre-service teachers move into field-based courses that require a standards-based approach to instruction in the semesters following this course. By using the Georgia Performance standards (GPS, 2004), the pre-service teachers gained familiarity with the language and the content of the standards.

At the mid-point of the semester when students completed the life science portion of the course, a life science posttest was administered. The life science posttest included those questions that addressed life science content. The crossover of methods occurred following the completion of life science. Students in the inquiry section for life science had traditional instruction for earth science. Students in the course with traditional instruction in life science had inquiry-based instruction for earth science. At the end of the semester when students completed the earth science portion of the course, a second posttest was administered. This earth science posttest included those questions that address earth science content.

The *Science Teacher Efficacy Belief Instrument* – revised, referred to as the STEBI-B, was a 23 item 5-point Likert instrument used to measure change in science teacher efficacy. Students responded to each statement by indicating their agreement ranging from Strongly Agree (5) to Strongly Disagree (1). Bleicher (2004) reviewed the STEBI, from Enoch and Riggs (1990), to verify clear separation in the two subscales:

Personal Science Teaching Efficacy (PSTE) and Science Teaching Outcome Expectancy (STOE) and to confirm instrument score reliability and validity. The PSTE subscale had 13 items. The STOE subscale had 10 items. Bleicher (2004) found the internal validity of the two scales to be upheld following two minor wording revisions on items 10 and 13 for clarification. For this study the revisions developed by Bleicher (2004) were used. The word “some” to qualify the word “student” was removed from each of these statements. Ten items on the STEBI-B were reverse-scored. The items for reverse scoring were 3, 6, 8, 10, 13, 17, 19, 20, 21, and 23.

The STEBI-B was used as a pre-assessment. Study participants were asked to complete this questionnaire at the beginning of the semester with the mindset of a future teacher, with a focus on science in general. At the midpoint of the semester, study participants were asked to take the STEBI-B again. The wording of the STEBI-B referred to general science efficacy and science teaching outcome expectancy. However, to focus participants’ attention on the perceived efficacy and teaching outcome expectancy for life or earth science, the wording of items that referred to general science were changed to reflect life science or earth science. For example, the general science wording for question #1 read, “When a student does better than usual in science, it is often because the teacher exerted a little extra effort.” The wording modified for life science on question #1 read, “When a students does better than usual in life science, it is often because the teacher exerted a little extra effort.” The midterm survey following the life science portion of the course was modified to focus their attention on life science. At the end of the semester, study participants were asked to take the STEBI-B for a final time. The final survey was modified to focus their attention

on earth science. See Appendix E for the general STEBI, Appendix I for the life STEBI, and Appendix K for the earth STEBI.

### **Data Collection**

Data were collected by obtaining permission from each student following approval from the Institutional Review Board to use student pre and post test scores from the ISCI course to measure change in content knowledge, and pre and post efficacy surveys. All data collected were kept in strict confidence. For all IRB documentation see Appendix A.

A pre-test was used at the beginning of the semester to gauge initial life and earth science content knowledge. This test was subdivided into life science questions to provide the life science pre-test score and earth science questions to provide the earth science pre-test score. See Appendix C. Students were asked through the use of a survey at the beginning of the semester to provide information regarding the number of high school and college level science courses that they had taken prior to enrolling in this course. Students provided both the number of science courses taken and the title of each course. See Appendix D. The *Science Teaching Efficacy Belief Instrument* (STEBI-B) was administered as a pre-assessment with students instructed to answer the survey questions from a general science perspective. See Appendix E. Course section A students were taught for the first eight weeks of the semester using an inquiry-based approach to the life science content, that included four iterations of an inquiry-based project during the life science portion of the class. This inquiry-based instruction was most closely described as guided inquiry. Students worked with a



partner or in a small lab group to develop hypotheses, an experimental design, collect data, and present their results in a written lab report. This instruction was considered *guided inquiry*, as there was some input provided by the course instructor to increase the rate at which the students can complete their exploration. For example, when students were exploring the membrane transport, there were several materials available which were recommended to test movement across membranes. Each group was encouraged to explore using different materials, such as starch and iodine or glucose and water, but the results from each lab group were shared with the class. For a sample guided inquiry lab see Appendix F.

Course section B students were taught for the same duration using a traditional instruction method that was comprised of “cookbook” type lab activities and direct instruction. A “style lab still allowed students to experience hands-on learning by actively participating in a lab activity, however, the students did not develop their own procedures for exploration; they followed the steps outlined on a lab sheet that explored just one way of demonstrating the concept, such as membrane transport. For sample traditional instruction lab see Appendix G. At the end of the first eight weeks of the semester, a midterm exam was given to each section serving as a post-test for the life-science portion of the course. See Appendix H. In addition, the self-efficacy survey was administered to both sections, modified to contain phrases that specifically relate to life science. See Appendix I.

Next a crossover of methods occurred. Course section A students that originally received instruction through an inquiry-based approach received earth science content through traditional methods of instruction. A “cookbook” style lab still allowed students

to experience hands-on learning by actively participating in a lab activity, however, the students did not develop their own procedures for exploration; they followed the steps outlined on a lab sheet that explored one way of demonstrating the concept, such as properties of water. Section B students received earth science instruction in an inquiry-based approach, that included four iterations of inquiry-based projects for the earth science portion of the class. This inquiry-based instruction was most closely described as guided inquiry. Students worked with a partner or in a small lab group to develop hypotheses, an experimental design, collect data, and present their results in a written lab report. This instruction was considered guided inquiry, as there was some input provided by the course instructor to increase the rate at which the students could complete their exploration. For example, when students were exploring earthquake activity, they explored which areas on earth's crust were more likely to have earthquake activity through real time earthquake monitoring through the United States Geological Survey (USGS) website. At the end of the semester, both sections took a post-test assessment of the earth science content. See Appendix J. In addition, the self-efficacy survey was administered to both sections, modified to contain phrases that specifically related to earth science. See Appendix K.

Following the completion of the course, volunteer focus group interviews were held during finals week or at a time that was most convenient to all participants to obtain qualitative data, which enhanced the researcher's understanding of the relationship between instructional method and content knowledge and science-teaching self-efficacy. Students were asked the following questions: 1) Which instructional method worked best for you to learn course content, the inquiry-based method during life

science or the traditional method during earth science? 2) Did you feel more comfortable in class during the life science or earth science portion of the class? Why? 3) At any point in the semester did you start to have a more favorable experience towards science? Yes or No? 4) Did you notice a change in your attitude towards teaching science after the first few classes of life science (or earth science, depending on which section the student experienced as inquiry)? 5) How do you see yourself using both inquiry-based instruction and traditional instruction in your future classroom? 6) Which instructional method do you feel more confident to use in your future classroom? Why? 7) Has your attitude towards teaching science changed over the course of this semester? If so, how? The interview sessions were audio recorded, and the researcher collected statements from the participants using a laptop computer. For interview protocol, see Appendix L.

A pilot study was conducted the semester prior to data collection (Term B, Summer 2012) to work out logistical issues with teaching a lab-based course using two different methods with close timing issues. In addition, it provided the instructor an opportunity to test all materials and equipment and to determine if additional materials were needed for teaching labs with two different instructional methods. Also, the interview process allowed the researcher to pre-identify labels and categories, and further develop interview questions. The interview responses from the pilot study were consistent with the findings from the actual study.

Table 2 illustrates the data collection points throughout the study.

Table 2

*Time Frame for Data Collection*

<p><b>August 2012</b></p> <ul style="list-style-type: none"> <li>▪ Survey of prior science courses</li> <li>▪ Pre-test of Life/Earth science content knowledge</li> <li>▪ Pre-STEBI-B</li> </ul>			
<p>First Half of Semester</p>	<p>Section A: 8 Weeks 29 students</p> <p>Life Science, inquiry-based method of instruction</p>	<p>Section B: 8 Weeks 27 students</p> <p>Life Science, traditional method of instruction (“cookbook” labs, and direct instruction)</p>	<p>Content Topics</p> <ul style="list-style-type: none"> <li>▪ Cells</li> <li>▪ Heredity</li> <li>▪ Ecology</li> </ul>
<p><b>October 2012</b> Mid-Term</p> <ul style="list-style-type: none"> <li>• Post-Test of Life science content</li> <li>• STEBI –B Post, adjusted for life science efficacy</li> </ul>			
<p>Second Half of Semester:</p>	<p>Section A: 8 Weeks 29 students</p> <p>Earth science, traditional methods of instruction (“cookbook” labs, and direct instruction)</p>	<p>Section B: 8 Weeks 27 students</p> <p>Earth Science, inquiry-based method of instruction</p>	<p>Content Topics</p> <ul style="list-style-type: none"> <li>▪ Properties of Water</li> <li>▪ Composition of Earth: Rocks/ Minerals</li> <li>▪ Astronomy</li> <li>▪ Weather/ Atmosphere</li> <li>▪ Constructive/ Destructive forces</li> </ul>
<p><b>December 2012</b> End of Semester</p> <ul style="list-style-type: none"> <li>▪ Post-test of Earth science content</li> <li>▪ STEBI-B Post, adjusted for earth science efficacy</li> <li>▪ Focus group interviews were conducted to address research question #4.</li> </ul>			

Table 3 aligns the research questions with the study instruments, both the data collection and data analysis.

Table 3

*Table of research questions, data collection, and data analysis*

Research Question	Instrument/Data Collection	Analysis
1. What is the effectiveness of inquiry-based instruction vs. traditional method of instruction in increasing life science and earth science content knowledge for elementary pre-service teachers?	<ul style="list-style-type: none"> <li>• Life/Earth Pre-test (Aug. 2012)</li> <li>• Life Posttest (Oct. 2012)</li> <li>• Earth Posttest (Dec. 2012)</li> </ul>	ANCOVA Descriptive Stats and Correlation
2. What is the effect of inquiry-based versus traditional instruction on self-efficacy for teaching science in elementary pre-service teachers?	<ul style="list-style-type: none"> <li>• STEBI-B for general science (Aug. 2012)</li> <li>• Post STEBI-B, modified for Life science (Oct. 2012)</li> <li>• Post STEBI-B modified for Earth science (Dec. 2012)</li> </ul>	ANCOVA Descriptive Stats and Correlation
3. What is the relationship between the number of prior science content courses, content knowledge, instructional method, and self-efficacy for teaching science in elementary pre-service teachers?	<ul style="list-style-type: none"> <li>• Prior courses survey (Aug. 2012)</li> <li>• Pre/Post science content tests (see #1 above)</li> <li>• Crossover design: 1<sup>st</sup> 8 weeks, Sect. A=inquiry, Sect. B= Trad. 2<sup>nd</sup> 8 weeks, Sect. A=Trad., Sect. B= inquiry</li> <li>• Pre/Post STEBI-B (see # 2 above)</li> </ul>	ANCOVA Descriptive Stats and Correlation
4. What do pre-service teachers think of inquiry-based versus traditional instructional methods?	<ul style="list-style-type: none"> <li>• Focus group interviews (Dec. 2012)</li> </ul>	Qual. Analysis of responses for classification of responses

## Data Analysis

In addition to descriptive statistics and correlation, Analysis of Covariance (ANCOVA) was used to address research questions 1-3. Quantitative data was analyzed using Statistical Package for Social Sciences (SPSS). ANCOVA was used to detect any differences between groups and equate groups on pre-existing differences (Gall, Gall & Borg, 2007). The STEBI-B was modified to focus the participants on life science or earth science following each respective portion of the course.

Six ANCOVA models were tested. Following life science instruction students completed the posttest on life science and the STEBI worded for life science. The STEBI produced scores for two sub-scales, life-science teaching efficacy and life-science teaching outcome expectancy. The factor of interest in the ANCOVA models was instructional type (inquiry-based or traditional instruction), and several covariates were included: pretest scores in life science, number of prior science courses taken, and pre-measures of teaching efficacy and teaching outcome expectancy. Thus, for the three outcomes - life science posttest scores, life science teaching efficacy, and for life science teaching outcome expectancy - three separate ANCOVA models were estimated to test for instructional differences while controlling for pre-test scores in life science, number of prior science courses taken, initial teaching efficacy, and initial teaching outcome expectancy.

For the earth science posttest scores, earth science teaching efficacy, and for earth science teaching outcome expectancy, three separate ANCOVA models were estimated to test for instructional differences while controlling for pre-test scores in earth

science, number of prior science courses taken, initial teaching efficacy, and initial outcome expectancy. Mean scores were used to adjust for correct scale in potential missing data, as some students may not have answered every question on the questionnaire.

In addition to the data collected through content examinations and survey, qualitative data were obtained through semi-structured oral interviews with a representative sampling of pre-service teachers from the integrated science courses: sections A and B. Pre-service teachers' perceptions of the effect of instructional method on their learning of content and confidence to teach science were recorded. Glesne and Peshkin (1992) referred to this interview technique when searching for an explanation of why something happened (p. 65). In addition, the authors stated that, "the interview is a validity check of the responses given to questionnaire items." (p.65) Therefore, following the responses to the *Science Teaching Efficacy Belief Instrument*, where students may respond with Strongly Agree (5) or Strongly Disagree (1), pre-service teachers could elaborate on *how* inquiry or traditional instruction impacted their science teaching efficacy and outcome for teaching science. All interviews were audio taped for accuracy and to allow the researcher more freedom for social interaction with the participants. Interview protocol is provided in Appendix L.

The researcher recognized the value of the qualitative interview as a way to validate the quantitative data. However, the researcher was also heedful to the cautions associated with process of qualitative interviewing. The interview questions were developed to be clear, open-ended, neutral, and sensitive, as discussed in Patton (1982). Also, the researcher recognized the status difference as a researcher and

course instructor. This awareness made the researcher careful to work towards minimizing status differences (Glesne, 1999) during the interview process and to guard against bias, and leading questions. The interview protocol was carefully followed, deviating only when the researcher probed for additional clarification from the participants. This clarification was useful in determining pre-service teacher responses regarding inquiry-based on hands-on instruction, but did not in any way influence participant responses to support one instructional method over another.

### **Limitations, Delimitations and Assumptions**

#### **Limitations**

1. The use of undergraduate students who have multiple blocked classes with their peers limited the study as students may discuss activities from one form of instruction and may wonder why the next class period did not have the same experience.
2. Another limitation could have been the frustration that students felt at the midpoint of the semester when the course format changed. Students who had experienced the inquiry approach may have felt frustrated with the lack of activity in a traditional instruction course. Likewise, students that began with the traditional format may have been surprised at the change in expectations for student involvement throughout the remainder of the course.
3. Carry over from one instructional method to another was a concern as students became accustomed to a particular style of instruction in class, and performance



expectations. When the crossover of instructional method occurred, students may have resisted the change in instruction type and performance expectations.

4. A prior courses survey was used to look for a relationship between self-efficacy and prior science courses. However, most students in the integrated science courses were sophomores or juniors in college. The science courses most frequently taken were biology or environmental science. Rarely if ever, was geology taken prior to this course. Therefore, students may have had more exposure to life science content prior to entering this course.

### **Delimitations**

1. The use of the ISCI course for Life/Earth science was purposeful sampling of elementary pre-service teachers.
2. *The Science Teacher Efficacy Belief Instrument (revised) STEBI-B* was the instrument chosen for survey of pre-service teacher self-efficacy for teaching science. The psychometric properties data for this instrument were carefully considered by Bleicher (2004), and resulted in minor revisions to the instrument. These revisions improved the psychometric properties and were included in the revised version- B. See Instruments section for details regarding revisions, and factor analysis.
3. A teacher-constructed exam used for assessment of content knowledge lacks psychometric properties data. However, content validity was determined using content standards for the course (See Appendix B).
4. A crossover design was used to present both populations with an experimental and a control aspect in this study. In the course of 16 weeks, students

experienced both methods of instruction. This allowed students to participate with both forms of pedagogy prior to their own classroom experience.

5. At the beginning of the semester, students were asked how many and which science courses they had completed prior to taking this class. This information was used to see if there was a general relationship between self-efficacy and number of content courses taken with relation to the form of instruction found in this course.

### **Assumptions**

1. It was an assumption that students were honest when completing the Science Teacher Self Efficacy Instrument at the beginning and end of the course.
2. It was an assumption that students demonstrated satisfactory effort of their total content knowledge on the pre-tests for content knowledge. Sometimes students in a pre-test situation may not complete answers to the fullest of their ability.

### **Definitions of Key Terms**

*Inquiry-based instruction:* In 1997, Chiappetta stated “teaching science as inquiry stresses active student learning and the importance of understanding a scientific topic” (23). The inquiry-based instruction for this study provided students opportunities for experiencing guided inquiry as well as active learning strategies that had them actively participating with the content through labs, demonstrations, and modeling. This approach has been referred to as “the experience before vocabulary model” (Chiappetta, 1997, p. 25), which provides an inductive method of instruction for students. Specifically, guided-inquiry was

used in which students had opportunities to develop labs and experience the experimental process, however, the instructor set the stage for the exploration with minimal boundaries to guide their study (Leonard & Penick, 2009; Martin-Hansen, 2002). Guided inquiry was chosen over full-inquiry as time was a factor and using guided inquiry the students were able to complete four iterations of guided inquiry-based labs, rather than one full inquiry-based lab. The form of guided inquiry utilized in the study involved the instructor or class collectively developing the question to explore and the instructor providing a range of materials for students to utilize in the development of their procedures.

*Traditional instruction:* The traditional instruction for this study provided students opportunities to gain content through direct instruction methods such as Cook-book labs and lecture. Cook-book labs refer to a deductive approach to instruction in which a concept is defined and experiences to demonstrate an idea follow. This approach is often referred to as “the vocabulary before experience model of teaching” (Chiappetta, 1997, p. 25).

## **Summary**

Teacher education programs across the United States are striving to produce teachers that are best qualified and demonstrate teaching practices that meet the needs of all populations. A lack of research on the relationship among inquiry, science teacher efficacy and content knowledge preceded this study. The purpose of this study was to determine what relationships existed between inquiry-based instruction, science content knowledge and self-efficacy among pre-service elementary teachers. This mixed

methods study analyzed content knowledge through pre and posttests and the change in self-efficacy over the course of a semester in a science content course. The experimental design provided the researcher an opportunity to see how a change in instructional method affected both content knowledge and efficacy in two science content areas. Such information will allow teacher preparation programs to structure their methods and content courses for pre-service teachers in the most beneficial way to promote critical thinking in classrooms and to enhance student learning at all levels.

## CHAPTER IV

### REPORT OF DATA AND DATA ANALYSIS

#### Introduction

The purpose of this study was to determine what relationships exist among inquiry-based instruction, science content knowledge and self-efficacy among elementary pre-service teachers. In addition, the number of prior science courses taken was considered as a possible factor affecting content knowledge and self-efficacy.

A mixed methods (QUAN./QUAL) design for research was used to analyze the relationship among type of instruction, content knowledge, and self-efficacy. The first part of the research was to collect and analyze quantitative data through a survey for pre-service teachers in elementary education on their self-efficacy for teaching science prior to taking a life/earth science content class, a survey to determine the number of prior science courses taken in both high school and college, and a pretest for general science content for two sections of Integrated Science (ISCI) in fall 2012. In addition to descriptive statistics, six ANCOVAs were performed to control for the covariates.

The structure for data collection included two integrated science courses of 30 students each. At the beginning of the semester, each class completed a pretest for science content knowledge, a survey of the number and kind of prior science courses taken, and a *Science Teacher Efficacy Belief Instrument (STEBI)*, with two subscales for self-efficacy, and expected science teaching outcome. The first eight weeks of the semester, Section A was taught life science with inquiry-based instruction, while Section

B was taught life science with traditional instruction. At the midpoint of the semester, both classes completed a posttest for life science, and a STEBI modified for life science. Then the method of instruction changed for each section. Section A students were taught earth science with traditional instruction, while Section B students were taught earth science with inquiry-based instruction. At the end of the semester, both classes completed a posttest for earth science, and a STEBI modified for earth science. After all surveys and posttests were completed, small focus group interviews were held to gather qualitative data from volunteer participants. These qualitative data were used to follow-up the quantitative data with participants' feedback and impressions of how their learning was impacted by different instructional types.

Table 4 summarizes the time frame and layout of the research design.

Table 4

*Time frame for data collection*

<b>August 2012</b> <ul style="list-style-type: none"> <li>▪ Survey of prior science courses</li> <li>▪ Pre-test of Life/Earth science content knowledge</li> <li>▪ Pre-STEBI-B</li> </ul>			
First Half of Semester	<b>Section A:</b> 8 Weeks 29 students  Life Science, inquiry-based method of instruction	<b>Section B:</b> 8 Weeks 27 students  Life Science, traditional method of instruction (“cookbook” labs, and direct instruction)	<b>Content Topics</b> <ul style="list-style-type: none"> <li>▪ Cells</li> <li>▪ Heredity</li> <li>▪ Ecology</li> </ul>
<b>October 2012</b> Mid-Term <ul style="list-style-type: none"> <li>• Post-Test of Life science content</li> <li>• STEBI –B Post, adjusted for life science efficacy</li> </ul>			
Second Half of Semester:	<b>Section A:</b> 8 Weeks 29 students  Earth science, traditional methods of instruction (“cookbook” labs, and direct instruction)	<b>Section B:</b> 8 Weeks 27 students  Earth Science, inquiry-based method of instruction	<b>Content Topics</b> <ul style="list-style-type: none"> <li>▪ Properties of Water</li> <li>▪ Composition of Earth: Rocks/ Minerals</li> <li>▪ Astronomy</li> <li>▪ Weather/ Atmosphere</li> <li>▪ Constructive/ Destructive forces</li> </ul>
<b>December 2012</b> End of Semester <ul style="list-style-type: none"> <li>▪ Post-test of Earth science content</li> <li>▪ STEBI-B Post, adjusted for earth science efficacy</li> <li>▪ Focus group interviews were conducted to address research question #4.</li> </ul>			

The dependent variables for each class were calculated mean scores for the life science posttest, the earth science posttest, and the two subscales of the *Science Teacher Efficacy Belief Instrument* –revised (STEBI-B): Personal Science Teaching Efficacy (13 items) and Science Teaching Outcome Expectancy (10 items) taken at the completion of life science and again at the end of earth science. These subscales contained a total of 10 items that were reverse scored and averaged on a five-point scale. The independent variable was instruction type: inquiry-based or traditional.

The second part of the research was the collection and analysis of qualitative data regarding pre-service teacher perceptions of instructional method and the impact on their understanding of life or earth science and self-efficacy. These qualitative data were collected through small focus-group interviews of volunteer participants that were audio-recorded and transcribed and then summarized to address the research questions.

### **Findings and Data Analysis**

The following research questions guided this study:

- 1) What is the effectiveness of inquiry-based instruction versus traditional methods of instruction in increasing life science and earth science content knowledge for elementary pre-service teachers?
- 2) What is the effect of inquiry-based versus traditional instruction on self-efficacy for teaching science in elementary pre-service teachers?
- 3) What is the relationship between the number of prior science content courses, content knowledge, instructional method, and self-efficacy for teaching science in elementary pre-service teachers?



4) What do pre-service teachers think of inquiry-based versus traditional instructional methods?

#### Quantitative Data

Quantitative data analysis began with descriptive statistics being computed for pretest means for each class, pre-STEBI efficacy and pre-STEBI outcome means. Section A of the Integrated Science course had 31 students. Section B of the Integrated Science course had 30 students. A total of five students were removed from the data set. Three of these were removed because of incompleteness of the STEBI instrument. Two were removed as outliers on the STEBI instrument. Using Cook's Distance (Agresti and Finlay, 2009) with a value of .78, these two individuals were high enough to cause a significant interaction and were removed entirely from the data set. This resulted in a sample of 56 students.

In a prior study by Sanger (2006) elementary teachers were taught using an inquiry approach to chemistry. It was noted that following this instruction type, the elementary teachers learned the chemistry content as well or better than students in a chemistry class with a traditional approach. Therefore, the content knowledge test was used in this study to see if there was a relationship between instructional type and content knowledge. In addition, Smith (2007) found that in order to produce teachers that can lead classrooms with inquiry instruction "requires educating teachers in a similar environment" (p. 563-564). This directly relates to the pre-service teachers' outcome expectancy for utilizing inquiry-based instruction in their future classrooms.

The demographic data for the study are included in Table 5.

Table 5

*Demographics for Life/Earth Science Courses*

<b>Inquiry-First</b>		<b>Total Number</b>
Gender	Female	27
	Male	2
Major	Early Childhood Education	25
	Middle Grades Education	4

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<b>Traditional-First</b>		
Gender	Female	25
	Male	2
Major	Early Childhood Education	25
	Middle Grades Education	2

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Research Question 1: What is the effectiveness of inquiry-based instruction versus traditional methods of instruction in increasing life science and earth science content knowledge for elementary pre-service teachers?

Descriptive statistics for the Inquiry-First class are included in Table 6.

Table 6

*Descriptive Statistics for Inquiry-First Course*

Prior Courses: High School		Prior Courses: College	
Anatomy	8	Anatomy	3
Astronomy	0	Astronomy	1
Biology	30	Biology	21
Chemistry	27	Chemistry	11
Environmental Science	5	Geology	2
Geology	4	Environmental Biology	9
Physical Science	9	Environmental Geology	2
Physics	12	Insects and People	1
AP Biology	2	Organic Chemistry	1
AP Chemistry	1	Physical Science	4
		Physics	1

	N	Minimum	Maximum	Mean	Standard Deviation
Prior Courses	29	2.00	10.00	5.62	1.76
Pre-STEBI					
Efficacy	29	2.46	4.46	3.65	0.53
Outcome	29	2.60	4.80	3.77	0.47
Life Pretest	29	6.00	52.00	20.34	13.22
Life Posttest	29	51.00	96.00	79.97	10.71
Life STEBI					
Efficacy	29	2.77	4.85	3.91	0.60
Outcome	29	3.10	4.50	3.71	0.41
Earth Pretest	29	2.00	31.00	12.38	8.57
Earth					
Posttest	29	65.00	99.00	86.83	9.55
Earth STEBI					
Efficacy	29	2.62	4.85	3.93	0.62
Outcome	29	3.10	4.90	3.88	0.43

Descriptive statistics for the Traditional-First class are included in Table 7.

Table 7

*Descriptive Statistics for Traditional-First Course*

Prior Courses: High School		Prior Courses: College			
Anatomy	6	Anatomy			0
Astronomy	1	Astronomy			3
Biology	27	Biology			19
Chemistry	21	Chemistry			6
Environmental Science	3	Geology			1
Geology	0	Environmental Biology			11
Physical Science	17	Environmental Geology			1
Physics	11	Insects and People			2
AP Biology	0	Organic Chemistry			0
AP Chemistry	1	Physical Science			3
		Physics			2
	N	Minimum	Maximum	Mean	Standard Deviation
Prior Courses	27	3.00	7.00	5.22	.93
Pre-STEBI					
Efficacy	27	2.43	3.93	3.25	.45
Pre-STEBI					
Outcome	27	3.00	4.30	3.66	.37
Life Pretest	27	9.00	42.00	21.74	9.96
Life Posttest	27	55.00	88.00	70.70	10.09
Life STEBI					
Efficacy	27	2.54	4.69	3.80	.51
Life STEBI					
Outcome	27	2.70	4.80	3.69	.45
Earth Pretest	27	1.00	39.00	13.11	8.50
Earth					
Posttest	27	58.00	97.00	86.89	8.17
Earth STEBI					
Efficacy	27	2.85	4.62	3.89	.55
Earth STEBI					
Outcome	27	3.10	4.40	3.69	.34

Table 8 shows the ANCOVA results and descriptive statistics for life science content knowledge.

Table 8

*ANCOVA Results and Descriptive Statistics for Life Science Content Knowledge by Instruction Type and Prior Science Courses*

Types of Instruction	Life Science Content Knowledge			
	Observed Mean	Adjusted Mean	SD	n
Inquiry	79.97	80.05	10.71	29
Traditional	70.70	70.61	10.10	27

Source	SS	df	MS	F
Life Science Pre-test	1450.59	1	1450.59	19.61*
Prior Courses	136.25	1	136.25	1.84
Instruction Type	1207.86	1	1207.86	16.33*
Error	4026.19	55	73.20	

*Note.*  $R^2 = .46$ ,  $Adj. R^2 = .42$ . Adjustments based on Life Science Pre-test mean = 21.02 and Prior Science courses mean = 5.43. Homogeneity of regression tested and not significant:  $F(\text{Instruct} \times \text{Prior}) = 2.06$  and  $F(\text{Instruct} \times \text{Pre-Test}) = 1.97$ ,  $p > .05$ . Pre-Test regression coefficient =  $.46^*$ , Prior courses regression coefficient = 1.42. Life science pretest mean for Inquiry = 20.34, for traditional = 21.74.

\*  $p < .05$ .

ANCOVA results indicate that mean Content Knowledge scores differ by instructional type, and that there is a positive association between Life Science Pre-test and Life Science Post test scores. Students in a course with Inquiry based instruction display adjusted means that are higher than the mean for the control students in a traditional instruction course. There is no statistically significant interaction between the number of Prior Science courses and content knowledge.

The Earth science *content* was the first measure of the study following this crossover. Table 9 summarizes ANCOVA for Earth Science content knowledge.

Table 9

*ANCOVA Results and Descriptive Statistics for Earth Science Content Knowledge by Instruction Type and Prior Science Courses*

Types of Instruction	Earth Science Content Knowledge			
	Observed Mean	Adjusted Mean	SD	n
Inquiry	86.89	86.68	8.17	27
Traditional	86.83	87.02	9.55	29
Source	SS	df	MS	F
Earth Science Pre-test	308.35	1	308.35	4.05*
Prior Courses	25.53	1	25.53	0.34
Instruction Type	1.55	1	1.55	0.02
Error	3963.67	52	76.22	

*Note.*  $R^2 = .08$ ,  $Adj. R^2 = .02$ . Adjustments based on Earth Science Pre-test mean = 12.73 and Prior Science courses mean = 5.43. Homogeneity of regression tested and not significant:  $F(\text{Instruct} \times \text{Prior}) = .00$ ,  $F(\text{Instruct} \times \text{Pretest}) = .02$ ,  $p > .05$ . Pre-Test regression coefficient = .28\*, Prior courses regression coefficient = -.48. Earth science pretest mean for Inquiry = 13.11, for traditional = 12.38.  
\*  $p < .05$ .

ANCOVA results indicate that mean Earth Science Content Knowledge scores do not differ by instructional type, and there is a positive association between Earth Science Pre-test and Earth Science Post test scores. Students in a course with inquiry-based instruction display adjusted means that are not higher than the mean for the control students in a traditional instruction course. There is no statistically significant interaction between the number of Prior Science courses and content knowledge.

Research Question 2: What is the effect of inquiry-based versus traditional instruction on self-efficacy for teaching science in elementary pre-service teachers?

At the midpoint of the semester following life science content, the Efficacy subscale of the STEBI-B was worded to specifically address efficacy for life science. Cronbach's alpha was calculated to establish reliability of the wording modifications for the Efficacy subscale to address Life Science. (N=56, Cronbach's alpha = .85) Table 10 summarizes the ANCOVA for Life Science STEBI for Efficacy.

Table 10  
*ANCOVA Results and Descriptive Statistics for Life STEBI: Efficacy Subscale by Instruction Type and Prior Science Courses*

Types of Instruction	Post Life STEBI: Efficacy			
	Observed Mean	Adjusted Mean	SD	n
Inquiry	3.91	3.76	.60	29
Traditional	3.80	3.96	.51	27

Source	SS	df	MS	F
Life STEBI: Efficacy Subscale	6.33	1	6.33	34.11*
Prior Courses	0.52	1	0.52	2.79
Instruction Type	0.45	1	0.45	2.42
Error	9.64	52	0.19	

Note.  $R^2 = .43$ , Adj.  $R^2 = .39$ . Adjustments based on Life STEBI: Efficacy Subscale mean = 3.46, and Prior Courses mean = 5.43. Homogeneity of regression tested and not significant:  $F(\text{Instruct} \times \text{Prior}) = 0.02$ , and  $F(\text{Instruct} \times \text{Efficacy}) = 1.04$   $p > .05$ . Pre-STEBI: Efficacy regression coefficient =  $.70^*$ , Prior courses regression coefficient =  $.07$ .

\*  $p < .05$ .

ANCOVA results indicate that mean *Science Teacher Efficacy Belief Instrument* (STEBI) efficacy sub-scores for life science do not differ statistically by instructional

type, but that there is a positive association between Pre-STEBI Efficacy and Post STEBI Efficacy scores. There is no statistically significant interaction between the number of Prior Science courses and science teacher efficacy. The interaction between instruction type\*prior courses and instruction type\*post-efficacy were tested and neither was significant. The efficacy subscale provides an indication of pre-service teacher perceived self-efficacy or confidence in the ability to teach life science. Students in a course with inquiry-based instruction display adjusted means that are not statistically higher than the mean for the control students in a traditional instruction course.



The Outcome subscale of the STEBI-B was worded to specifically address outcome expectancy or the likelihood for teaching life science. Cronbach's alpha was calculated to establish reliability of the wording modifications for the Outcome subscale to address Life Science. (N=56, Cronbach's alpha = .79) Table 11 summarizes the ANCOVA for Post Life Science STEBI: Outcome.

Table 11

*ANCOVA Results and Descriptive Statistics for Post Life STEBI: Outcome Subscale by Instruction Type and Prior Science Courses*

Types of Instruction	Post Life STEBI: Outcome			
	Observed Mean	Adjusted Mean	SD	n
Inquiry	3.71	3.68	0.41	29
Traditional	3.69	3.73	0.45	27
Source	SS	df	MS	F
Life STEBI: Outcome Subscale	2.47	1	2.47	17.21*
Prior Courses	0.09	1	0.09	0.60
Instruction Type	0.03	1	0.03	0.21
Error	7.46	52	0.14	

*Note.*  $R^2 = .25$ ,  $Adj. R^2 = .21$ . Adjustments based on Life STEBI: Outcome Subscale mean = 3.72, and Prior Courses mean = 5.43. Homogeneity of regression tested and not significant:  $F(\text{Instruct} \times \text{Prior}) = 3.64$ ,  $F(\text{Instruct} \times \text{Outcome}) = 0.02$ ,  $p > .05$ . Pre-STEBI: Outcome subscale regression coefficient =  $0.50^*$ , Prior Courses regression coefficient = 0.03.

\*  $p < .05$ .

ANCOVA results indicate that mean *Science Teacher Efficacy Belief Instrument* (STEBI) outcome sub-scores do not differ statistically by instruction type but that there is a positive association between Pre-STEBI: Outcome and Post Life STEBI: Outcome scores. The outcome subscale provides an indication of pre-service science teaching

outcome expectancy or the likelihood that they will teach life science. Also, there is no statistically significant interaction between the number of Prior Science courses and science teaching outcome expectancy.

At the midpoint of the semester, a crossover of instruction type occurred in conjunction with the change of content. Section A, which was previously receiving inquiry-based instruction for life science, was switched to traditional instruction earth science. Section B, which was previously receiving traditional instruction for life science, was switched to inquiry-based instruction for earth science.

The Efficacy subscale of the STEBI-B was worded to specifically address efficacy for Earth science. Cronbach's alpha was calculated to establish reliability of the wording modifications for the Efficacy subscale to address Earth Science. (N=56, Cronbach's alpha = .91) Table 12 summarizes the ANCOVA for Post Earth STEBI: Efficacy.

Table 12

*ANCOVA Results and Descriptive Statistics for Post Earth STEBI: Efficacy Subscale by Instruction Type and Prior Science Courses*

Types of Instruction	Post Earth STEBI: Efficacy			
	Observed Mean	Adjusted Mean	SD	n
Inquiry	3.89	4.04	0.55	27
Traditional	3.93	3.80	0.62	29
Source	SS	df	MS	F
Earth STEBI: Efficacy Subscale	5.01	1	5.01	20.07*
Prior Courses	0.52	1	0.52	2.07
Instruction Type	0.65	1	0.65	2.62
Error	12.97	52	0.25	

*Note.*  $R^2 = .31$ ,  $Adj. R^2 = .27$ . Adjustments based on Earth STEBI: Efficacy Subscale mean = 3.46, and Prior Courses mean = 5.43. Homogeneity of regression tested and not significant:  $F(\text{Instruct} * \text{Prior Courses}) = .13$ ,  $F(\text{Instruct} * \text{Efficacy}) = 2.43$   $p > .05$ . Pre-STEBI: Efficacy regression coefficient =  $.62^*$ , Prior Courses regression coefficient =  $.07$ . \*  $p < .05$ .

ANCOVA results indicate that mean *Science Teacher Efficacy Belief Instrument* (STEBI) efficacy sub-scores for Earth science do not differ by instructional type, and that there is a positive association between Pre-STEBI: Efficacy and Post Earth STEBI: Efficacy scores. The efficacy subscale provides an indication of pre-service teacher perceived self-efficacy or confidence in the ability to teach Earth science. There is no

statistically significant interaction between the number of Prior Science courses and science teacher efficacy.

The Outcome subscale of the STEBI-B was worded to specifically address outcome expectancy for Earth science. Cronbach's alpha was calculated to establish reliability of the wording modifications for the Outcome subscale to address Earth Science. (N=56, Cronbach's alpha = .76) Table 13 summarizes the ANCOVA for Post Earth STEBI: Outcome.

Table 13  
*ANCOVA Results and Descriptive Statistics for Post Earth STEBI: Outcome Subscale by Instruction Type and Prior Science Courses*

Types of Instruction	Post Earth STEBI: Outcome			
	Observed Mean	Adjusted Mean	SD	n
Inquiry	3.69	3.71	0.34	27
Traditional	3.88	3.87	0.43	29
Source	SS	df	MS	F
Earth STEBI: Outcome Subscale	1.21	1	1.21	9.17*
Prior Courses	0.02	1	0.02	0.12
Instruction Type	0.33	1	0.33	2.54
Error	6.84	52	0.13	

*Note.*  $R^2 = .21$ ,  $Adj. R^2 = .16$ . Adjustments based on Earth STEBI: Outcome Subscale mean = 3.72, and Prior Courses mean = 5.43. Homogeneity of regression tested:  $F(\text{Instruct} * \text{Prior Courses}) = .94$ ,  $F(\text{Instruct} * \text{Outcome}) = .52$   $p > .05$ ,  $p < .05$ . Pre-STEBI: Outcome subscale regression coefficient =  $.35^*$ , Prior courses regression coefficient =  $-.01$ .  $p < .05$ .

ANCOVA results indicate that mean *Science Teacher Efficacy Belief Instrument* (STEBI) outcome sub-scores do not differ by instructional type, and that there is a

positive association between Pre-STEBI: Outcome and Post Earth STEBI: Outcome scores. The outcome subscale provides an indication of pre-service science teaching outcome expectancy or the likelihood that they will teach Earth science. There is no statistically significant interaction between the number of Prior Science courses and science teaching outcome expectancy.

Research Question 3: What is the relationship between the number of prior science content courses, content knowledge, instructional method, and self-efficacy for teaching science in elementary pre-service teachers?

Tables 14 and 15 provide t-tests and means to show differences between instruction type, content knowledge, self-efficacy and teaching outcome. Table 16 provides correlations for Prior Science Courses, content knowledge and self-efficacy.

Table 14

*Results of t-tests and Descriptive Statistics for Post-Life Science Content Knowledge, Post Life STEBI: Efficacy, and Post Life STEBI: Outcome by Instruction Type*

Outcome	Group						95% CI for Mean Difference	t	df
	Inquiry			Traditional					
	M	SD	n	M	SD	n			
Life Content	79.97	10.71	29	70.70	10.10	27	3.68, 14.85	3.32*	54
Life STEBI-Efficacy	3.91	0.60	29	3.80	0.51	27	-0.19, 0.41	0.74	54
Life STEBI-Outcome	3.71	0.41	29	3.69	0.45	27	-0.21, 0.25	0.18	54

\* $p < .05$ .

There are statistically significant differences, at the .05 level of significance, between inquiry-based instruction and traditional instruction in life science content.

There are no statistically significant differences between inquiry-based instruction and traditional instruction in science teaching efficacy or outcome for teaching life science.

Results show that pre-service teachers with inquiry-based instruction scored higher on post-life science content. Separate tables were used to show the crossover method of instruction between the two classes.

Table 15

*Results of t-tests and Descriptive Statistics for Post-Earth Science Content Knowledge, Post Earth STEBI: Efficacy, and Post Earth STEBI: Outcome by Instruction Type*

Outcome	Group						95% CI for Mean Difference		t	df
	Inquiry			Traditional						
	M	SD	n	M	SD	n				
Earth Content	86.89	8.17	27	86.83	9.55	29	-4.84, 4.72	- 0.03	54	
Earth STEBI-Efficacy	3.89	0.55	27	3.93	0.62	29	-0.28, 0.35	0.25	54	
Earth STEBI-Outcome	3.69	0.34	27	3.88	0.43	29	-0.01, 0.40	1.87	54	

There are no statistically significant differences, at the .05 level of significance, between inquiry-based instruction and traditional instruction in earth science content, science teaching efficacy or outcome for teaching earth science. Results show that pre-service teachers with traditional instruction scored higher on post-earth science content, though not significantly different. In addition, there was no statistical difference between inquiry-based instruction and traditional for the two subscales of the STEBI – efficacy and outcome in earth science.

Table 16

*Correlations and Descriptive Statistics for Prior Science Courses, Content Knowledge and Self-Efficacy*

	1	2	3	4	5	6	7
1. Prior Science Courses	---						
2. Post Life Science Content	0.34*	---					
3. Post Life STEBI Efficacy	0.22	0.21	---				
4. Post Life STEBI Outcome	0.07	0.11	0.37**	---			
5. Post Earth Science Content	-0.06	0.44**	0.03	-0.02	---		
6. Post Earth STEBI Efficacy	0.19	0.21	0.76**	0.34	0.12	---	
7. Post Earth STEBI Outcome	-0.03	0.21	0.26	0.56	0.12	0.35**	---
M	5.43	75.50	3.86	3.70	86.86	3.92	3.79
SD	1.43	11.33	0.55	0.43	8.83	0.58	0.40
Scale Min/Max Values	1 to 10	0 to 100	1 to 5	1 to 5	0 to 100	1 to 5	1 to 5

*Note.* n = 56.

\* p < .05,

\*\* p < .01.

Statistical analysis reveals that Post Life Science Content was statistically related to the number of Prior Science Courses and Post Earth Science Content, at the .05 and .01 level of significance, respectively. Life STEBI Efficacy was statistically related to



both Life STEBI Outcome and Earth STEBI Outcome, at the .01 level of significance. Earth STEBI Efficacy was statistically related to Earth STEBI Outcome at the .01 level of significance. There was not a statistically significant relationship between Prior Science Courses and Life or Earth Efficacy or Outcome. These results indicate that pre-service teachers with higher numbers of Prior Science Courses scored higher on the Life Science Posttest. Also pre-service teachers that scored higher on the Post Life Science test, also scored higher on the Post Earth Science test. Post Life STEBI Efficacy, which is a measure of pre-service teachers' self-confidence in Life Science, was statistically related to the Life STEBI Outcome or the likelihood of teaching life science and Earth STEBI efficacy.

#### Qualitative Data

Researcher developed questions were used to collect qualitative data to address Research Question 4: What do pre-service teachers think of inquiry-based versus traditional instructional methods?

Interviewing can be a powerful tool to triangulate data (Glesne, 1999; Meloy, 1994) and the researcher chose this method to capture pre-service teacher opinions regarding the use of different methods of instruction and the impact instructional method had on content knowledge and self-efficacy, which were the quantitative measures. The interview process allowed pre-service teachers opportunities to elaborate on the inquiry or traditional process of learning. As Marshall and Rossman (2006) point out, focus group interviews are often simple ways to capture participants' expressions of their

views through a supportive environment. Their perceptions of the effect of instructional method on their learning of content and confidence to teach science were recorded. Glesne and Peshkin (1992) referred to this interview technique when searching for an explanation of why something happened (p. 65). In addition, the authors state that, “the interview is a validity check of the responses given to questionnaire items.” Therefore, following the responses to the *Science Teaching Efficacy Belief Instrument*, where students may respond with Strongly Agree (5) or Strongly Disagree (1), pre-service teachers can elaborate on *how* inquiry or traditional instruction impacted their science teaching efficacy and outcome for teaching science.

After reviewing the literature, seven interview questions were developed to capture pre-service teacher impressions of inquiry-based versus traditional instruction methods on the ability to understand content, the expected teaching outcome with either of the instructional methods, and the effect of instructional method on their attitude towards science. The oral interviews were conducted with a volunteer sampling of pre-service teachers from both class sections at a predefined time. Each interview session was audio recorded, as well as having notes taken while participants were responding. Following the interview, the audio recording was used to develop a complete transcript of the interview. These responses are presented as verbal descriptions and summarized according to similar responses. The interview protocol can be found in Appendix L. Deviation from the interview protocol was only used to clarify responses from pre-service teachers, such as urging them to give specific examples from class that would allow the researcher to know whether they were referring to inquiry or traditional instruction labs. Researcher observation, though anecdotal in nature and not

an official form of data collected allowed the researcher to recognize participant differences in the inquiry-based or traditional instruction experience. The researcher noted an obvious difference in class participation and interaction among class members with the Inquiry First class that was not observed in the Traditional First class. Triangulation of the data through analysis of both the qualitative and quantitative displays a clearer relationship among the various measures (Glesne, 1999).

The pre-service teachers in Section A experienced eight weeks of inquiry-based instruction followed by eight weeks of traditional instruction. They will be referred to as *Inquiry First*. The pre-service teachers in Section B experienced the reverse, with eight weeks of traditional instruction followed by eight weeks of inquiry-based instruction. They will be referred to *Traditional First*. Eight students participated and responded in the small group interviews from Section A, Inquiry First. Six students participated and responded in the small group interviews for Section B, Traditional First.

*Interview Question 1: Which instructional method, worked best for you to learn course content, the inquiry-based method during life science (or Earth for Section B) or the traditional method during earth science (Life Science for Section B)?*

Students from Section A, Inquiry First, responded that the inquiry-based method of instruction worked best for them learning the content because they “participated in experiments.” Also, one student acknowledged that the inquiry instruction forced her to learn the material. “There’s no sitting back. That helped me to retain it better.” There was one student that felt the inquiry-instruction was “really hard.” She said, “I was wondering if something was messed up or if we did it wrong” while doing inquiry. Some of the student responses confused the use of hands-on instruction with inquiry.

Statements reflecting instructional techniques that were hands-on rather than inquiry-based were not included as data supporting inquiry-based instruction.

From Section B, Traditional First, most students preferred the inquiry instruction, as well. One student summarized it as “actually getting in there and doing it myself helps me hold on to the information for a longer time. It wasn’t as hard to memorize.” However, another student admitted, “I like the first part better (*life science-traditional instruction*). I like to be told what to do. I like step-by-step instructions.”

*Interview Question 2: Did you feel more comfortable in class during the life science or earth science portion of the class? Why?*

Section A, Inquiry First, students discussed the inquiry labs as beneficial for their learning process, but tedious to complete. They stated that planning and writing lab reports creates anxiety.

For the second part of class, the traditional earth science instruction, I felt more comfortable, because I wasn’t doing the lab reports. Yeah. I think ‘cause there’s so much research with the inquiry. If you do the wrong thing, and it doesn’t make sense or if you’re not backing it up with the right information, well, the inquiry is more tedious. (Section A interview, 2012)

However, another student felt better prepared after inquiry instruction for the midterm, but not after traditional instructional for the final. She states:

The good thing about the lab reports in inquiry, was even though it was a lot of work, I knew the definitions and everything for the midterm exam on life science. When I was looking over the study guide after the traditional instruction this time

for the earth science final exam, I knew what everything was, but it wasn't, well- the exact definition didn't come to mind as easily. (Section A interview, 2012)

Two students in Section A, Inquiry First, discussed discomfort throughout the entire class – whether inquiry or traditional instruction was being used. They admitted that it was personal frustration that they should know some of the material, but couldn't remember it from prior classes.

In Section B, Traditional First, all of the respondents felt more comfortable in Earth Science with inquiry instruction. They suggested that it might be attributed to comfort level with the class and peers in general after eight weeks of getting to know each other, or perhaps preference for Earth science content over life science. However, they also all acknowledged dislike for writing lab reports. They felt they were a hassle, and didn't like working in groups at any time.

*Interview Question 3: At any point in the semester did you start to have a more favorable experience towards science? Yes or No?*

Section A, Inquiry First pre-service teachers did not acknowledge favor towards science changing throughout the semester. One stated, "I just really like science." And another enjoyed it so much:

It helped me to make sure that I wanted to change my major to biology!! I wanted to before. Not in a bad way, in a good way. It was my original major. I loved the REAL science. (Section A interview, 2012)

Of the six Section B, Traditional First pre-service teachers that participated, two admitted entering the class hating science, but changing the way they felt over the course of the semester. “After this class, I am more interested in it. I feel like this class is a foundation maybe and I understand it.” Another: “I really liked designing the labs. I feel like I’m really not proficient enough yet, but I really like the way these classes are set up to teach how to do labs and things.”

*Interview Question 4: Did you notice a change in your attitude towards science after the first few classes of life science or earth science?*

Neither group of volunteers noticed a change in attitude towards science for life or earth. However, one pre-service teacher from Section A, Inquiry First elaborated on writing lab reports:

The lab reports are good, because you are applying what you learned. Like, you are putting it in perspective of, Oh, this happened because of this. If you don’t understand what it’s about, you wouldn’t be able to find the right research. So it gives you a good understanding of what you are doing. (Section A interview, 2012)

*Interview Question 5: How do you see yourself using both inquiry-based instruction and traditional instruction in your future classroom?*

Of the respondents to this question from Section A, Inquiry First, *all* plan to use inquiry in the classroom following completion of this class. They felt that by participating in inquiry themselves, they could appreciate the way it helped them learn content.

Based upon this course, I see myself doing a lot more of, if I were to be a teacher, doing a lot more of, experimental, hands-on. Like I really learned how important that is to help you grasp the concept rather than reading it. I would definitely do a lot more of that. (Section A interview, 2012)

Section B, Traditional First pre-service teachers agreed that there are benefits to teaching using both methods, but *none* stated that they could see themselves using inquiry in science. One student acknowledged that inquiry would be useful for other subjects though. “I think it is a kind of method that we can use for other subjects. It is another way to reach all the different types of learners; whether they are hands on or inquiry based.”

*Interview Question 6: Which instructional method do you feel more confident to use in your future classroom? Why?*

Pre-service teachers in Section A, Inquiry First began the discussion with the use of inquiry in their future classrooms. All respondents indicated that they would use inquiry. In fact, the interview discussion veered towards the *implementation* of using group work or partners as a teaching method. There was no question about whether they would use inquiry; they were focused on the strategies to employ inquiry. They felt that working in pairs would be the most effective method for using inquiry in the classroom.

Section B, Traditional First pre-service teachers felt more confident to teach using traditional instruction methods. They indicated that they plan to gradually include inquiry-based methods over time. However, they thought that their confidence in using traditional instruction was also based on what they had personally experienced

throughout their educational history. They had seen and directly participated with traditional instruction more often.

*Interview Question 7: Has your attitude towards teaching science changed over the course of this semester? If so, how?*

Section A, Inquiry First pre-service teachers had several positive comments about how much more interesting science has become for them and their outlook towards teaching science and for being in their own classroom. “I feel like I’m wanting to teach science now. I have more experiments that I know I can do.”

And another student responded that the class provided the refresher that she needed to prepare for teaching science:

I haven’t had a science class in like two years. So, when we got that survey in the beginning, how confident are you with teaching science, well, I know science. I need a refresher, but I feel a lot more comfortable with it now. (Section A interview, 2012)

Section B, Traditional First pre-service teachers expressed a dramatic increase in their confidence for teaching science, even if science is not their favorite subject. They felt capable of teaching content that previously they dreaded. “My attitude, no. But I am way more confident that I can teach science and actually enjoy teaching science now.”

## SUMMARY

The quantitative data indicated that instructional type does impact science content knowledge, specifically life science content knowledge in pre-service teachers.



The instructional type does not seem to impact pre-service teacher self-efficacy in life or earth science. Nor does instructional type seem to impact pre-service teacher expected outcome or likelihood for teaching life or earth science. There was a statistically significant relationship between the number of prior science courses and life science content. There was no difference in the relationship of prior courses on earth science content, self-efficacy or teaching outcome expectancy in life or earth science.

The qualitative data demonstrates pre-service teacher recognition of the impact of instruction type on learning. The participant responses showed that the students retained content knowledge longer and with personal confidence in understanding better with inquiry-based instruction. Pre-service teachers who started the semester with inquiry-based instruction were more likely to plan to use this type of instruction in their own classrooms. Pre-service teachers who did not receive inquiry-based instruction until halfway through the semester were less likely to plan to use this instruction type in their own classrooms. They stated a preference for traditional instruction based on their personal experience with traditional instruction over a longer time-span – their educational history. The qualitative data showed a positive attitude towards science.

## CHAPTER V

### FINDINGS, CONCLUSIONS, IMPLICATIONS

#### AND RECOMMENDATIONS

Developing student learners that are capable of critical thinking is a goal of educators today; and having teachers in place to guide these students to become critical thinkers is essential. Teachers are more likely to use specific teaching strategies when they are comfortable and fully understand the process of such teaching strategies. Research shows that when pre-service teachers experience or learn material in a particular way, they are more likely to teach using that method in their future classroom (Haefner-Zemba-Saul, 2004; Sanger, 2007; Smith, 2007; Tessier, 2010). The purpose of this study was to determine the relationships between inquiry-based instruction, science content knowledge and self-efficacy among pre-service elementary teachers through four research sub-questions.

The data for the study were gathered through examination of content knowledge, efficacy surveys, survey of prior science courses, and semi-structured oral interviews with pre-service teachers. Pre-service elementary education majors in two sections of Integrated Life/Earth science courses were taught using a crossover method of inquiry-based instruction and traditional instruction in one semester. These pre-service teachers were pre-assessed through a pre-examination of content knowledge, a self-efficacy survey, and a prior courses survey. At the midpoint of the semester, their content knowledge for life science and self-efficacy for life science were collected. Then the instructional method for each class was switched. At the completion of the

semester, the content knowledge and self-efficacy was again collected. Following the semester, the semi-structured oral interviews were conducted with a representative sampling of pre-service teachers from each of the courses.

## Analysis and Discussion of Research Findings

### Quantitative Research

Research Question 1: What is the effectiveness of inquiry-based instruction versus traditional methods of instruction in increasing life science and earth science content knowledge for elementary pre-service teachers?

Data analysis for the quantitative section began with the reporting of demographic data for each class of pre-service teachers. In addition the descriptive statistics for the numbers of prior science courses and each quantitative measure was included. ANCOVA's were used for analysis of content knowledge by instruction type. The first class of pre-service teachers had 29 students and had inquiry-based instruction for the first eight weeks of the semester. All students completed eight lab-activities during the life science portion of the class. In the inquiry-based class, four of these eight labs were considered inquiry-based instruction. The other four incorporated hands-on instruction with traditional or teacher centered instruction. The four inquiry-based labs were considered guided inquiry which required the students to develop their own method of investigation and experimentation, although the initial question for

investigation was provided by the instructor. Students worked in groups of either two or four persons per lab. At the completion of the lab, students would analyze the data and write conclusions based on their data and observations in a formal lab report. Results from each group were shared with the class and similarities and differences were discussed among groups.

The second class of pre-service teachers had 27 students and had traditional instruction for the first eight weeks of the semester. These students completed eight life science labs as well. All eight labs covered the same content as the inquiry-based section, however, the labs were considered “cook-book” style labs, where students followed pre-determined directions and answered analysis questions at the end. There was no opportunity for this group to design or alter the method from other groups or from the teacher’s original design. There was no formal lab report associated with the “cookbook” style labs.

For post life science content knowledge, students with inquiry-based instruction had a significantly higher adjusted mean than those with traditional instruction for life science. Results of the independent samples t-test showed that mean post life science content scores differed between inquiry-based instruction ( $M = 79.97$ ,  $SD = 10.71$ ,  $n = 29$ ) and traditional instruction ( $M = 70.70$ ,  $SD = 10.10$ ,  $n = 27$ ) at the .05 level of significance ( $t = 3.32^*$ ,  $df = 54$ ,  $p < .05$ , 95% CI for mean difference 3.68 to 14.85). On average inquiry-based instruction scored higher in life science than traditional instruction. The pre-test mean for each class was 20.34 (inquiry) and 21.00 (traditional), which does not show a significant difference between group means prior to beginning the course. It was interesting to note how

low the pre-test scores were considering the fact that biology was the most frequently named prior course when surveyed.

Following the crossover of instructional method at the midpoint of the semester, pre-service teachers in the inquiry-based instruction class of earth science content did not score significantly higher on earth science content. Results of the independent samples t-test showed that mean earth science content scores were not significantly different between inquiry-based instruction ( $M = 86.89$ ,  $SD = 8.17$ ,  $n = 27$ ) and traditional instruction ( $M = 86.83$ ,  $SD = 9.55$ ,  $n = 29$ ) at the .05 level of significance ( $t = -0.03$ ,  $df = 54$ ,  $p < .05$ , 95% CI for mean difference  $-4.84$ ,  $4.72$ ). On average inquiry-based instruction did not score higher in earth science than traditional instruction. It was interesting to note, that the pre-service teachers in traditional earth science were the same group that outperformed in inquiry for life science. The researcher believed that there was a carryover effect based on the way that this group of pre-service teachers continued to participate in class and the questions that they asked. For example, the first earth science lab was Properties of Water. The traditional instruction lab had a series of “cook-book” type steps that carefully led the pre-service teachers through a demonstration of the properties of water. When the Section A, Inquiry First group participated in this traditional lab activity they would continually ask questions about what would happen if they deviated from the specified method. One pre-service teacher specifically asked if she could try different types of soap to see how it affected the adhesion of water on a penny. Throughout the traditional lab, this group wanted to explore in ways that were different from the directions given. Section B, Traditional First pre-service teachers did not display this behavior. In fact, the pre-service teachers were

resistant to change in instruction type, and complained about having to design a method to test water properties on their own. They kept asking to be told exactly how they should proceed with the investigation without taking ownership of the learning. The researcher observed that an early expectation for student centered learning through inquiry sets the tone for student engagement.

The pre-examination scores in earth and life science indicated that there was no significant difference between the two groups of pre-service teachers. However, clearly one group developed a different way of looking at and retaining the content. The earth science pre-test means for each class were 13.11 (inquiry) and 12.38 (traditional), which does not show a significant difference between group means prior to beginning the course. Also, these extremely low pretest means were not surprising when the types of prior science courses were examined. Pre-service teachers had little to no exposure with earth science content prior to taking this class. However, there was a tremendous increase in content knowledge for each section regardless of instruction type. Observed Earth posttest means were 86.89 (inquiry) and 86.83 (traditional).

Research Question 2: What is the effect of inquiry-based versus traditional instruction on self-efficacy for teaching science in elementary pre-service teachers?

The *Science Teaching Efficacy Belief Instrument* (STEBI) was used to determine pre-service teacher self-efficacy for teaching science, which was the first subscale of this instrument. The pre-STEBI was worded to demonstrate an efficacy for teaching

general science. In other words, at the beginning of the semester, how confident are you, the pre-service teacher, in teaching *any* science if placed in a classroom at this moment? Following life science, at the midpoint of the semester, students were surveyed again, and the STEBI was modified to represent self-efficacy for teaching life science specifically. Results of the independent samples t-test showed that there was no statistically significant difference between inquiry-based instruction ( $M = 3.91$ ,  $SD = 0.60$ ,  $n = 29$ ) and traditional instruction ( $M = 3.80$ ,  $SD = 0.51$ ,  $n = 27$ ) in science teaching self-efficacy for life science at the .05 level of significance ( $t = 0.74$ ,  $df = 54$ ,  $p < .05$ , 95% CI for mean difference  $-0.19$  to  $0.41$ ). On average there was no difference between inquiry-based instruction and traditional instruction for life science teaching self-efficacy. It was interesting to note the pre-STEBI means for efficacy for each class: Section A, Inquiry First = 3.65, and Section B, Traditional First = 3.25, suggesting high self-confidence despite life science pre-test percentages of 20.34, and 21.74, respectively. Review of the prior science courses survey indicated that the most frequently taken prior science classes were biology. Geology or any earth science was rarely noted. Perhaps pre-service teachers felt that with prior courses in life science, they were confident to teach life science at an elementary level.

The second subscale of the *Science Teaching Efficacy Belief Instrument* (STEBI) was used to determine teaching outcome expectancy or the likelihood of teaching science. During the first half of the semester, this measure specifically targeted life science. Results of the independent samples t-test showed that there was no statistically significant difference between inquiry-based instruction ( $M = 3.71$ ,  $SD = 0.41$ ,  $n = 29$ ) and traditional instruction ( $M = 3.69$ ,  $SD = 0.45$ ,  $n = 27$ ) in expected

science teaching outcome for life science at the .05 level of significance ( $t = 0.18$ ,  $df = 54$ ,  $p < .05$ , 95% CI for mean difference -0.21 to 0.25). On average there was no difference between inquiry-based instruction and traditional instruction for expected life science teaching outcome, although there was an overall increase in pre-service teacher outcome expectancy following the life-science portion of the class. As noted in the focus group interviews, at least one Inquiry First pre-service teacher reported that she felt confident to teach science with the labs and materials that she had used in class.

The *Science Teaching Efficacy Belief Instrument* (STEBI) was used following the earth science portion of the class to determine pre-service teacher self-efficacy related to earth science. Again, the pre-STEBI was worded to demonstrate an efficacy for teaching general science. Following earth science, at the end of the semester, pre-service teachers were surveyed again, and the STEBI was modified to represent self-efficacy for teaching earth science specifically. Results of the independent samples t-test showed that there was no statistically significant difference between inquiry-based instruction ( $M = 3.89$ ,  $SD = 0.55$ ,  $n = 27$ ) and traditional instruction ( $M = 3.93$ ,  $SD = 0.62$ ,  $n = 29$ ) in science teaching efficacy for earth science at the .05 level of significance ( $t = 0.25$ ,  $df = 54$ ,  $p < .05$ , 95% CI for mean difference -0.28 to 0.35). On average there was no difference between inquiry-based instruction and traditional instruction for earth science teaching efficacy. Again, it was interesting to note the pre-STEBI means for efficacy for each class: Section A, Inquiry First = 3.65, and Section B, Traditional First = 3.25., for pre-service teachers scoring percentages of 13.11 (inquiry), and 12.38 (traditional) in earth science content, respectively in earth science content,



their confidence for teaching science seemed very high. The researcher noted the pretest means for earth science were much lower than the pretest scores for life science. Again, this was attributed to the types of prior science courses that pre-service teachers had taken.

The second subscale of the *Science Teaching Efficacy Belief Instrument* (STEBI) was used to determine teaching outcome or the likelihood of teaching science. During the second half of the semester, this measure specifically targeted earth science. Results of the independent samples t-test showed that there was no statistically significant difference between inquiry-based instruction ( $M = 3.69$ ,  $SD = 0.34$ ,  $n = 27$ ) and traditional instruction ( $M = 3.88$ ,  $SD = 0.43$ ,  $n = 29$ ) in expected science teaching outcome for earth science at the .05 level of significance ( $t = 1.87$ ,  $df = 54$ ,  $p < .05$ , 95% CI for mean difference -0.01 to 0.40). On average there was no difference between inquiry-based instruction and traditional instruction for expected earth science teaching outcome.

Research Question 3: What is the relationship between the number of prior science content courses, content knowledge, instructional method, and self-efficacy for teaching science in elementary pre-service teachers?

The results from the correlation show that the number of prior science courses is significantly related to the Post Life Science Content. Examination of the prior science courses data displays that most students have taken biology. This background content

may have had an impact on their familiarity with the content and therefore the retention. In addition, students that scored high on the life science posttest were likely to score high on the earth science posttest. The number of prior science courses was not related to the life or earth science efficacy or expected teaching outcome. However, the Post Life STEBI Efficacy subscale was statistically related to the Life STEBI Outcome subscale and Earth STEBI Efficacy subscale. Therefore, pre-service teachers that were confident in life science content were also confident in earth science content, and the confidence in life science led to a higher likelihood for teaching life science. Results from the t-tests show that post life science content means were significantly higher for pre-service teachers in inquiry-based instruction. The researcher felt that the prior exposure to more life science classes than earth science classes led to increased familiarity with the content for students.

## Qualitative Research

Research Question 4: What do pre-service teachers think of inquiry-based versus traditional instructional methods?

As Glesne and Peshkin (1992) point out interviewing in small groups can be beneficial for some people; encouraging them to talk by responding to group member responses and not just the interviewer. The researcher found this to be the case. After the initial interview question was asked, the small group would take turns answering and commenting on one another's responses. This sometimes seemed to jog their memory over parts of the course and the method of instruction.

*Interview Question 1: Which instructional method, worked best for you to learn course content, the inquiry-based method during life science (or Earth for Section B) or the traditional method during earth science (Life Science for Section B)?*

Pre-service teacher responses to this question confirmed the idea that participation in inquiry instruction forces students to be active participants in the learning process. Furthermore, in order to develop a method of lab design, the inquiry-based group had to communicate with each other, the instructor and explore related content through the preparation of their literature review. Their responses to this level of engagement indicated that it helped them retain the information better because of the multiple times and ways in which they thought about the content, which confirmed the quantitative results from ANCOVA. The student that preferred the traditional instruction admitted that his/her reason was not controlled by the level of learning that occurred, but a preference for being told what to do. Such activity does not develop a critical or capable thinker, nor does it develop a teacher that is well equipped to guide students in inquiry.

The level of engagement in Section A during the inquiry-based part of the class led to an overall different atmosphere within the classroom. Students were more communicative with one another and with the instructor. On a daily basis students were talking with one another to plan and work together. Frequently, the researcher was listening to and talking with the lab groups, which led to a familiarity with pre-service teacher names, etc. The Section B, Traditional First class maintained a more reserved air throughout the semester. There were fewer opportunities for pre-service teachers to interact with one another or the instructor in the first few weeks of the semester. This

seemed to be a crucial component in developing engaged learners. Even when the instruction type flipped, Section B, Traditional First never developed the interactive quality that the other class had. The researcher believed that the first few weeks of the semester set the stage for expectations of behavior and level of learner engagement. Therefore, Section B pre-service teachers remained resistant to a new instruction type and working with peers when the crossover occurred.

*Interview Question 2: Did you feel more comfortable in class during the life science or earth science portion of the class? Why?*

The comfort level of students throughout the course seemed to be controlled by their familiarity with one another and the instructor over time spent in the course, more than by instruction type. Both classes discussed frustration with writing lab reports, not because of discomfort from lack of ability, but from the amount of time that they took to complete. This course is a 3.0 hour class taken primarily by sophomores and some juniors. The expectation to do much work outside of class is very low. At this point in their college career, they have not realized the time commitments that teaching will entail, and feel that this course should follow the same format as other core classes in which they can simply show up. Attendance alone is a huge problem. For groups to divide the work load and prepare for labs outside of class is difficult when students do not take responsibility for their outside assignments. The two most successful lab groups were those who chose to use Google Drive to share their documents. Although recommended to all students as a means for sharing and adding to their lab reports, only two groups actually did this. Therefore, the comfort level expressed by the pre-service teachers does not directly relate to their self-efficacy for teaching science. Both

classes had a high level of self-efficacy for teaching science prior to this course. The interview participants felt that their exposure to science through classes they had enrolled in throughout their education gave them the needed confidence to teach science.

*Interview Question 3: At any point in the semester did you start to have a more favorable experience towards science? Yes or No?*

Neither inquiry-based nor traditional instruction seemed to have an impact on changing pre-service teacher science experience. Both classes had pre-service teachers that felt the same towards science throughout the semester. Two of the students that started with traditional instruction and switched to inquiry at the midpoint indicated that they entered the semester hating science. By the end of the semester they felt more interested in science and felt that the class provided them with a foundation for teaching science. However, they did not indicate if this change in favorability was related to the switch in instructional method.

*Interview Question 4: Did you notice a change in your attitude towards science after the first few classes of life science or earth science?*

Neither class reported a change in attitude towards science related to instruction type. The only student to elaborate on this question confirmed the use of inquiry validated her understanding of the content and her perspective of learning, but did not specifically address inquiry as changing her attitude towards science.

*Interview Question 5: How do you see yourself using both inquiry-based instruction and traditional instruction in your future classroom?*

Pre-service teachers from Section A, Inquiry First affirmed the value of having participated in the process of inquiry themselves. They felt that they were more likely to use inquiry in their future classrooms because they recognized the benefits from doing inquiry. They could envision themselves being the teachers that would use inquiry having seen it and participated with it from the other side. Pre-service teachers from Section B, Traditional First only discussed the use of inquiry in their future classrooms beyond science content. They recognized it as a method of learning that would be beneficial for different types of learners within various content. Section B, Traditional First did not indicate their use of inquiry in future classrooms, just an appreciation of how inquiry could be beneficial.

*Interview Question 6: Which instructional method do you feel more confident to use in your future classroom? Why?*

The interview participants from Section A, Inquiry First began their discussion of the value of teaching using inquiry-based instruction. However, the conversation shifted to issues that can arise during experiments with lab groups. They continued discussing how they planned to use large or small groups, and that in fact they thought that lab pairs were actually the ideal situation for conducting experiments. The researcher saw this as a positive discussion – they were all planning to use inquiry in their classroom, they were just working out the details of how to implement it most effectively. No one spoke against using inquiry in their future classrooms. Section B, Traditional First had a very different response to this question. All of the interview participants agreed with the value of inquiry for learning material and retaining it. However, they all said that they would most likely start their teaching career using traditional instruction. They kept

emphasizing that this was the instruction that they were most familiar with from having received this throughout their own education, so they were most likely going to use what they had seen modeled. They agreed with one another that over time they hoped to shift their instruction to include more inquiry in science. Despite their responses to benefits of inquiry, they planned to teach using traditional instruction. The researcher felt as though their responses to interview question 5 may have been out of respect for the researcher's interest in inquiry and not their personal beliefs.

*Interview Question 7: Has your attitude towards teaching science changed over the course of this semester? If so, how?*

Interview participants from both sections expressed their anticipation of being in their own classroom and looking forward to teaching in general, but also feeling ready to teach science. They felt far more prepared than when they took the efficacy survey on the first day of class.

### Implications

In reviewing the data in relation to the research questions for this study, it was concluded that pre-service teachers benefit from inquiry-based instruction. Although only the life science content score exhibited quantitative data to support the statement that inquiry-based instruction is more effective for increasing content knowledge, taken in conjunction with the interviewer responses it was clear that inquiry-based instruction has value in the classroom. The most crucial implication for inquiry-based instruction was the direct participation of future teachers in this type of learning. They are less likely to use instructional methods in which they are not directly involved, and

recognizing the gains of using inquiry will only come with repeated exposure. Section A, Inquiry First pre-service teachers had early exposure to this teaching method, which seemed to carry over for the entire semester. Section B, Traditional First pre-service teachers did not appear convinced of the benefits of inquiry, since there was no plan to implement such instruction in their future classrooms.

In addition, although only the life science content showed a significant increase for inquiry-based instruction, the researcher noted that pre-service teachers achieved the same level of content whether in inquiry or traditional instruction. This demonstrated that the same amount of content could be covered and to the same level, while using either method of instruction. Since one of the complaints with moving to inquiry-based instruction has been the inability to cover the same amount of content, this study demonstrates that is not the case. Also, the Life STEBI Efficacy subscale showed higher post scores for inquiry-based instruction than the traditional instruction. Therefore, two of the six measures did show higher results for inquiry-based instruction. Further exploration with the use of inquiry-based instruction may improve our understanding of the use of inquiry.

The shift for schools full of lazy learners needs to start in teacher education programs. Even the pre-service teachers arrive to class as customers to be served. If pre-service elementary teachers display an open dislike for math and science, how can we not expect this attitude to carryover to their students? It is essential that teacher education therefore reach the pre-service teachers that can make a shift in learner attitudes and experiences. As the researcher found, traditional schooling leads to traditional schooling. However, when different and perhaps higher expectations are set



forth from the beginning, pre-service teachers (students) raised the level of expectation and shifted their attitude from one waiting to be served to one in charge of their own learning opportunity. Rheinberger's statement, "A research experiment is a device to bring forth something unknown – in fact, something which does not even exist in the form in which it is going to be produced" produced an unknown product for pre-service teachers from this study. Their expectation to passively attend a science class, was disrupted by the student-centered approach to instruction through inquiry. Their dialogue in the follow-up interviews displayed a new and unexpected awareness and value for student driven classrooms. Moreover, their direct participation as students in the process helped them to realize the value of the experience through the eyes of students, not just as educators (Britzman, 1991). For this reason, curriculum studies programs and teacher education programs have the responsibility to provide non-traditional learning opportunities for future educators to bring about this shift. In addition, collaboration with content-based departments across campus could reinforce the pedagogy presented in education courses. If the desire is for future and current educators to move away from traditional instruction, then teacher education programs need to model what they preach.

### Recommendations for Further Research

1. A larger sample size would be beneficial to observe the relationships among instruction type, content knowledge and self-efficacy.

2. A study should be undertaken to increase the number of inquiry-based labs over the course of an entire semester – rather than just half of one. In addition, having an entire semester in a class such as Integrated Science would allow pre-service teachers opportunities to use inquiry-based instruction in more than one content area, for example inquiry-based labs in life science AND earth science.
3. This research should continue into successive semesters for pre-service teachers to have additional and continued exposure to inquiry-based instruction as a method of instruction. The Science methods class that elementary majors take should involve pre-service teachers in inquiry to reinforce this exposure.
4. A longitudinal study to follow pre-service teachers into their future classrooms and conduct follow-up surveys to see how inquiry-based instruction is being utilized would be beneficial.
5. Being able to look at the quantitative data prior to the oral interviews would allow the researcher the opportunity to target questions related to the data for the participants. For example, the ability to investigate prior courses with pre-service teachers and what they think about the impact of prior courses on their self-efficacy would be beneficial.
6. Lastly, layering this study with a learning styles inventory of the pre-service teachers would allow the researcher the opportunity to see how specific types of learners respond to different instructional methods.

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## APPENDICES

APPENDIX A  
INSTITUTIONAL REVIEW BOARD FORMS

Georgia Southern University Office of Research Services & Sponsored Programs <b>Institutional Review Board (IRB)</b>		
Phone: 912-478-0843		Veazey Hall 2021
Fax: 912-478-0719	IRB@GeorgiaSouthern.edu	P.O. Box 8005 Statesboro, GA 30460

**To:** Heather Scott  
Dr. Missy Bennett

**CC:** Charles E. Patterson  
Vice President for Research and Dean of the Graduate College

**From:** Office of Research Services and Sponsored Programs  
Administrative Support Office for Research Oversight Committees  
(IACUC/IBC/IRB)

**Initial Approval Date:** 07/18/12

**Expiration Date:** 05/31/13

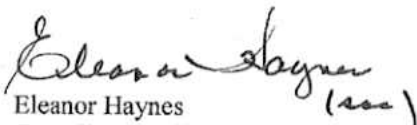
**Subject:** Status of Application for Approval to Utilize Human Subjects in Research

After a review of your proposed research project numbered **H13013** and titled **"Inquiry, Efficacy, and Science Education,"** it appears that (1) the research subjects are at minimal risk, (2) appropriate safeguards are planned, and (3) the research activities involve only procedures which are allowable. You are authorized to enroll up to a maximum of 65 subjects.

*Therefore, as authorized in the Federal Policy for the Protection of Human Subjects, I am pleased to notify you that the Institutional Review Board has approved your proposed research.*

If at the end of this approval period there have been no changes to the research protocol; you may request an extension of the approval period. Total project approval on this application may not exceed 36 months. If additional time is required, a new application may be submitted for continuing work. In the interim, please provide the IRB with any information concerning any significant adverse event, **whether or not it is believed to be related to the study**, within five working days of the event. In addition, if a change or modification of the approved methodology becomes necessary, you must notify the IRB Coordinator **prior** to initiating any such changes or modifications. At that time, an amended application for IRB approval may be submitted. Upon completion of your data collection, you are required to complete a *Research Study Termination* form to notify the IRB Coordinator, so your file may be closed.

Sincerely,

  
 Eleanor Haynes  
 Compliance Officer

## GEORGIA SOUTHERN UNIVERSITY INSTITUTIONAL REVIEW BOARD

### PROPOSAL NARRATIVE

#### **Personnel.**

Heather Scott, Principal Investigator: doctoral candidate, project designer, will gather and analyze all data.

Missy Bennett, Advisor: doctoral committee chair.

#### **Purpose:**

The purpose of this study is to determine what relationships exist among inquiry-based instruction, science content knowledge and self-efficacy in pre-service elementary teachers. The following research sub-questions will guide this study:

What is the effectiveness of inquiry-based instruction versus traditional methods of instruction in increasing life science and earth science content knowledge for elementary pre-service teachers? What is the effect of inquiry-based versus traditional instruction on self-efficacy for teaching science in elementary pre-service teachers? What is the relationship between the number of prior science content courses, content knowledge, instructional method, and self-efficacy for teaching science in elementary pre-service teachers? What do pre-service teachers think of inquiry-based versus traditional instructional methods?

Effective use of inquiry-based instruction is a glaring weakness in science education for today's schools. Although many researchers understand the value of inquiry in our quest for knowledge as a society, and even the value of inquiry to develop critical thinking in the youth of today, the use of inquiry-based instruction remains absent in our educational system. Since elementary school is a primary time to develop the basic skills for science as a process, this should be the focus of teacher education programs; to strength the confidence in pre-service elementary teachers to accept the challenge to bring inquiry-based instruction into the classroom.

The use of inquiry-based instruction in developing student content knowledge and critical thinking skills has seen a push by researchers and the National Science Teachers Association (NSTA, 2012) in recent years. However, teachers are reluctant to incorporate inquiry into their classrooms because of the lack of familiarity with the process. Elementary teachers in particular have a lack of confidence in teaching science on many levels, and using inquiry feels very uncontrolled and uncomfortable. In order for pre-service teachers to gain confidence in using new methods of instruction in their future classrooms, they need to have opportunities to learn through experiencing the same processes that they will use for instruction in the future and reflecting on the personal experiences gained through such. By measuring the increase in content knowledge gained through two opposing methods of instruction and assessing pre-service teacher efficacy for the content knowledge as well as the potential for future classroom use, it is possible to determine the effect of inquiry-based and traditional instruction on elementary pre-service teachers.

The use of inquiry-based instruction is gradually gaining ground in K-12 classrooms and the post-secondary arena. There are studies that have looked at the use of inquiry to increase content knowledge and there are studies that have looked at attitudes towards science with inquiry instruction. However, a gap exists with the use of inquiry instruction for pre-service elementary teachers and its impact on content knowledge and self-efficacy for teaching science.

It is important to realize the need for pre-service teacher science content to increase. During a university program of study, education majors completing science courses receive content in the method most often utilized in universities, which is direct instruction. Thus far, we have failed to see a successful carryover of this content into the elementary classroom. The Board of Regents of the University System of Georgia (2006) has mandated two additional science content classes for elementary majors to cover life, earth and physical science. However, without altering the pedagogy, why would we see a significant change in the way that these future teachers teach science in their classrooms?

**Outcome:**

The participants in this study will benefit from exposure to inquiry-based instruction for development of their personal understanding of inquiry in science education and how to implement such instruction for their future classroom. In addition, the information gained from this study will inform the teacher preparation programs in the College of Education at Georgia Southern University as well as educator preparation programs through dissemination in education venues.

**Describe your subjects:**

Purposeful sampling will be used for this study, with the Integrated Science (ISCI) 2001, Life/Earth Science specifically designated as the course to explore this study. Two sections of this course will be used in the study. Each course has 30 students enrolled. As this course is required for all early childhood majors, the students enrolled will be early childhood education majors. Two content areas, life science and earth science, will be utilized through the crossover design. Each content area will have an experimental and a control aspect, between the two course sections.

At the beginning of the course, the students will be informed that the ISCI 2001 course is part of a research study. The informed consent letter will give them the opportunity to refuse to participate. Students will still be expected to complete all of the course assignments and examinations associated with the course. If they choose not to participate in the self-efficacy questionnaire or the prior science courses survey, they can submit a blank copy of the questionnaire or survey and place in the collection envelope in the classroom.

At the end of the course, all students will have the opportunity to volunteer for small focus group interviews to collect qualitative data; even if these students chose not to participate in the initial surveys. These interview sessions will be audio taped, and a

graduate assistant will record student responses during the interview session for later transcription.

Graduate assistants will administer the pre/posttests, and surveys, and code and assign numbers to each so as to remove identity from student paperwork. All instruments used for the purpose of research will be kept in a locked file for three years and destroyed after that time, and no identifying information will be released or published that could identify specific students.

### **Methodology (Procedures):**

A pre-test administered by graduate assistants will be used at the beginning of the semester to gauge initial content knowledge. See Appendix A. Students will also be asked through the use of a survey administered by a graduate assistant at the beginning of the semester to provide information regarding the number of high school and college level science courses that they have taken prior to enrolling in this course. See Appendix B. The Science Teaching Self Efficacy Instrument (STEBI-B) will be administered by a graduate assistant as a pre-assessment with students instructed to answer the survey questions from a general science perspective. See Appendix C. Course section A students will be taught for the first eight weeks of the semester using an inquiry-based approach to the life science content, that includes four iterations of an inquiry-based project during the life science portion of the class. This inquiry-based instruction is most closely described as guided inquiry. Students will work with a partner or in a small lab group to develop an experimental design that can be used to support or refute their hypothesis based on the evidence provided through the course of their exploration. This instruction is considered guided inquiry, as there will be some input provided by the course instructor to increase the rate at which the students can complete their exploration. For example, when students are exploring the membrane transport, there will be several materials available which are recommended to test movement across membranes. Each group will be encouraged to explore using different materials, such as starch and iodine or glucose and water, and the results from each lab group will be shared and discussed with the class.

Course section B students will be taught for the same duration using a traditional instruction method that is comprised of “cookbook” type lab activities and direct instruction. A “cookbook” style lab will still allow students to experience hands-on learning by actively participating in a lab activity, however, the students will not be developing their own procedures for exploration; they will be following the steps outlined on a lab sheet that explore one way of demonstrating the concept, such as membrane transport. At the end of the first eight weeks of the semester, a midterm exam administered by a graduate assistant will be given to each section serving as a post-test for the life-science portion of the course. See Appendix D. In addition, the self-efficacy survey will be administered by a graduate assistant to both sections, and modified to contain phrases that specifically relate to life science. See Appendix E.

Now a crossover of methods will occur. Course section A students that originally received instruction through an inquiry-based approach will receive earth science

content through traditional methods of instruction. A “cookbook” style lab will still allow students to experience hands-on learning by actively participating in a lab activity, however, the students will not be developing their own procedures for exploration; they will be following the steps outlined on a lab sheet that explore one way of demonstrating the concept, such as properties of water. Section B students will now receive earth science instruction in an inquiry-based approach, that includes four iterations of inquiry-based projects for the earth science portion of the class. This inquiry-based instruction is most closely described as guided inquiry. Students will work with a partner or in a small lab group to develop an experimental design that can be used to support or refute their hypothesis based on the evidence provided through the course of their exploration. This instruction is considered guided inquiry, as there will be some input provided by the course instructor to increase the rate at which the students can complete their exploration. For example, when students are exploring the difference between direct and indirect light on earth’s surface and how that affects seasonal changes on earth, a flashlight will be provided and students will be given a guiding question to explore with light and surface area. At the end of the semester, both sections will take a post-test assessment of the earth science content administered by a graduate assistant. See Appendix F. In addition, the self-efficacy survey will be administered by a graduate assistant to both sections, and modified to contain phrases that specifically relate to earth science. See Appendix G. Students will be given the opportunity to participate in small focus group interviews to provide qualitative data regarding the use of inquiry in science education. A graduate assistant will administer the interview questions and audiotape them for later transcription and analysis. The questions that will be used in the focus group interviews are included in Appendix H.

In addition to descriptive statistics and correlation, Analysis of Covariance (ANCOVA) will be used to address research questions 1-3. Quantitative data will be analyzed using Statistical Package for Social Sciences (SPSS). ANCOVA will be used to detect any differences between groups and equate groups on pre-existing differences (Gall, Gall & Borg, 2007). The STEBI-B will be modified to focus the participants on life science or earth science following each respective portion of the course.

Six ANCOVA models will be tested. Following life science instruction students will complete the posttest on life science and the STEBI worded for life science. The STEBI will produce scores for two sub-scales, life-science teaching efficacy and life-science teaching outcome expectancy. The factor of interest in the ANCOVA models is instructional type (inquiry-based or traditional instruction), and several covariates will be included: pretest scores in life science, number of prior science courses taken, and pre-measures of teaching efficacy and teaching outcome expectancy. Thus, for the three outcomes - life science posttest scores, life science teaching efficacy, and for life science teaching outcome expectancy - three separate ANCOVA models will be estimated to test for instructional differences while controlling for pre-test scores in life science, number of prior science courses taken, initial teaching efficacy, and initial teaching outcome expectancy.

For the earth science posttest scores, earth science teaching efficacy, and for earth science teaching outcome expectancy, three separate ANCOVA models will be estimated to test for instructional differences while controlling for pre-test scores in earth science, number of prior science courses taken, initial teaching efficacy, and initial outcome expectancy. Mean scores will be used to adjust for correct scale in potential missing data, as some students may not answer every question on the questionnaire or examination.

Following the focus group interviews, a qualitative analysis of the participants' responses will be conducted to identify categories that describe the differences for participants in inquiry-based or traditional instruction. These categories will be labeled and classified as properties of inquiry-based or traditional instruction for students in science education (Strauss & Corbin, 1998). In addition, classification that correlates with self-efficacy will be identified to note differences, if they exist, between the two methods of instruction. At the completion of the analysis and labeling of the responses, the researcher will report the findings in summarized statements.

**Special Conditions:**

**Risk.**

There are minimal to no risks to participants in this study.





**COLLEGE OF EDUCATION**

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**DEPARTMENT OF TEACHING AND LEARNING**

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### **INFORMED CONSENT: SURVEY**

As a doctoral candidate and instructor in the College of Education, I wish to learn more about instructional methods that may affect the science teaching self-efficacy of pre-service teacher candidates and their content knowledge. The specific purpose of this research is to study the relationship among instructional methods (inquiry vs. traditional), content knowledge, science teaching self-efficacy, and prior science courses taken.

Participation in this research will include completion of a pretest/posttest for content knowledge in life/earth science, a science teaching efficacy belief instrument (general), a survey of prior courses taken in high school and college, a science teaching efficacy belief instrument (modified for life science), and a science teaching belief instrument (modified for earth science), and the opportunity to participate in a volunteer focus group interview. By signing this consent form, I understand that my individual information will be maintained confidentially and only reported as part of statistical data. I also understand that I will not be asked to provide data, including work samples, from P-12 students.

The risks from participating in this study are no more than would be encountered in everyday life. If you do experience discomfort from participating in this research, you have the option to contact the Counseling Center to make an appointment to speak to someone, 912-478-5541.

There are no direct benefits to participation in this study other than the experience of participating in a research process that may benefit future pre-service teacher candidates in your program.

Data collected for the focus group interviews will be done on a volunteer basis at a time deemed most convenient to all of the volunteers. If student data is collected outside the bounds of normal coursework, then data collection will last no more than 60 minutes.

The records of this study will be kept private, and your identity will be kept confidential to the extent required by law. Specifically, research records will be kept in a locked file for three years from the collection date and can be accessed only by researchers. At the end of this time frame, the data will be destroyed. The results will be analyzed in terms of averages across participants rather than in terms of individual performance. In any form of report that I may publish, I will not include any information that will make it possible to identify a research participant.

Participants have the right to ask questions and have those questions answered. If you have questions about this study, please contact the researcher named above or the researcher's faculty advisor, whose contact information is located at the end of the informed consent. For questions concerning your rights as a research participant, contact Georgia Southern University Office of Research Services and Sponsored Programs at 912-478-0843.

There is no compensation for participation in this study.

Participants may choose not to participate by not signing this consent form or, if the data being collected is outside the bounds of normal coursework, participants may end their participation at any time, or request that certain personal data not be used by sending an email request using your Georgia Southern University email account to the principal investigator, Heather Scott, at [hscott@georgiasouthern.edu](mailto:hscott@georgiasouthern.edu).

There is no penalty for deciding not to participate in the study. Your grade will not be affected in any way by your choice to participate or not participate in this study. Although you must complete all coursework that is assigned by the instructor, it is entirely up to you to decide whether or not your assignments may be included in the data set.

You must be 18 years of age or older to consent to participate in this research study. If you consent to participate in this research study and to the terms above, please sign your name and indicate the date below.

You will be given a copy of this consent form to keep for your records. This project has been reviewed and approved by the GSU Institutional Review Board under tracking number H13013.

Title of Project: Inquiry, Efficacy, and Science Education

Principal Investigator: Heather Scott, Department of Teaching and Learning, College of Education, Georgia Southern University, PO Box 8134, Statesboro, Ga. 30460. Telephone: (912) 478-5932;

Email: [hscott@georgiasouthern.edu](mailto:hscott@georgiasouthern.edu)

Faculty Advisor: Missy Bennett, Department of Teaching and Learning, College of Education, Georgia Southern University, PO Box 8134, Statesboro, Ga. 30460. Telephone: (912) 478-0356;

Email: [mbennett@georgiasouthern.edu](mailto:mbennett@georgiasouthern.edu)

\_\_\_\_\_  
Participant Signature Date

I, the undersigned, verify that the above informed consent procedure has been followed.

\_\_\_\_\_  
Investigator Signature Date



**COLLEGE OF EDUCATION**

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**DEPARTMENT OF TEACHING AND LEARNING**

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### **INFORMED CONSENT: INTERVIEW**

As a doctoral candidate and instructor in the College of Education, I wish to learn more about instructional methods that may affect the science teaching self-efficacy of pre-service teacher candidates and their content knowledge. The specific purpose of this research is to study the relationship among instructional methods (inquiry vs. traditional), content knowledge, science teaching self-efficacy, and prior science courses taken.

Participation in this research will include completion of a pretest/posttest for content knowledge in life/earth science, a science teaching efficacy belief instrument (general), a survey of prior courses taken in high school and college, a science teaching efficacy belief instrument (modified for life science), and a science teaching belief instrument (modified for earth science), and the opportunity to participate in a volunteer focus group interview. By signing this consent form, I understand that my individual information will be maintained confidentially and only reported as part of statistical data. I also understand that I will not be asked to provide data, including work samples, from P-12 students.

The risks from participating in this study are no more than would be encountered in everyday life. If you do experience discomfort from participating in this research, you have the option to contact the Counseling Center to make an appointment to speak to someone, 912-478-5541.

There are no direct benefits to participation in this study other than the experience of participating in a research process that may benefit future pre-service teacher candidates in your program.

Data collected will be done throughout the normal activities of coursework or class time. If student data is collected outside the bounds of normal coursework, then data collection will last no more than 30 minutes.

The records of this study will be kept private, and your identity will be kept confidential to the extent required by law. Specifically, research records will be kept in a locked file for three years from collection date and can be accessed only by researchers. At the end of this time frame, the data will be destroyed. The results will be analyzed in terms of averages across participants rather than in terms of individual performance. In any form of report that I may publish, I will not include any information that will make it possible to identify a research participant.

Participants have the right to ask questions and have those questions answered. If you have questions about this study, please contact the researcher named above or the researcher's faculty advisor, whose contact information is located at the end of the informed consent. For questions concerning your rights as a research participant, contact Georgia Southern University Office of Research Services and Sponsored Programs at 912-478-0843.

There is no compensation for participation in this study.

Participants may choose not to participate by not signing this consent form or, if the data being collected is outside the bounds of normal coursework, participants may end their participation at any time, or request that certain personal data not be used by sending an email request using your Georgia Southern University email account to the principal investigator, Heather Scott, at [hscott@georgiasouthern.edu](mailto:hscott@georgiasouthern.edu).

There is no penalty for deciding not to participate in the study. Your grade will not be affected in any way by your choice to participate or not participate in this study. Although you must complete all coursework that is assigned by the instructor, it is entirely up to you to decide whether or not your assignments may be included in the data set.

You must be 18 years of age or older to consent to participate in this research study. If you consent to participate in this research study and to the terms above, please sign your name and indicate the date below.

You will be given a copy of this consent form to keep for your records. This project has been reviewed and approved by the GSU Institutional Review Board under tracking number H13013.

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Principal Investigator: Heather Scott, Department of Teaching and Learning, College of Education, Georgia Southern University, PO Box 8134, Statesboro, Ga. 30460. Telephone: (912) 478-5932;

Email: [hscott@georgiasouthern.edu](mailto:hscott@georgiasouthern.edu)

Faculty Advisor: Missy Bennett, Department of Teaching and Learning, College of Education, Georgia Southern University, PO Box 8134, Statesboro, Ga. 30460. Telephone: (912) 478-0356;

Email: [mbennett@georgiasouthern.edu](mailto:mbennett@georgiasouthern.edu)

\_\_\_\_\_  
Participant Signature

\_\_\_\_\_  
Date

I, the undersigned, verify that the above informed consent procedure has been followed.

\_\_\_\_\_  
Investigator Signature

\_\_\_\_\_  
Date





## APPENDIX B

### CONTENT KNOWLEDGE EXAMINATION ALIGNED WITH LEARNING OUTCOMES AND GPS

<b>Pre/Post Test Questions</b>	<b>DOE Learning Outcome</b>	<b>Georgia Performance Standard</b>
1-6. On a diagram, name and describe the function of the following organelles: rough endoplasmic reticulum, Golgi apparatus, cytoplasm, mitochondria, lysosome, nucleus	SWBAT identify different cell components and their functions.	S7L2. Students will describe the structure and function of cells, tissues, organs, and organ systems. b. Relate cell structures (cell membrane, nucleus, cytoplasm, chloroplasts, mitochondria) to basic cell functions.
7. In diffusion, molecules move from areas of ___ concentration to areas of ___ concentration.	SWBAT explain the integration of cellular components.	S7L2. Students will describe the structure and function of cells, tissues, organs, and organ systems. a. Explain that cells take in nutrients in order to grow and divide and to make needed materials.
8. In algae and the leaves of green plants, photosynthesis occurs in cells that contain ____.	SWBAT explain the process and significance of photosynthesis.	S7L2. Students will describe the structure and function of cells, tissues, organs, and organ systems. a. Explain that cells take in nutrients in order to grow and divide and to make needed materials.
9. Write the equation for cellular respiration. Where does this process occur and what is the importance of oxygen for this process?	SWBAT explain the process and significance of cellular respiration.	S7L4. Students will examine the dependence of organisms on one another and their environments. a. Demonstrate in a food web that matter is transferred from one organism to another and can recycle between organisms and their environments.
10. Explain how photosynthesis is an intricate part of the interdependence of life.	SWBAT explain the process and significance of photosynthesis.	S7L4. Students will examine the dependence of organisms on one another and their environments. b. Explain in a food web that sunlight is the source of energy and that this energy moves from organism to organism.
11. When moving from one trophic level to the next, only 10% of the total energy is transferred. Where does the other 90% go?	SWBAT demonstrate an understanding of the intricacy and concepts of food webs.	S7L4. Students will examine the dependence of organisms on one another and their environments. a. Demonstrate in a food web that matter is transferred from one organism to another and can recycle between organisms and their environments.
12. In our diffusion lab, we used iodine to show if there was any movement through the plastic bag. Iodine is called a(n) ____, because it changes color when it comes into contact with starch.	SWBAT demonstrate the ability to explain characteristics associated with all living things: cells, growth, exchange of materials with the environment, homeostasis, etc.	S7L2. Students will describe the structure and function of cells, tissues, organs, and organ systems. d. Explain that tissues, organs, and organ systems serve the needs cells have for oxygen, food, and waste removal.
13. The basic structural unit of all living things is a ____.	SWBAT recognize the cell as the fundamental unit of life.	S7L2. Students will describe the structure and function of cells, tissues, organs, and organ systems. a. Explain that cells take

		in nutrients in order to grow and divide and to make needed materials.
14. Insects make up about ___ in relative abundance of the animal species on Earth.	SWBAT recognize similarities and differences between organisms, and group living organisms based on characteristics.	S7L1. Students will investigate the diversity of living organisms and how they can be compared scientifically.
15. When one organism in a relationship benefits and the other organism is not affected, this relationship is called ___.	SWBAT demonstrate an understanding of symbiotic relationships, i.e. mutualism, commensalism, and parasitism.	S7L1. Students will investigate the diversity of living organisms and how they can be compared scientifically.
16. Describe a physical adaptation that would benefit an insect as a predator.	SWBAT demonstrate an understanding of predator/prey relationships, strategies and adaptive significance.	S7L4. Students will examine the dependence of organisms on one another and their environments. d. Categorize relationships between organisms that are competitive or mutually beneficial.
17. Name the three main body segments of an insect and tell the primary function of each.	SWBAT group living organisms based on characteristics.	S7L1. Students will investigate the diversity of living organisms and how they can be compared scientifically.
18. Name two characteristics that are unique to mammals.	SWBAT group living organisms based on characteristics.	S7L1. Students will investigate the diversity of living organisms and how they can be compared scientifically.
19. Carnivores have teeth that are specialized adaptations for being a ___.	SWBAT demonstrate an understanding of predator/prey relationships, strategies and adaptive significance.	S7L4. Students will examine the dependence of organisms on one another and their environments. d. Categorize relationships between organisms that are competitive or mutually beneficial.
20. Rodents have rootless incisors. If we (humans) had rootless incisors, what would we do diligently for our teeth?	SWBAT group living organisms based on characteristics.	S7L1. Students will investigate the diversity of living organisms and how they can be compared scientifically.
21. Use the following boxes to draw each step in the cell cycle and name it. Clearly show where the chromosomes are positioned during each phase.	SWBAT demonstrate the ability to explain mechanisms for transmission of traits between generations.	S7L2. Students will describe the structure and function of cells, tissues, organs, and organ systems. a. Explain that cells take in nutrients in order to grow and divide and to make needed materials.
22. The cellular process that duplicates genetic material prior to its distribution to the daughter cells is ___.	SWBAT demonstrate the role of DNA in heredity.	S7L2. Students will describe the structure and function of cells, tissues, organs, and organ systems. a. Explain that cells take in nutrients in order to grow and divide and to make needed materials.
23. Using the template strand of DNA provided, identify which strand of DNA would be the complementary strand after replication. Template	SWBAT demonstrate the role of DNA in heredity.	S7L2. Students will describe the structure and function of cells, tissues, organs, and organ systems. a. Explain that cells take in nutrients in order to grow and divide and to make needed materials.

strand: GCAATCGCACATTG		
24. The cellular process _____ is composed of two steps: transcription and translation.	SWBAT demonstrate the role of DNA in heredity.	S7L2. Students will describe the structure and function of cells, tissues, organs, and organ systems. a. Explain that cells take in nutrients in order to grow and divide and to make needed materials.
25. A normal human karyotype would contain how many total chromosomes? (Not pairs)	SWBAT distinguish between inherited traits and learned behaviors.	S7L3. Students will recognize how biological traits are passed on to successive generations. a. Explain the role of genes and chromosomes in the process of inheriting a specific trait.
26. Indicate what the normal female sex chromosomes would be. ____	SWBAT distinguish between inherited traits and learned behaviors.	S7L3. Students will recognize how biological traits are passed on to successive generations. a. Explain the role of genes and chromosomes in the process of inheriting a specific trait.
27. Gregor Mendel experimented with true breeding pea plants that exhibited spherical seeds and dented seeds. The spherical seeds were dominant. Draw a Punnett Square and show the genotypic and phenotypic ratios for the offspring for a cross between a heterozygous pea plant with spherical seeds and a pea plant with dented seeds.	SWBAT distinguish between inherited traits and learned behaviors.	S7L3. Students will recognize how biological traits are passed on to successive generations. c. Recognize that selective breeding can produce plants or animals with desired traits.
28. How does the cohesive property of water work? Use words and/or diagrams to explain your answer.	SWBAT demonstrate a basic understanding of the water cycle.	S6E3. Students will recognize the significant role of water in earth processes. a. Explain that a large portion of the Earth's surface is water, consisting of oceans, rivers, lakes, underground water, and ice.
29. Draw a water molecule. Label the atoms and any charges associated with it.	SWBAT demonstrate a basic understanding of the water cycle.	S6E3. Students will recognize the significant role of water in earth processes. a. Explain that a large portion of the Earth's surface is water, consisting of oceans, rivers, lakes, underground water, and ice.
30. Describe how sedimentary rocks are formed as part of the rock cycle.	SWBAT differentiate rocks and demonstrate a basic understanding of the rock cycle.	S6E5. Students will investigate the scientific view of how the earth's surface is formed. c. Classify rocks by their process of formation. d. Describe processes that change rocks and the surface of the earth.
31. Name one of the metamorphic rocks that we studied. Identify its texture and explain what texture refers to in a metamorphic rock.	SWBAT differentiate rocks and demonstrate a basic understanding of the rock cycle.	S6E5. Students will investigate the scientific view of how the earth's surface is formed. c. Classify rocks by their process of formation. d. Describe processes that change rocks and the surface of the earth.

<p>32. Name this phase of the moon:</p>  <p>How do you know that it is this phase?</p>	<p>SWBAT demonstrate an understanding of stars, planets, and the solar system.</p>	<p>S6E2. Students will understand the effects of the relative positions of the earth, moon and sun. a. Demonstrate the phases of the moon by showing the alignment of the earth, moon, and sun.</p>
<p>33. Name this phase of the moon:</p>  <p>How do you know that it is this phase?</p>	<p>SWBAT demonstrate an understanding of stars, planets, and the solar system.</p>	<p>S6E2. Students will understand the effects of the relative positions of the earth, moon and sun. a. Demonstrate the phases of the moon by showing the alignment of the earth, moon, and sun.</p>
<p>34. Name this phase of the moon:</p>  <p>How do you know that it is this phase?</p>	<p>SWBAT demonstrate an understanding of stars, planets, and the solar system.</p>	<p>S6E2. Students will understand the effects of the relative positions of the earth, moon and sun. a. Demonstrate the phases of the moon by showing the alignment of the earth, moon, and sun.</p>
<p>35. Name this phase of the moon:</p>  <p>How do you know that it is this phase?</p>	<p>SWBAT demonstrate an understanding of stars, planets, and the solar system.</p>	<p>S6E2. Students will understand the effects of the relative positions of the earth, moon and sun. a. Demonstrate the phases of the moon by showing the alignment of the earth, moon, and sun.</p>
<p>36. Draw a diagram and describe why the moon changes phases.</p>	<p>SWBAT demonstrate an understanding of stars, planets, and the solar system.</p>	<p>S6E2. Students will understand the effects of the relative positions of the earth, moon and sun. a. Demonstrate the phases of the moon by showing the alignment of the earth, moon, and sun.</p>
<p>37. The ____ is the layer in the atmosphere where weather occurs.</p>	<p>SWBAT demonstrate an understanding of stars, planets, and the solar system.</p>	<p>S6E4. Students will understand how the distribution of land and oceans affects climate and weather. a. Demonstrate that land and water absorb and lose heat at different rates and explain the resulting effects on weather patterns.</p>
<p>38. Describe what happens when air near Earth's surface warms?</p>	<p>SWBAT understand and describe how weathering forms soil and how weather and erosion change the earth's surface.</p>	<p>S6E4. Students will understand how the distribution of land and oceans affects climate and weather. a. Demonstrate that land and water absorb and lose heat at different rates and explain the resulting effects on weather patterns.</p>
<p>39. If a flashlight represented sunlight shining on the Earth, which angle would heat the lit area the most, a 90 degree angle or a 60 degree angle? Why?</p>	<p>SWBAT measure and describe changes in weather and how they relate to the water cycle and position of the earth and sun.</p>	<p>S6E2. Students will understand the effects of the relative positions of the earth, moon and sun. c. Relate the tilt of the earth to the distribution of sunlight throughout the year and its effect on climate.</p>
<p>40. In general, where does the Earth have higher temperatures? Why?</p>	<p>SWBAT measure and describe changes in weather and how they relate to the water cycle and position of the earth and sun.</p>	<p>S6E2. Students will understand the effects of the relative positions of the earth, moon and sun. c. Relate the tilt of the earth to the distribution of sunlight throughout the year and its effect on climate.</p>



<p>41. Draw a diagram and describe how Earth's tilt is related to the seasons. Use the following words to label/describe your diagram: summer solstice, winter solstice, autumnal equinox, vernal equinox, winter, spring, summer, fall, direct light, indirect light, and axis.</p>	<p>SWBAT measure and describe changes in weather and how they relate to the water cycle and position of the earth and sun.</p>	<p>S6E2. Students will understand the effects of the relative positions of the earth, moon and sun. c. Relate the tilt of the earth to the distribution of sunlight throughout the year and its effect on climate.</p>
<p>42. When tectonic plates push together on Earth's surface, the area is referred to as a(n) _____ boundary.</p>	<p>SWBAT recognize and describe the different geologic processes that shape earth.</p>	<p>S6E5. Students will investigate the scientific view of how the earth's surface is formed. e. Recognize that lithospheric plates constantly move and cause major geological events on the earth's surface.</p>
<p>43. Underneath a divergent boundary, the mantle would move <b>up</b> or <b>down</b> in the convection cell? Circle one.</p>	<p>SWBAT recognize and describe the different geologic processes that shape earth.</p>	<p>S6E5. Students will investigate the scientific view of how the earth's surface is formed. e. Recognize that lithospheric plates constantly move and cause major geological events on the earth's surface.</p>
<p>44. When tectonic plates pull apart on Earth's surface, the area is referred to as a(n) _____ boundary.</p>	<p>SWBAT recognize and describe the different geologic processes that shape earth.</p>	<p>S6E5. Students will investigate the scientific view of how the earth's surface is formed. e. Recognize that lithospheric plates constantly move and cause major geological events on the earth's surface.</p>
<p>45. What happens when dense crust pushes against buoyant crust, as in an oceanic/continental boundary?</p>	<p>SWBAT recognize and describe the different geologic processes that shape earth.</p>	<p>S6E5. Students will investigate the scientific view of how the earth's surface is formed. d. Describe processes that change rocks and the surface of the earth. e. Recognize that lithospheric plates constantly move and cause major geological events on the earth's surface.</p>
<p>46. Name the two types of crust found on Earth's surface and the predominant rock type that makes up each type of crust.</p>	<p>SWBAT recognize and describe the different geologic processes that shape earth.</p>	<p>S6E5. Students will investigate the scientific view of how the earth's surface is formed. a. Compare and contrast the Earth's crust, mantle, and core including temperature, density, and composition. e. Recognize that lithospheric plates constantly move and cause major geological events on the earth's surface.</p>
<p>47. Which type of Earth's crust is thinner, yet denser?</p>	<p>SWBAT recognize and describe the different geologic processes that shape earth.</p>	<p>S6E5. Students will investigate the scientific view of how the earth's surface is formed. a. Compare and contrast the Earth's crust, mantle, and core including temperature, density, and composition.</p>

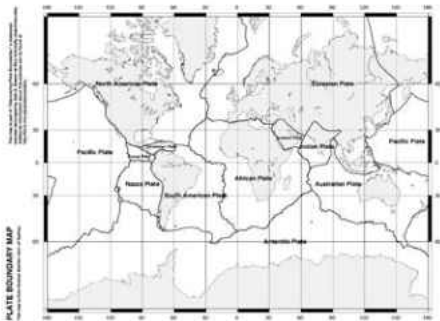
48. Along the western edge of California is a transform fault called the San Andreas fault. Look at the diagram of this feature and explain what will eventually happen in relation to Los Angeles and San Francisco?



SWBAT recognize and describe the different geologic processes that shape earth.

S6E5. Students will investigate the scientific view of how the earth's surface is formed.  
 d. Describe processes that change rocks and the surface of the earth. e. Recognize that lithospheric plates constantly move and cause major geological events on the earth's surface.

49-55. Using the Plate boundary map provided, label the following: an oceanic/continental plate boundary (A), a continental/continental plate boundary (B), an oceanic/oceanic plate boundary (C), a subduction zone (D), a convergent boundary (E), a divergent boundary (F), and a transform boundary (G).



SWBAT recognize and describe the different geologic processes that shape earth.

S6E5. Students will investigate the scientific view of how the earth's surface is formed.  
 d. Describe processes that change rocks and the surface of the earth. e. Recognize that lithospheric plates constantly move and cause major geological events on the earth's surface. f. Explain the effects of physical processes (plate tectonics, erosion, deposition, volcanic eruption, gravity) on geological features including oceans (composition, currents, and tides).

# APPENDIX C

## Life/Earth Science Content Knowledge Pre-Test

Pre-Test

Life/Earth Science Fall 2012

Name: \_\_\_\_\_

Name and function of each organelle.

1. \_\_\_\_\_

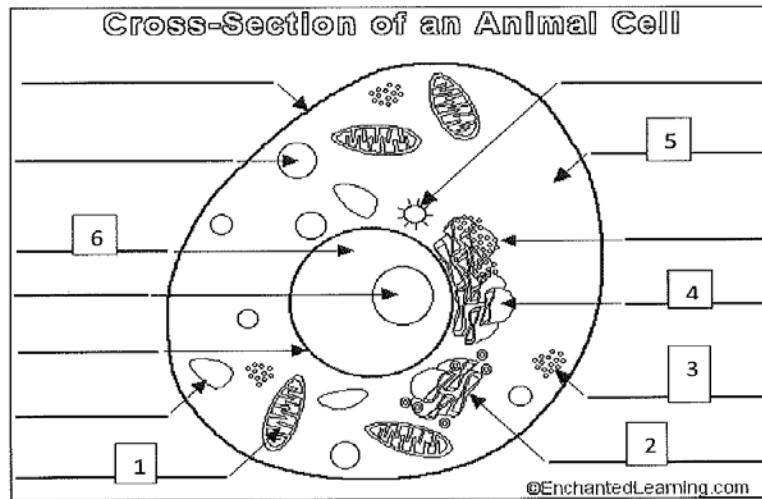
4. \_\_\_\_\_

2. \_\_\_\_\_

5. \_\_\_\_\_

3. \_\_\_\_\_

6. \_\_\_\_\_



7. In diffusion, molecules move from areas of \_\_\_\_\_ concentration to areas of \_\_\_\_\_ concentration.

8. In algae and the leaves of green plants, photosynthesis occurs in cells that contain this organelle: \_\_\_\_\_.

9. Write the equation for cellular respiration. Where does this process occur and what is the importance of oxygen for this process?

10. Explain how photosynthesis is an important part of the interdependence of life.

11. When moving from one trophic level to the next, only 10% of the total energy is transferred. Where does the other 90% go?

12. In our diffusion lab, we used iodine to show if there was any movement through the plastic bag. Iodine is called an \_\_\_\_\_, because it changes color when it comes into contact with starch.

13. The basic structural unit of all living things is a \_\_\_\_\_.

14. When one organism in a relationship benefits and the other organism is not affected, this relationship is called \_\_\_\_\_.

15. Describe a physical adaptation that would benefit a mammal as a *predator*.

\_\_\_\_\_

16. Name two characteristics that are unique to all mammals:

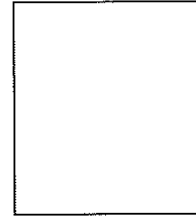
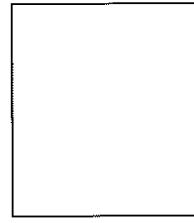
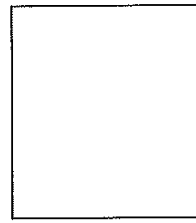
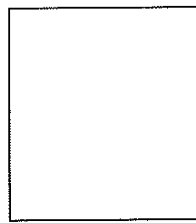
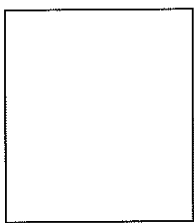
a. \_\_\_\_\_

b. \_\_\_\_\_

17. Carnivores have teeth that are specialized for being a \_\_\_\_\_.

18. Rodents have rootless incisors. If we (humans) had rootless incisors, what would we do diligently for our teeth? \_\_\_\_\_

19. Use the following boxes to draw each step in the cell cycle and name it. Clearly show where the chromosomes are positioned during each phase.



\_\_\_\_\_

20. The cellular process that duplicates the genetic material prior to its distribution to the daughter cells is \_\_\_\_\_.

21. Using the template strand of DNA provided, identify which strand of DNA would be the complementary strand after *replication*. Template Strand: **GCAATCGCACATTG**

22. The cellular process \_\_\_\_\_ is composed of two steps: transcription and translation.

23. A normal human karyotype would contain how many chromosomes?

(total number, not pairs) \_\_\_\_\_

24. Indicate what the normal female sex chromosomes would be. \_\_\_\_\_

25. Gregor Mendel experimented with true breeding pea plants that exhibited spherical seeds and dented seeds. The spherical seeds were dominant. Draw a Punnett Square and show the genotypic and phenotypic ratios for the offspring for a cross between a heterozygous pea plant with spherical seeds and a pea plant with dented seeds.

26. How does the cohesive property of water work? Use words and/or diagrams to explain your answer. \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

27. Draw a water molecule. Label the atoms and any charges associated with it.

28. Describe how sedimentary rocks are formed as a part of the rock cycle.  
\_\_\_\_\_  
\_\_\_\_\_

29. Name one of the metamorphic rocks that we studied. Identify its *texture* and explain what *texture* refers to in a metamorphic rock.  
Rock: \_\_\_\_\_  
Texture: \_\_\_\_\_

30. Name this phase of the moon: \_\_\_\_\_



Why is it this phase:  
\_\_\_\_\_

31. Name this phase of the moon: \_\_\_\_\_



Why is it this phase:

\_\_\_\_\_

32. Name this phase of the moon: \_\_\_\_\_



Why is it this phase:

\_\_\_\_\_

33. Name this phase of the moon: \_\_\_\_\_



Why is it this phase:

\_\_\_\_\_

34. Draw a diagram and describe why the moon changes phases.

35. The \_\_\_\_\_ is the layer in the atmosphere where weather occurs.

36. Describe what happens as air near Earth's surface warms.

\_\_\_\_\_  
\_\_\_\_\_

37. If a flashlight represented sunlight shining on a globe, which angle would heat the surface the most, a 90 degree angle or a 60 degree angle? Why? \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

38. In general, where does the world have higher temperatures? Why? \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

39. Draw a diagram **AND** describe how Earth's tilt is related to the seasons. Use the following words to label your diagram: Summer solstice, Winter solstice, autumnal equinox, vernal equinox, winter, spring, summer, fall, direct light, indirect light.

40. When tectonic plates push together on Earth's surface, the area is referred to as a(n) \_\_\_\_\_ boundary.

41. Underneath a divergent boundary, the mantle would move **up** or **down** in the convection cell? Circle one.

42. When tectonic plates pull apart on Earth's surface, the area is referred to as a(n) \_\_\_\_\_ boundary.

43. What happens when dense crust pushes against buoyant crust, as in an oceanic/continental boundary? \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

44. Name the two types of crust found on Earth's surface and the predominant rock type that makes up each type of crust.

a. Crust: \_\_\_\_\_, type of rock: \_\_\_\_\_

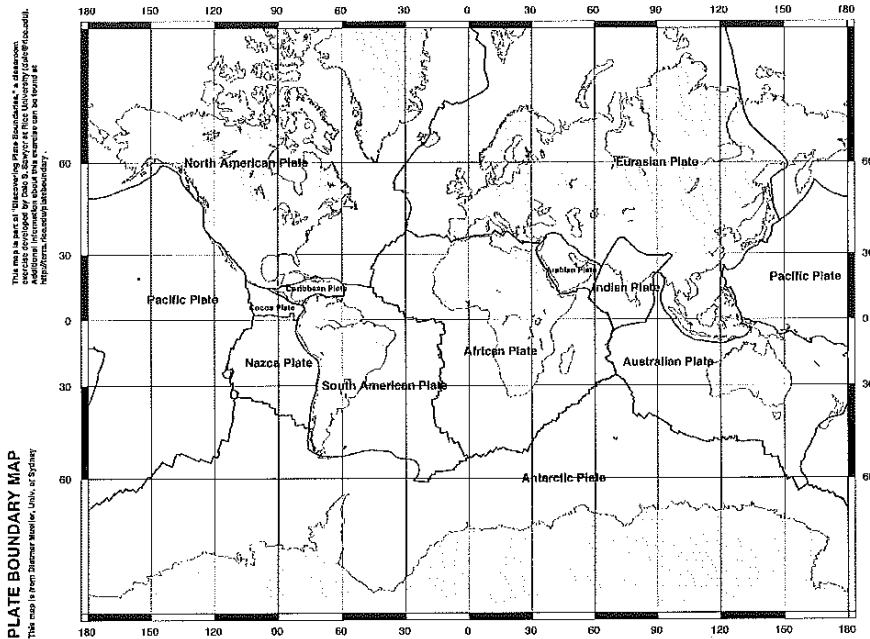
b. Crust: \_\_\_\_\_, type of rock: \_\_\_\_\_

45. Which type of crust is thinner, yet more dense? \_\_\_\_\_

46. Along the western edge of California is a transform fault called the San Andreas fault. Look at the diagram of this feature and explain what will eventually happen in relation to Los Angeles and San Francisco.







47-53. Using the Plate boundary map provided, label the following: an oceanic/continental plate boundary (A), a continental/continental plate boundary (B), an oceanic/oceanic plate boundary (C), a subduction zone (D), a convergent boundary (E), a divergent boundary (F), and a transform boundary (G).

54. Write a hypothesis for the following question:

How does light affect plant growth?

55. Design an experiment to test this hypothesis.

## APPENDIX D

### PRIOR SCIENCE COURSES SURVEY

Demographic and prior science courses survey

1. Male or Female
2. Declared major
3. Please name all of the science courses taken prior to this semester.

High School:

Freshman year:

Sophomore year:

Junior year:

Senior year:

College:

## APPENDIX E

### PRE-STEBI FOR GENERAL SCIENCE EFFICACY

As a future science teacher, please indicate the degree to which you agree or disagree with each statement below using the following indicators:

**1= STRONGLY DISAGREE, 2= DISAGREE, 3= UNCERTAIN, 4= AGREE, 5= STRONGLY AGREE**

Question:	Response				
	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
1. When a student does better than usual in science, it is often because the teacher exerted a little extra effort.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
2. I will continually find better ways to teach science.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
3. Even if I try very hard, I will not teach science as well as I will most subjects.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
4. When the science grades of students improve, it is often due to their teacher having found a more effective teaching approach.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
5. I know the steps necessary to teach science concepts effectively.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
6. I will not be very effective in monitoring science experiments.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
7. If students are underachieving in science, it is most likely due to ineffective science teaching.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
8. I will generally teach science ineffectively.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
9. The inadequacy of a student's science background can be overcome by good teaching.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
10. The low science achievement of students cannot generally be blamed on their teachers.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
11. When a low-achieving child progresses in science, it is usually due to extra attention given by the teacher.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
12. I understand science concepts well enough to be effective in teaching elementary science.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE

As a future science teacher, please indicate the degree to which you agree or disagree with each statement below using the following indicators:  
**1= STRONGLY DISAGREE, 2= DISAGREE, 3= UNCERTAIN, 4= AGREE, 5= STRONGLY AGREE**

Question:	Response				
	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
13. Increased effort in science teaching produces little change in students' science achievement.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
14. The teacher is generally responsible for the achievement of students in science.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
15. Students' achievement in science is directly related to their teacher's effectiveness in science teaching.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
16. If parents comment that their child is showing more interest in science, it is probably due to the child's teacher.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
17. I will find it difficult to explain to students why science experiments work.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
18. I will typically be able to answer students' science questions.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
19. I wonder if I will have the necessary skills to teach science.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
20. Given a choice, I will not invite the principal to evaluate my science teaching.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
21. When a student has difficulty understanding a science concept, I will usually be at a loss as to how to help the student understand.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
22. When teaching science, I will usually welcome student questions.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
23. I do not know what to do to turn students on to science.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE

## APPENDIX F

### SAMPLE GUIDED INQUIRY LAB

#### **How many drops of water can fit on a penny?**

**Engage:** Paper clip demo. (How many paper clips can a full jar of water hold?) In your own words, write the definition for: Cohesion, Adhesion, Surface Tension.

**Explore:** How many drops of water can fit on one side of a penny?

Write a hypothesis/prediction using if/then wording about how many drops of water a penny can hold. Include the relationship between the independent and dependent variable. Next, record the # of drops that each group member predicts in your data table.

Part A: This is a control test for comparison with later results.

1. Draw a data table to record 4 trials and an average in your lab notebook.
2. Place a penny on a paper towel.
3. Use a pipette to place drops of water on the penny (one at a time) until the water runs over the edge of the penny.
4. Record the number of drops for that trial in the table.
5. Repeat steps 1-4 for 3 additional trials.

Part B: This section involves a testing liquid, soap.

Write a hypothesis/prediction using if/then wording about how many drops of water your penny can hold *now*. Include the relationship between the independent and dependent variable. Next, record the # of drops that each group member predicts in your data table.

1. Smear your finger very lightly on the soap dispenser to get a film of soap on your finger.
2. Take another penny, and rub the soap film on the surface of the penny.
3. Place the penny on a paper towel.
4. Use a pipette to place drops of water on the penny (one at a time) until the water runs over the edge of the penny.
5. Record the number of drops for that trial in the table.
6. Repeat steps 1-5 for 3 additional trials.

**Explain:** explain your results in your lab notebook from both parts of the experiment in terms of *cohesion and adhesion*.

Compare your data tables to the other lab groups in class. Provide at least 2 reasons for any similarities and differences you identify.

What could we have done to make sure that all groups ended up with similar results?

What is the control for this experiment? What is the independent variable? What is the dependent variable?

**Elaborate:** Based on the results from this investigation, develop a new hypothesis and prediction and write an experimental design to test it with your lab group.

## APPENDIX G

### SAMPLE TRADITIONAL INSTRUCTION LAB

#### Lab: Properties of Water

Water is everywhere. It's in the air we breathe. It's in our sink faucets, and it's in every cell of our body. Water is an unusual substance with special properties. Just think about the wonder of

1. How does water rise from the roots of a redwood tree to the very top?
2. How do insects walk on water?
3. Why does ice float rather than sink?
4. Why do people become seriously ill, or die, if they go without liquid for a week or so?
5. How would life in a lake be affected if ice sank and lakes froze from the bottom up?

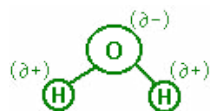
#### Materials:

Chromatography paper strips  
Cylinders  
Detergent  
Vis-à-vis black ink pens  
Wax paper  
10 ml grad. Cylinders

scissors  
beaker  
cooking oil  
red food coloring  
water  
medicine droppers

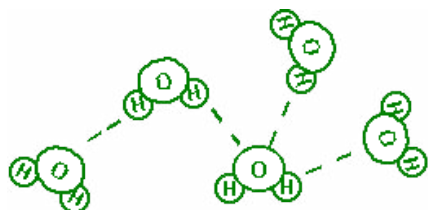
50 ml. grad.  
stirring rods  
Pennies  
glass slides

Water covers about three fourths of the surface of the earth. It is ubiquitous. It is also one of the simplest yet most important molecules in living systems. It makes up from 50 to 95 percent of the weight of living organisms. The cytoplasm of a cell is a water-based solution that contains a variety of ions, salts, and molecules, which make life 'happen.' Water is literally involved in every facet of life.



The simplicity of the water molecule belies the complexity of its properties. Based on its small size and light weight, one can predict how it *should* behave, yet it remains liquid at much higher temperatures than expected. It also boils and freezes at much too high, or low, of a temperature for a molecule of its size. Many of these unexpected properties of water are due to the fact that water molecules are attracted to each other like small magnets (cohesion). This attraction results in turn from the structure of the water molecule and the characteristics of the atoms it contains.

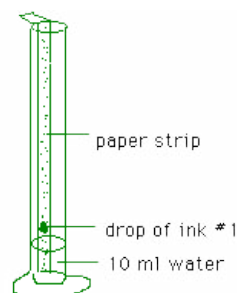
Each molecule of water is made up of two atoms of hydrogen connected to one atom of oxygen, as shown below. This is summarized in the familiar formula, H<sub>2</sub>O.



Atoms are most stable when they have a particular configuration of their outer shells, a concept, which will be discussed in future labs. These configurations explain why hydrogen in water will take on a **partial positive charge** and why oxygen will take on a **partial negative charge**. These partial charges cause water molecules to 'stick' to each other like magnets. *The 'stickiness' in this particular case is due to hydrogen bonding. In this case, hydrogen bonding involves the attraction between the positively charged hydrogen atom of one water molecule and the negatively charged oxygen atom of another water molecule.* As no electrons are actually shared however, **hydrogen bonds** are much weaker than covalent bonds - they easily break and easily form again.

### Exercise 1: The Climbing Property of Water

1. Water moves to the tops of tall trees due to **capillary action** combined with root pressure and **evaporation** from the stomata (openings) in the leaves. Water will also climb up paper, and often the migrating water will carry other molecules along with it. The distance traveled by these other molecules will vary with their **mass** and **charge**.
2. How fast do you think water would climb a strip of absorbent paper about one-half inch wide?  
about one inch per \_\_\_\_\_ (time)
3. Obtain a 50 ml graduated cylinder, and tear off a strip of chromatography paper that is just long enough to hang over the side of the cylinder (inside) and reach to the bottom. See diagram on next page.



50 ml graduated cylinder

4. Run the paper strip along the edge of some scissors to take the curl out of it.



5. Place a single small spot from a black Vis-a-Vis pen on the paper, about one inch from the bottom, and let it **dry**.

6. Put 10 ml of water into the graduated cylinder and place the strip of paper in the cylinder so that the bottom end is immersed in water and the drop of ink is just above the surface of the water – NOT touching the water. Fold the paper over the top side.

7. Note the starting time below.

8. Watch and note the time at 5-minute intervals. When the water climbs to the top of the paper, remove the paper from the water, and let it dry.

<b>Time (minutes)</b>	<b>Distance (inches)</b>
0	
5	
10	
15	
20	
25	
30	

9. How did the ink change? Tape/staple the paper onto the page here, and label each color on the strip.

10. How do you explain the results? Your explanation should involve **capillary action**, **polar molecules** and **hydrogen bonding**.

## **Exercise 2: Surface Tension and Adhesion “Dirty Penny”**

**2a. Drop behavior – water on a penny.**

1. Obtain a medicine dropper and a small (10 ml) graduated cylinder. Make sure the dropper is clean.
2. Drop water into the graduated cylinder with the dropper, counting each drop.
3. How many drops, of the size produced by your medicine dropper, are in each cubic centimeter (cc) of water? (1 cubic centimeter = 1 milliliter)? \_\_\_\_\_ drops
4. Conversely, how much water is in each drop? (divide 1cc by the number of drops)  
\_\_\_\_\_ cc. per drop, average
5. Now, let's see how many drops of water you can place on the surface of a penny before it overflows.
6. How many drops do you predict? Have each person make a prediction.

person	#1	
person	#2	
person	#3	
person	#4	
Total	1 - 4	
Average		

7. Drop water from the dropper onto a penny, keeping careful count of each drop. Draw a diagram below showing the shape of the water on the penny after one drop, when the penny is about half full, and just before it overflows.



8. How many drops were you able to place on the surface of the penny before it overflowed? \_\_\_\_\_ drops
9. If the number of drops is very different from your prediction, explain what accounts for the difference.
10. Explain your results in terms of *cohesion*.

## 2b. Effects of Detergent “Clean Penny”

1. With your finger, spread one small drop of detergent on the surface of a dry penny. Smear it lightly.

- How many drops do you think this penny will hold after being smeared with detergent, more, less, or the same as before? Why?
- Specifically, how many drops do you think it will hold? Have each person make a prediction.

person	#1	
person	#2	
person	#3	
person	#4	
Average		

- Using the same dropper as before, add drops of water to the penny surface. Keep careful count of the number of drops, and draw the water on the penny after one drop, about half full, and just before overflowing.



- How many drops were you able to place on the penny before it overflowed this time? \_\_\_\_\_ drops
- Did the detergent make a difference? Describe the effect of the detergent.
- What does the **detergent** do to have this effect on water?
- Explain how **detergents** act as cleaning agents, considering the **cohesion** among water molecules and the affects of **amphipathic molecules**.

### 2c. Drop shape on glass and wax paper.

- What will be the shape of a drop of water on (a) a piece of wax paper and (b) a glass slide. Draw the shape of the drop you expect on each surface:

\_\_\_\_\_ Wax paper    glass

- Why did you predict as you did? What assumptions are guiding your thinking?
- Perform the experiment. Place several drops of water on each surface and draw the results below.

\_\_\_\_\_ Wax paper    glass

- Compare your predictions with your observations and explain.

5. Can you explain the differences in drop behavior in terms of **adhesion** - that is, the formation (or absence) of **hydrogen bonds** between molecules of different types? Which molecules?

### Exercise 3: Cohesion of Water

#### 3a: Water and Oil

1. Using a **50 mL** graduated cylinder, add ~ 3 inches of water.
2. What will happen if you add cooking oil? (Predict by choosing a, b, c, d, or e below)
  - a. the oil will float on top of the water
  - b. the oil will sink to the bottom of the water
  - c. the oil will dissolve in the water
  - d. the oil will become mixed up with the water
  - e. other (what?)

Oil is a **hydrophobic** or 'water hating' molecule, so called because its chemical structure does not allow the formation of hydrogen bonds. Therefore, oil does not dissolve in water. When mixed, the two substances form separate layers, and because oil is less dense, it sits on top of water.

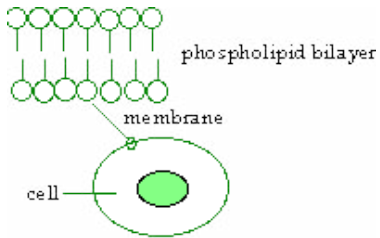
3. Gently add **5 ml** of cooking oil by tilting the cylinder of water slightly and letting the oil run slowly down the inside of the cylinder.
4. What happened?
5. Save this graduated cylinder with its contents and get a clean 50 mL cylinder for the next experiment.

#### 3b: Oil and water

1. Using a **50 mL** graduated cylinder, add **5 ml** of oil.
2. What will happen when you add water? (Predict by choosing a, b, c, d, or e below)
  - a. the water will float on top of the oil
  - b. the water will sink to the bottom of the oil
  - c. the water will dissolve in the oil
  - d. the water/oil will become mixed
  - e. other (what?)
3. Gently add ~**2 inches** of water by tilting the cylinder of oil slightly and letting the water run slowly down the inside of the cylinder. What happened?
4. Which is less dense (that is that has less weight per ml.), oil or water?
5. 

---

This characteristic behavior of water and oil is of critical importance for living things, determining many properties of the cell. Can you explain how? Consider the picture that follows:



6. What mechanism causes water molecules and oil molecules to separate from one another? Your explanation should involve **polar** and **non-polar** molecules, the effects of **polarity** on the molecular interactions, and **hydrogen bonding**.

### 3c: Water, Oil and Dye

1. Predict what will happen if you add a few drops of a water-soluble dye solution to each of the above graduated cylinders containing water and oil. Will the dye mix with the water, the oil, or both?
2. Perform the experiment. Add a few drops of dye to each cylinder. Use a glass-stirring rod (or shake cylinder with thumb over opening) to penetrate the interface between each layer, giving the dye access to both water and oil. How does the dye behave in each cylinder? Does it diffuse into the oil? Into the water?
3. Compare your predictions and results. Explain any differences.
4. Stir the contents of each cylinder with a stirring rod and then let it sit.
5. Will the contents remain mixed? Why do you think so?
6. Observe what happens, compare with your prediction, and explain why it happens. Your explanation should involve **polarity**, **polar** and **non-polar** molecules, **solution** and **hydrogen bonding**.

## APPENDIX H

### Life Science Content Knowledge Posttest with Scored Rubric

Mid-Term Exam

Life Science Fall 2012

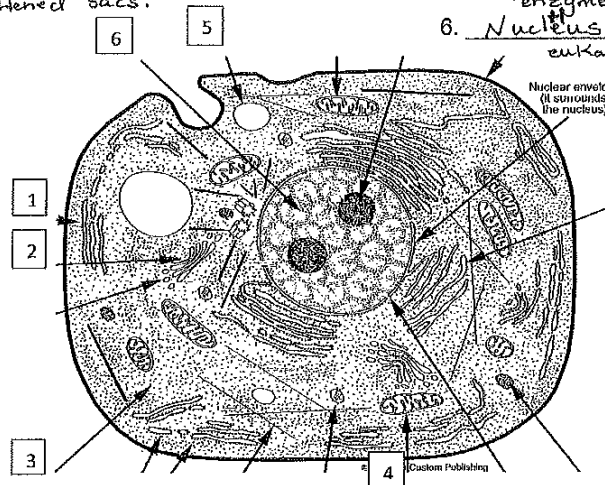
Name: Scoring Guide

Name and function of each organelle.

+12

1. Rough Endoplasmic retic. - membranous organelle<sup>+1</sup> studded w/ ribosomes; transport.
2. Golgi Apparatus - membranous<sup>+1</sup> stack of flattened sacs.

3. Cytoplasm - jelly-like substance that supports organelles.<sup>+1</sup>
4. Mitochondria - membranous organelle, site of cellular respiration.<sup>+1</sup>
5. Lysosome - organelles<sup>+1</sup> that contain enzymes to digest things.
6. Nucleus - the control center of eukaryotic cells.<sup>+1</sup>



+2

7. In diffusion, molecules move from areas of high<sup>+1</sup> concentration to areas of low<sup>+1</sup> concentration.

+1

8. In algae and the leaves of green plants, photosynthesis occurs in cells that contain chloroplasts<sup>+1</sup>

+6

9. Write the equation for cellular respiration. Where does this process occur and what is the importance of oxygen for this process?  
 $+4C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ ; Occurs in the mitochondria.<sup>+1</sup>

+1 Oxygen is necessary for all of the aerobic steps to occur which produce ~38 ATP.

10. Explain how photosynthesis is an important part of the interdependence of life.

+3

Photosynthesis converts solar radiation into glucose.<sup>+1</sup> Plants are an essential component to any food cycle (chain or web) as they are producers.<sup>+1</sup> Without them, there wouldn't be any other trophic levels.<sup>+1</sup>

11. When moving from one trophic level to the next, only 10% of the total energy is transferred. Where does the other 90% go?

+2

The rest of the energy is lost through metabolic processes (ingestion, digestion, etc.).<sup>+2</sup> and given off as heat.

26pts.

1

+1 12. In our diffusion lab, we used iodine to show if there was any movement through the plastic bag. Iodine is called an indicator +1, because it changes color when it comes into contact with starch.

+1 13. The basic structural unit of all living things is a cell +1.

+1 14. Insects make up about 75% +1 in relative abundance of the animal species on Earth.

+1 15. When one organism in a relationship benefits and the other organism is not affected, this relationship is called commensalism +1.

+2 16. Describe a physical adaptation that would benefit an insect as a predator.

Large claws or biting mouthparts for holding prey. +2

17. Name the *three main* body segments of an insect and tell the primary function of each.

	Name	Function
+6	a. <u>head +1</u>	<u>Control center + sensory +1</u>
	b. <u>thorax +1</u>	<u>Mobility - wings + legs +1</u>
	c. <u>abdomen +1</u>	<u>digestive + reproductive structures +1</u>

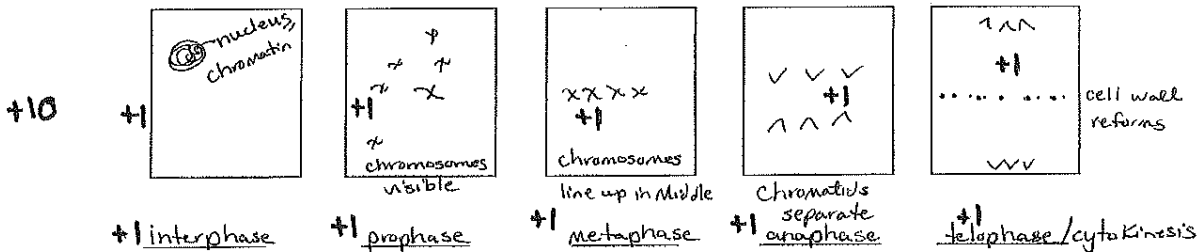
18. Name two characteristics that are unique to all mammals:

- +2 a. hair +1  
 b. nurse their young +1

19. Carnivores have teeth that are specialized for being a predator.

+1 20. Rodents have rootless incisors. If we (humans) had rootless incisors, what would we do diligently for our teeth? Chew to grind them down. +1

21. Use the following boxes to draw each step in the cell cycle and name it. Clearly show where the chromosomes are positioned during each phase.



+1 22. The cellular process that duplicates the genetic material prior to its distribution to the daughter cells is replication +1.

26pts

+4 23. Using the template strand of DNA provided, identify which strand of DNA would be the complementary strand after replication.

Template Strand: GCA|ATC|GCA|CAT|TG  
CGT|TAG|CGT|GTA|AC

+1 24. The cellular process Protein synthesis is composed of two steps: transcription and translation.

+1 25. A normal human karyotype would contain how many chromosomes? (total number, not pairs) 46

+1 26. Indicate what the normal female sex chromosomes would be. XX

+8 27. Gregor Mendel experimented with true breeding pea plants that exhibited spherical seeds and dented seeds. The spherical seeds were dominant. Draw a Punnett Square and show the genotypic and phenotypic ratios for the offspring for a cross between a heterozygous pea plant with spherical seeds and a pea plant with dented seeds.

	S	s
S	Ss	sS
s	sS	ss

+2 Genotype - 50% Ss  
 50% ss

+2 Phenotype - 50% Spherical  
 50% dented

+4 28. The basis of the scientific method is inquiry – which is asking questions and then trying to come up with answers. If scientists see something they don't understand, they have the urge to ask questions. So...if we came up with the question, "**Why do spiders spin webs?**" what would be a good hypothesis and prediction to start our experimental process?

Hypothesis written as a testable statement; shows relationship between an independent variable and a dependent variable.

+2

+2

3

19 Pts. total



29. How would you design an experiment to test plant growth?

Include the following:

- +1 A question +1
- +2 A hypothesis independent<sup>+1</sup> + dependent<sup>+1</sup> variables with relation
- +2 List independent and dependent variables; identified/labeled
- Write your method – In DETAIL!! +10
- +10 Looking for attention to detail – to the point of repeatability; does not have to be complex – just thorough.  
Example might be : temperature affect on plant growth

30. The Canadian Lynx eats snowshoe hares. Look at the following data collected from a population study on Lynx and hares. What does this data tell you? How can you display it in a way that shows how these populations cycle in relation to one another? You may use the graph paper provided.

Year	Lynx	Hares
1880	15	85
1885	60	130
1890	25	20
1895	42	40
1900	10	40
1905	7	60
1910	35	20
1915	20	70
1920	40	15
1925	18	20

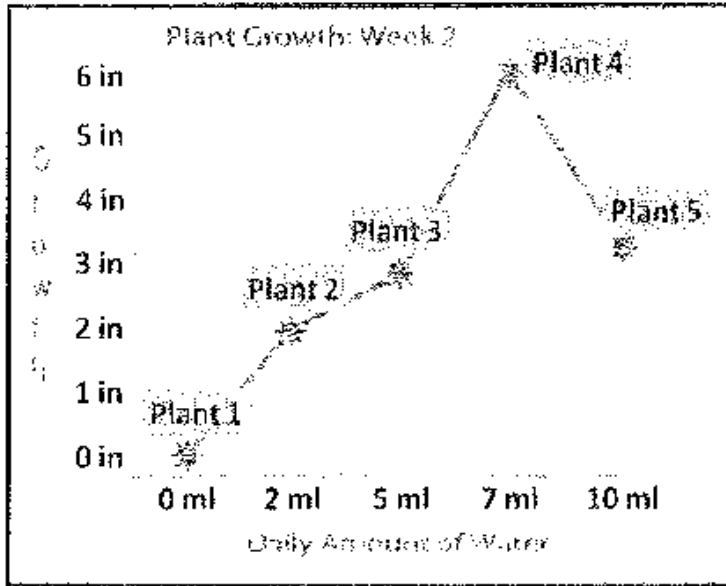
Can student produce a line graph with independent/  
dependent variables in correct place and labeled<sup>+2</sup>  
accordingly? Should produce a graph that  
shows how two populations affect one another.

+ 8

Accuracy on graph +2

Title +1

31. Using the data provided, write what the initial question, hypothesis and prediction may have been. Then, what could be a new question as a result of this data set?



- +1 Question +1
- +2 hypothesis: independent variable + dependent variable with relationship. +1
- +2 new question: relates directly to data. demonstrates +2 extension beyond initial study.

5pts

99 pts. to final exam

## APPENDIX I

### POST LIFE STEBI MODIFIED FOR LIFE SCIENCE

As a future life science teacher, please indicate the degree to which you agree or disagree with each statement below using the following indicators:

**5= STRONGLY AGREE, 4= AGREE, 3= UNCERTAIN, 2= DISAGREE, 1= STRONGLY DISAGREE**

Question:	Response				
	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
1. When a student does better than usual in life science, it is often because the teacher exerted a little extra effort.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
2. I will continually find better ways to teach life science.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
3. Even if I try very hard, I will not teach life science as well as I will most subjects.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
4. When the life science grades of students improve, it is often due to their teacher having found a more effective teaching approach.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
5. I know the steps necessary to teach life science concepts effectively.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
6. I will not be very effective in monitoring life science experiments.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
7. If students are underachieving in life science, it is most likely due to ineffective science teaching.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
8. I will generally teach life science ineffectively.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
9. The inadequacy of a student's life science background can be overcome by good teaching.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
10. The low life science achievement of students cannot generally be blamed on their teachers.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
11. When a low-achieving child progresses in life science, it is usually due to extra attention given by the teacher.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
12. I understand life science concepts well enough to be effective in teaching elementary science.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE

As a future life science teacher, please indicate the degree to which you agree or disagree with each statement below using the following indicators:  
**5= STRONGLY AGREE, 4= AGREE, 3= UNCERTAIN, 2= DISAGREE, 1= STRONGLY DISAGREE**

Question:	Response				
	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
13. Increased effort in life science teaching produces little change in students' life science achievement.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
14. The teacher is generally responsible for the achievement of students in life science.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
15. Students' achievement in life science is directly related to their teacher's effectiveness in life science teaching.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
16. If parents comment that their child is showing more interest in life science, it is probably due to the child's teacher.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
17. I will find it difficult to explain to students why life science experiments work.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
18. I will typically be able to answer students' life science questions.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
19. I wonder if I will have the necessary skills to teach life science.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
20. Given a choice, I will not invite the principal to evaluate my life science teaching.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
21. When a student has difficulty understanding a life science concept, I will usually be at a loss as to how to help the student understand.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
22. When teaching life science, I will usually welcome student questions.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
23. I do not know what to do to turn students on to life science.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE

## APPENDIX J

### Earth Science Content Knowledge Posttest with Scored Rubric

Final Exam

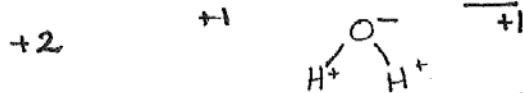
Earth Science Fall 2012

Name: Scoring Guide

1. How does the cohesive property of water work? Use words and/or diagrams to explain your answer.

+2 Cohesion of water involves water molecules sticking to water molecules with hydrogen bonding.  $H^+ \overset{+1}{O} \cdots \overset{-1}{O} - H$  A good example is the way water beads-up on a penny. +1

2. Draw a water molecule. Label the atoms and any charges associated with it.



3. Describe how sedimentary rocks are formed as a part of the rock cycle. +1

+3 Sedimentary rocks can be formed through weathering and erosion to form sediment, and then compaction and cementation to form the rock. Any rock type (Meta, Sed, Igni) can be broken down to a sedimentary rock. +1

4. Name one of the metamorphic rocks that we studied. Identify its texture and explain what texture refers to in a metamorphic rock.

Rock: Marble +1

+3 Texture:

Non-foliated; texture refers to the banding patterns that appear at the the rock was formed. Marble has a random structure w/ no distinct therefore = non-foliated. +1

5. Name this phase of the moon: Waning Gibbous +1



Why is it this phase: +1

Light on the left, more than half lit.

6. Name this phase of the moon: First Quarter +1



Why is it this phase: +1

Light on the right, exactly half lit.

7. Name this phase of the moon: New Moon +1



Why is it this phase: +1

No light visible. +1

No pts.

1

8. Name this phase of the moon: Waxing Crescent <sup>+1</sup>

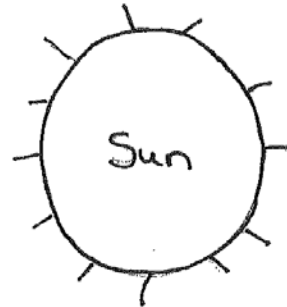
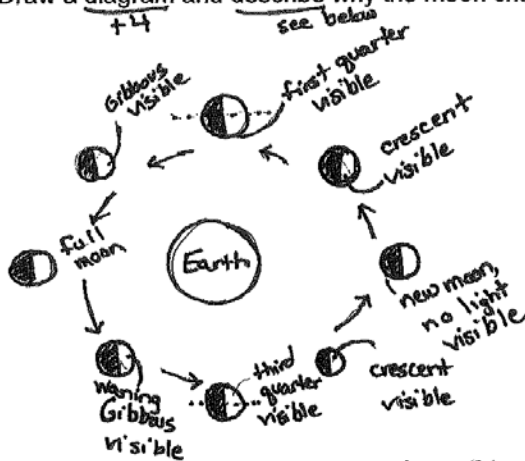
+2



Why is it this phase: <sup>+1</sup>  
Light on the right, less than half lit.

9. Draw a diagram and describe why the moon changes phases.

+7



The moon changes phases depending on how much of the reflected light is visible from earth. This refers to the sun-earth-moon angle. Half of the moon is lit at any time, but only a portion of that may be visible. <sup>+1</sup>

+1

10. The troposphere <sup>+1</sup> is the layer in the atmosphere where weather occurs.

11. Describe what happens as air near Earth's surface warms.

+2

Convection: the warm begins to rise, eventually cooler air that is higher in the atmosphere falls. This causes a cycle. <sup>def'n = +1</sup>

12. If a flashlight represented sunlight shining on a globe, which angle would heat the surface the most, a 90 degree angle or a 60 degree angle? Why? 90° angle would <sup>+1</sup>

+2

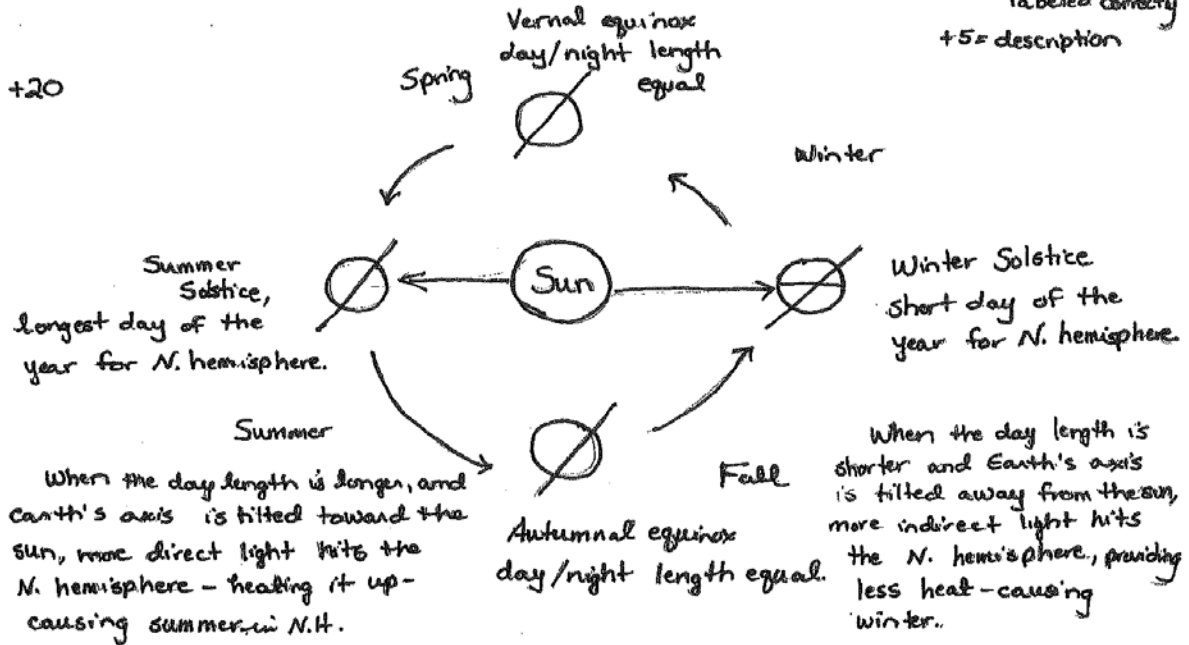
heat a smaller area more. The 60° angle disperses the same amt. of <sup>describe = +1</sup>

13. In general, where does the world have higher temperatures? Why? Between the (Tropics) of Cancer and Capricorn. These areas receive more direct light than other parts of the globe. <sup>+1</sup>

+2

16pts.

14. Draw a diagram <sup>+5</sup> AND describe how Earth's tilt is related to the seasons. Use the following words to label your diagram: Summer solstice, Winter solstice, autumnal equinox, vernal equinox, winter, spring, summer, fall, direct light, indirect light. <sup>+10 = words labeled correctly</sup>  
<sup>+5 = description</sup>



- +1 15. When tectonic plates push together on Earth's surface, the area is referred to as a(n) convergent <sup>+1</sup> boundary.
- +1 16. Underneath a divergent boundary, the mantle would move up <sup>+1</sup> or down in the convection cell? Circle one.
- +1 17. When tectonic plates pull apart on Earth's surface, the area is referred to as a(n) divergent <sup>+1</sup> boundary.
- +2 18. What happens when dense crust pushes against buoyant crust, as in an oceanic/continental boundary? a subduction zone forms. The dense crust gets pushed under the buoyant crust and becomes resorbed into the mantle. <sup>+1</sup>  
 describe = +1
- 25 pts.



19. Name the two types of crust found on Earth's surface and the predominant rock type that makes up each type of crust.

+4

a. Crust: Oceanic +1, type of rock: basalt +1

b. Crust: Continental +1, type of rock: granite +1

+1

20. Which type of crust is thinner, yet more dense? Oceanic, basalt +1

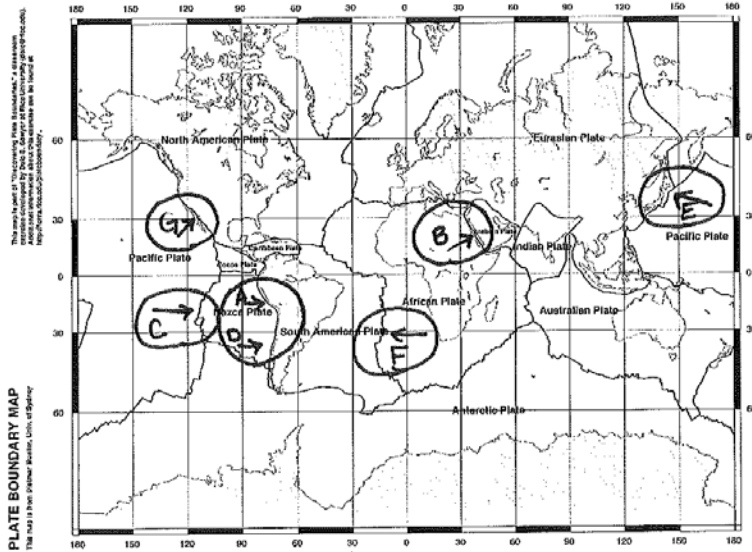
21. Along the western edge of California is a transform fault called the San Andreas fault. Look at the diagram of this feature and explain what will eventually happen in relation to Los Angeles and San Francisco.

+3

8 pts.



The transform fault is an area where the Pacific plate and the North American plate are sliding past one another. Because rock is being neither created nor destroyed, it is causing Los Angeles to move closer to San Francisco. +1



+7

22-28. Using the Plate boundary map provided, label the following: an oceanic/continental plate boundary (A), a continental/continental plate boundary (B), an oceanic/oceanic plate boundary (C), a subduction zone (D), a convergent boundary (E), a divergent boundary (F), and a transform boundary (G).

+4

29. The basis of the scientific method is inquiry – which is asking questions and then trying to come up with answers. If scientists see something they don't understand, they have the urge to ask questions. So...if we came up with the question, "**Does the moon have any affect on tides?**" what would be a good hypothesis/prediction to start our experimental process?

Hypothesis written as a testable statement; shows relationship between an independent variable and a dependent variable.

11 pts. total

30. How would you design an experiment to test properties of water?

Include the following:

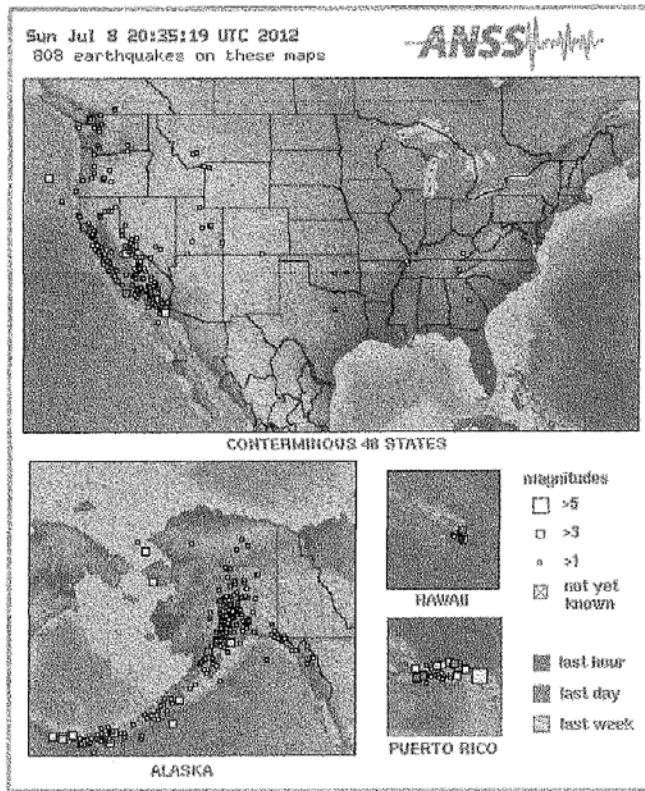
- +1 A question +1
- +2 A hypothesis <sup>+1</sup>Independent + <sup>+1</sup>dependent variables with relation.
- +2 List independent and dependent variables, identified/labeled
- +10 Write your method – In DETAIL! +10  
Looking for attention to detail – to the pt. of repeatability,  
does not have to be complex – just thorough.

15pts

31. Earthquake activity is carefully monitored to identify active earthquakes in various regions. Using the map provided, write a hypothesis that could guide your study of plate tectonics.

+4

hypothesis written with independent and dependent variable - demonstrating understanding of plate boundaries and earthquake activity. +2 +2



32. From data provided, write an analysis that connects your hypothesis with this data.

+4

Analysis to include magnitude and/or frequency of earthquakes associated with convergent and transform boundaries. (+2 boundary types)

33. What step would you take next to test your hypothesis?

+4

Evidence of student understanding that earthquake activity should be monitored over time. +2

12 pts

Monitoring of other boundaries could provide additional data to support hypothesis +2

103 pts total exam

## APPENDIX K

### POST EARTH STEBI MODIFIED FOR EARTH SCIENCE

As a future life science teacher, please indicate the degree to which you agree or disagree with each statement below using the following indicators:  
**5= STRONGLY AGREE, 4= AGREE, 3= UNCERTAIN, 2= DISAGREE, 1= STRONGLY DISAGREE**

Question:	Response				
	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
1. When a student does better than usual in earth science, it is often because the teacher exerted a little extra effort.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
2. I will continually find better ways to teach earth science.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
3. Even if I try very hard, I will not teach earth science as well as I will most subjects.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
4. When the earth science grades of students improve, it is often due to their teacher having found a more effective teaching approach.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
5. I know the steps necessary to teach earth science concepts effectively.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
6. I will not be very effective in monitoring earth science experiments.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
7. If students are underachieving in earth science, it is most likely due to ineffective science teaching.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
8. I will generally teach earth science ineffectively.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
9. The inadequacy of a student's earth science background can be overcome by good teaching.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
10. The low earth science achievement of students cannot generally be blamed on their teachers.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
11. When a low-achieving child progresses in earth science, it is usually due to extra attention given by the teacher.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
12. I understand earth science concepts well enough to be effective in teaching elementary science.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE

Question:	Response				
	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
13. Increased effort in earth science teaching produces little change in students' earth science achievement.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
14. The teacher is generally responsible for the achievement of students in earth science.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
15. Students' achievement in earth science is directly related to their teacher's effectiveness in earth science teaching.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
16. If parents comment that their child is showing more interest in earth science, it is probably due to the child's teacher.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
17. I will find it difficult to explain to students why earth science experiments work.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
18. I will typically be able to answer students' earth science questions.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
19. I wonder if I will have the necessary skills to teach earth science.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
20. Given a choice, I will not invite the principal to evaluate my earth science teaching.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
21. When a student has difficulty understanding an earth science concept, I will usually be at a loss as to how to help the student understand.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
22. When teaching earth science, I will usually welcome student questions.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE
23. I do not know what to do to turn students on to earth science.	1	2	3	4	5
	STRONGLY DISAGREE				STRONGLY AGREE

APPENDIX L  
INTERVIEW PROTOCOL

**Interview Questions for Section A (Inquiry First)**

- 1) Which instructional method, worked best for you to learn course content, the inquiry-based method during life science or the traditional method during earth science?
- 2) Did you feel more comfortable in class during the life science or earth science portion of the class? Why?
- 3) At any point in the semester did you start to have a more favorable experience towards science? Yes or No?
- 4) Did you notice a change in your attitude towards science after the first few classes of life science?
- 5) How do you see yourself using both inquiry-based instruction and traditional instruction in your future classroom?
- 6) Which instructional method do you feel more confident to use in your future classroom? Why?
- 7) Has your attitude towards teaching science changed over the course of this semester? If so, how?

### **Interview Questions for Section B (Traditional First)**

- 1) Which instructional method, worked best for you to learn course content, the inquiry-based method during earth science or the traditional method during life science?
- 2) Did you feel more comfortable in class during the life science or earth science portion of the class? Why?
- 3) At any point in the semester did you start to have a more favorable experience towards science? Yes or No?
- 4) Did you notice a change in your attitude towards science after the first few classes of earth science?
- 5) How do you see yourself using both inquiry-based instruction and traditional instruction in your future classroom?
- 6) Which instructional method do you feel more confident to use in your future classroom? Why?
- 7) Has your attitude towards teaching science changed over the course of this semester? If so, how?