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The Implementation of Science Inquiry: A Mixed Methods Study of Pre-Service Traditional Teachers, Non-Traditional Teachers and Their Pre-Conceived Epistemological Beliefs

Patricia L. O'Donnell
Lehigh University

The Implementation of Science Inquiry: A Mixed Methods Study of Pre-Service Traditional Teachers, Non-Traditional Teachers and Their Pre-Conceived Epistemological Beliefs

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Patricia L. O'Donnell, M.Ed.

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Committee Members:

Lynn Columba

Warren R. Heydenberk

Jeffrey Sands

Kathleen Dolgos

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Abstract

Research was conducted through collaborative partnerships to explore which two pre-service teacher types, traditional or non-traditional, are implementing inquiry-based instruction in their field assignments in order to meet the inquiry-based science *Standards* (NRC, 1996, 2000). To reach the goal of scientific literacy of all citizens, our educational culture needs to accept inquiry as an important teaching method. Since the institution of the science Standards (NRC, 1996, 2000), educators have been required to implement science inquiry in their teaching methodologies. Unfortunately, not all educators have been trained to use inquiry by their college education or subject professors. The lack of modeling or instruction may have caused many teachers to have conflicting beliefs about the importance of inquiry. Using inquiry as a science teaching tool may be hindered as a reflection of pre-service teachers' lack of comprehension, desire, or ability. Thus, student teachers' pre-conceived beliefs and knowledge about teaching and learning science may affect their willingness to teach inquiry (Fang, 1996; Roehrig and Luft, 2004). A mixed method statistical analysis was conducted to differentiate between the inquiry teaching and learning of two teacher types, including how their pre-conceived beliefs affect their capacity and propensity to teach inquiry-based science. The Statistical analysis of this research study can facilitate increased awareness about shortfalls in today's science inquiry teaching in the classroom. The research findings in this study can assist in promoting the development of pre-service teacher preparation curriculum and give insight into further advancement of the employment of science inquiry into teacher preparation programs.

CHAPTER 1

Introduction

Need for the Study

Over the past several, decades, there have been serious concerns about science education in the United States. The launch of *Sputnik* in 1957 signaled the science community to initiate programs to address the problems. Conant (1959) published a report about the American high schools which helped shape new educational policies. Conant's goals were both social and intellectual. Schools needed to provide a general quality education for diverse student groups for America to produce more engineers and scientists as well as improved scientifically educated citizens. In order for Conant's model to succeed, a quality education was necessary for all students without sacrificing higher academic standards necessary for increasing the number of students who choose engineering and other scientific fields (Bybee, 1997; DeBoer, 1991).

By 1983, the United States Department of Education formulated a report through the National Commission on Excellence in Education called *A Nation at Risk.* The report indicated that our educational system was producing "a rising tide of mediocrity" that threatened the United States economic and defense systems. The account stated concerns that the United States was falling behind in adequately educating its students in science, technology, and scientific literacy. The paper also emphasized that high school students should receive three years of science and math including a longer school day and year. The report suggested that universities prepare teachers with elevated expectations (Conant, 1959; National Research Council [NRC], 2001).

During the 1980's, the relationship between science, technology, society, and scientific literacy was recognized as an essential theme in science education (DeBoer, 1991). In 1989, The American Association for the Advancement of Science (AAAS) published *Science for All Americans* as part of Project 2061 in which scientific literacy was recommended for all high school students. Rutherford and Ahlgren (1989) considered education necessary to properly prepare people to lead responsible and fulfilling lives. Later, the National Science Teachers Association (NSTA) published *Scope, Sequence, & Coordination* which discussed core science content (NRC, 1996). Assessments were performed to compare the United States students' science and mathematics scores globally. The International Mathematics and Science Studies (TIMSS) compared the United States students' performances in mathematics and science with other countries performances. The United States students were lagging behind in their scores. AAAS put together a framework called *Benchmarks for Science Literacy* (1993) for states, districts, and educators to explain what all students should comprehend or be able to accomplish in science, math, and technology by the end of grades 2, 5, 8, 12 (AAAS, 1993).

The NRC, along with the United States Department of Education, National Science Foundation (NSF), AAAS, American Chemical Society (ACS), and other political and scientific stakeholders, coordinated efforts to establish a set of standards called *The National Science Education Standards* (hence forth called *Science Standards*) which were published in 1996 and again in 2001(NRC, 1996, 2000). The *Science Standards* address three core areas including content, teaching, and assessment. The *Science Standards* consist of seven chapters with an underlying vision of scientific literacy for all students through the use of more student-centered inquiry-based teaching methods (NRC, 1996, 2000). Inquiry has been deemed the key to generating a more scientifically literate society (Bybee, 2000; Minstrell and VanZee, 2000; NRC, 2000; Zemelman, Daniels, and Hyde, 1998). Additionally, the *Science Standards* “bring coordination, consistency, and coherence to the improvement of science education. The *Standards* take science education beyond the constraints of the present and toward a shared vision of the future,” (NRC, 1996, p.3). However, the vision cannot reach fruition unless the *Science Standards* permeate the entire educational system.

Statement of the Problem

Evidence shows that today’s society in the United States and globally has participated in making many uninformed decisions due to scientifically illiterate citizens as seen by the wreckage enveloping our environment including poor energy choices, transportation choices, recycling habits, health care and wellness approaches, cultural decisions including lack of workers entering the science profession, including many other choices made by superstitious unfounded beliefs (Hobson, 2000). To produce more scientifically literate and productive citizens, teachers must demonstrate the significance of science in their students’ everyday lives. Throughout the last century in the United States, educational methodologies such as discovery learning, hands-on science, process learning, and inquiry have been recycled over the years as important educational strategies for teaching and learning science. Research as far back as Dewey’s lab school (1933), Schwab’s (1962) Biological Science Curriculum Study (BSCS), E. Karplus and R. Karplus’s (1970) three stage learning cycle, Bybee’s (1997, 2002) five essential features of inquiry, and Hammerman’s (2005) eight essentials of inquiry-based science all stressed the value of experiential learning for improved student preparation to reap more scientifically literate citizens who make informed decisions about their future.

Scientific literacy and inquiry are both included in the *Science Standards* (NRC, 1996, 2000). They have been established for teaching and learning science in the United States educational system. However, there is a goal for our educational culture to buy into inquiry teaching methods to reach the objective of scientific literacy for all citizens. Scientific literacy includes having a better understanding and knowledge of scientific subject matter, the nature of science, and the ability to reason and think procedurally as scientists in order to make informed decisions in an ever growing technological society (Alberts, 1999; Minstrell and VanZee, 2000; NRC, 1996). The inquiry standards specify proficiencies students need to inquire as well as the meta-cognitive ability to comprehend the process of inquiry (NRC, 2000). Authentic science inquiry is often synonymous with constructivism where children build upon experiences while continuously create and invent their own cognitive systems and beliefs to logically figure out their world (Zemelman, Daniels, and Hyde, 1998). Students who learn through authentic inquiry participate in the identical thinking strategies and scientific endeavors scientists demonstrate in the field. Scientific inquiry (understood in this paper as authentic inquiry) refers to the multitude of processes scientists apply while studying the natural world to produce evidence-based explanations. Inquiry also includes active learning skills performed by students while constructing new knowledge and understanding of a variety of scientific concepts and their meanings in the natural world. Inquiry is an intricate multidimensional process that cultivates innate curiosity of learners and provides teachers with appropriate strategies for motivational learning (Minstrell and VanZee, 2000; NRC, 1996, 2000; Roehrig and Luft, 2004a). Inquiry involves discovering the nature of science with the relevant processes. Students learn to observe, question, infer, investigate, review, analyze, interpret, predict, and communicate results through critical and coherent deliberation. Lastly, students consider alternative explanations for their inquiries. Thus, inquiry proceeds further than conducting hands-on science activities or experiments (Bybee, 1997; NRC, 1996, 2000). During inquiry lessons, the traditional authoritative role of the teacher and the passive role of the student must transform to a non-traditional approach. In the non-traditional approach, the students become active learners and the teacher's role changes to an active learning facilitator.

Unfortunately, implementing an inquiry-based curriculum may be more arduous if teacher's beliefs do not support science reform efforts. Chinn and Malhotra (2001) argue that many inquiry assignments given in classrooms encourage reasoning abilities with dissimilar qualities from authentic professional scientific endeavors. Often textbook-based science curricula, select what the authors deem as *simple inquiry*. The type of classroom inquiry utilized depends upon each teacher's embedded epistemological beliefs about what it means to "do science" (Windschitl, 2004). Thus, inquiry can be found in many classes, but must be delineated as to whether the inquiry is an authentic scientific inquiry (inquiry used during professional scientific research) or a simple inquiry (activity that has been taken from textbooks or cookbook labs that have been slightly modified). "The cognitive processes needed to reason about simple inquiry tasks are often different from the cognitive processes used in authentic scientific inquiry" (Chinn & Malhotra, p.176). Furthermore, cognitive process discrepancies infer underlying epistemological dissimilar beliefs between simple inquiry and authentic inquiry. Therefore, a teacher's epistemological beliefs about the learning and teaching of science can immensely influence classroom inquiry practice and implementation (Fang, 1996; Chinn and Malhotra, 2001; Roehrig and Luft, 2004b; Roehrig and Kruse, 2005).

Purpose of the Study

The purpose of this study was to investigate whether there was a difference between pre-service traditional teachers versus pre-service non-traditional teachers and their ability and willingness to teach inquiry. This study investigated whether teachers' pre-conceived beliefs about science inquiry effected science inquiry implementation.

Importance of the Study

According to the NRC (2001):

> A large and growing body of research data—as well as recommendations from professional societies—indicate that the preparation and ongoing professional development of teachers in science, mathematics, and technology for grades K-12 needs rethinking and improvement, and not just on a small scale. There is now a great deal of evidence that this situation permeates much of the system of teacher preparation and professional development, including the recruiting, preparing, inducting, and retaining of teachers. Indeed, many teachers themselves report frustration with current methods of and approaches to teacher education. (p.1)

Due to the need for effective teaching and student learning, the *Science Standards* were developed through a team approach as part of revitalizing the science curriculum. Hence, with the institution of the *Science Standards* (NRC, 1996, 2000), science educators are required to apply science inquiry into their teaching methodologies to reconstruct science learning. Unfortunately, educators have not all been trained to manage science inquiry lessons. Some educators have not experienced inquiry modeling by their college education professors due to lack of educational training in science methods and/or philosophical educational differences. However, with the exponential growth of science, technology, and industry, many educators and scientists now appreciate the requirements for broader and more applicable science educational curriculum for today's world (Deboer, 1991). Therefore, it is important to give further attention to teaching practices and methodologies for all students including higher education students (NRC, 2001; Rothman and Narum, 1999). Teacher education instruction needs to emphasize basic principles, best practice, and proper inquiry implementation to enhance teachers' abilities (Goodlad, 1990; Howey, 1996). Unfortunately, many people believe teaching comes naturally, therefore anybody can instruct students adequately (Murray, 1996). The above notion hurts the advancement of the inquiry-based reform efforts.

Problems arise in teacher preparation colleges with the adaption of inquiry programs. Often teacher demographics do not match student demographics. University professors are not trained in methods of teaching, particularly inquiry, unless they are education professors (Merseth, 1993; Murray, 1996). Most scientific doctoral programs emphasize research but their graduates obtain college positions that involve teaching. The absence of modeling and training by university science professors may have caused many teachers to have conflicting beliefs about the importance of inquiry. Using inquiry as a teaching tool may be hindered as a reflection of the teacher's lack of comprehension, desire, or ability. Thus, a teacher's pre-conceived beliefs and understanding about teaching and learning science may affect their willingness to teach inquiry (Fang, 1996; Roehrig and Luft, 2004b).

Furthermore, our pre-service teaching demographic is becoming more heterogeneous. "An increasing number of vigorous, mature adults are seeking a meaningful occupation and a way to contribute to society," (Hollis and Houston, 1991, p. 30). Therefore, more non-traditional students have been entering teacher preparation programs. Due to the present teacher education standards, professors must remember to account for the differences in the changing demographics concerning traditional versus non-traditional pre-service teachers by redesigning teacher preparation programs accordingly. Meanwhile, studying the differences between traditional and non-traditional pre-service science teachers and their ability and/or willingness to teach inquiry, should give some insight into further advancement of the use of science inquiry techniques in science teacher preparation programs.

Major fundamental changes in teaching content, pedagogy, and continual professional development are needed to better impact the needs of today's teachers and students (Loucks-Horsley, S., Hewson, P., Love, N., and Stiles, K., 1998). Current statistics regarding the teaching profession in the United States show that nearly fifty percent of all students who enter pre-service teaching programs do not become teachers. Thirty percent of certified teachers who enter the profession leave within the first five years (Darling-Hammond and Berry, 1998; Henderson, 2000). The statistics for mathematics and science teachers are even more staggering. The *No Child Left Behind Act* (2002) requires all districts to have plans to increase the number of qualified teachers in subjects such as science to ensure that all children are taught by experienced qualified teachers. The literature suggest that career-long professional development, restructuring schools, changes in teacher preparation programs, and collaborative reform efforts will help solve some of the teacher education and retention problems (Goodlad, 1990, 1994; Holmes Group, 1986, 1990, 1995). Collaborative partnerships have been effective in developing the *Science Standards* for educational reform.

In order to meet the teaching *Science Standards* (NRC, 1996, 2000) for inquiry, research needs to be conducted through collaborative partnerships to find out which teachers are teaching inquiry and which teachers are not using inquiry. Thus, finding out the reasons for the differences in teaching practices would enhance the development of pre-service science curriculum. Also, it would be of significant interest to find out whether those who teach inquiry meet all five-essential features of inquiry (Bybee, 1997). The five essential features of inquiry range from teacher-centered to student-centered. *Benchmarks for Scientific Literacy* (*Benchmarks*) call for more student centered scientific research (Minstrell and Van Zee, 2000). Schwab (1962) and Dewey (1933) felt that inquiry should be a priority to increase students' abilities to conduct inquiring investigations. Instruction through inquiry promotes students' understanding of the nature of science as well as the process of science. Inquiry needs to be taught and modeled properly by all science teachers for students to be able to inquire on their own in order to become scientifically literate and productive citizens (Rutherford and Ahlgren, 1989).

Definition of Terms

The following is a list of terms that are useful for understanding the vocabulary important to the research study.

Pre-Service Teachers. Student teachers participating in classroom field experiences.

Traditional Pre-Service Teachers. Students have followed a traditional route to complete their teacher education program. These students went directly from secondary education to college matriculation without interruption through to their last year of student teaching.

Non-Traditional Pre-Service Teachers. Students have followed a non-traditional route to complete their teacher education program. Students took a variety of routes and more years to get to their student teaching (These students may have alternate degrees, alternative work experience, or have raised children which have interrupted their education process).

Science Inquiry. Scientific inquiry refers to the various authentic ways scientists study the natural world and produce evidence-based explanations. Inquiry also includes the active learning of skills used by students to gain knowledge and understanding of a variety of scientific concepts and their meanings in the natural world through observing, questioning, hypothesizing, gathering, interpreting, predicting, communicating, etc. Inquiry is a complex multidimensional process that fosters natural curiosity and provides teachers with a suitable strategy for motivational learning (Minstrell and VanZee, 2000; NRC, 1996, 2000; Roehrig and Luft, 2004a). When teaching inquiry science, the teacher will use the Five-Essential features of inquiry model (Bybee, 1997, 2002).

Five-Essential Features of Inquiry. Teachers engage learners in scientifically oriented questions. Next, learners should give priority to evidence which allows them to evaluate explanations that address scientific questions. Students formulate explanations and conclusions from evidence discovered through evaluating the scientific questions. Explanations are evaluated by learners in light of alternative explanations that reflect scientific understanding. Lastly, students communicate and defend their proposed explanations (Bodzin and Beerer, 2003; Bybee, 2002; NRC, 2000).

Scientific Literacy. Developing the knowledge, ability, and understanding of scientific subject matter, the nature of science, and scientific reasoning in order to think procedurally as scientists so informed decisions can be made in an ever growing technological society (Alberts, 1999; Minstrell and VanZee, 2000; NRC, 1996).

Standards. A document published by the NRC consisting of seven chapters with an underlying vision of scientific literacy for all students. The document provides a framework for educational stakeholders that address three core areas including content, teaching, and assessment (NRC, 1996, 2000).

Benchmarks. This is a companion report to SFAA recommending what "all students should know and be able to do in science, mathematics, and technology by the end of grades 2, 5, 8, and 12" (AAAS, 1993, p. xi).

No Child Left Behind. A United States Federal Act of Congress aimed at improving the performance of the United States School System through standards-based education reform based on accountability to improve individual outcomes in education. By the year 2014, all students attending public high schools will demonstrate proficiency and adequate yearly progress in reading and math and at a later date science. At the state level, NCLB necessitates the development and implementation of accountability plans (NCLB, 2002).

Teacher-centered. This is a traditional classroom teaching method giving teachers total control of the classroom subject matter, methodologies, and direction. This approach involves the direct presentation of the material by the teacher who is deemed the sole manager of student learning.

Student- centered. Learner-centered classrooms place students at the center of classroom organization and respect their learning needs, strategies, and styles. In learner-centered classrooms, instruction places students at the center of their learning and emphasizes thought provoking processes where students can be observed working individually, in pairs, or small groups on distinct tasks and projects such as explaining, finding evidence, providing examples, and generalizing in an effort to acquire an understand of certain topics.

Constructivism. This is a philosophy of learning based on the premise that learners build on prior knowledge by reflecting on experiences to develop their own understanding of the world in which they live. Thus, learners generate new rules and mental images in order to construct new meanings (Yager, 1991).

Epistemology. A branch of philosophy concerned with the nature of knowledge and how the truth of knowledge is known. Learning is guided and influenced by such views on knowing and knowledge (Tillema and Orland-Barak, 2006). Scientific epistemology concerns the nature of science and “the logical and philosophical grounds, upon which scientific claims are advanced and justified,” (Sandoval, 2004, p. 635).

CHAPTER 2

Literature Review

Introduction

The history of science education in the last century, though cyclical, has produced numerous modifications that have evolved overtime. Current and past trends in science education are addressed showing the foundations and the implications for change which are embedded in educational philosophies and thinking throughout the decades.

History of Science Education

Science in the nineteenth century was generally studied as a provision for mental discipline of the mind. Science teaching was very idealistic and authoritarian. By the turn of the century, the laws of nature and God became questionable due to new discoveries. With the growth of science, technology, and industry, educators and scientists saw the need for a broader and more practical science education curriculum (DeBoer, 1991). Students needed independent development and judgment not passive acceptance of authority. Scientific reason could free people from authoritarian teaching and empower them to get at the truth independently. Educators such as Froebel and Herbart based teaching more on sensing, experimenting, and reasoning because they firmly felt these were the child's innate modes of learning. Thus, science education was finally seen as vital for teaching elementary students in addition to secondary students. Herbart felt that learners could "construct" ideas through direct experience and social interaction and consequently students can build upon those paradigms (DeBoer, 1991). Therefore, Herbart's teaching concepts were additionally more realistic in nature and applied a combination of direct instruction that included inductive reasoning. Teaching was starting to be perceived as more active in form than a solely passive learning environment (DeBoer, 1991). Herbart's instructional strategies were supportive of today's *Benchmarks for Scientific Literacy* (henceforth called *Benchmarks)* because students' prior experiences and connections to new concepts are strategies that *Benchmarks* established as key learning approaches (American Association for the Advancement of Science [AAAS], 1993).

Another key historical theorist in science instruction was John Dewey. Dewey (1933) directly influenced science teaching today through his "Discovery Learning.' This process has become a key method in acquiring scientific knowledge (Rakow, 1986). Because of more scientific advances and technology, conveying every science concept in twelve years has become more difficult, thus the discovery approach emphasized more scientific thinking and processes and less content. The above learning type was one of the precursors to inquiry, which is a major component in the development of modern scientific literacy (Rakow, 1986; DeBoer, 1991; Bybee, 1997). The progressive ideas of Dewey aligned philosophically with *Benchmarks* because they emphasized general education for all students using inquiry based techniques in order for students to become responsible citizens.

The Harvard Committee led by James B. Conant published a report in 1947 recommending that scientists and nonscientists alike be taught science concepts through historical developments and societal relationships. His goals for education were both social and intellectual as shown in many of his publications including *The American High School Today* (Conant, 1959). He felt women and minorities should be taught science in order to achieve a more diverse scientifically literate society. The key to success with

Conant's model was to provide quality education for all students without sacrificing higher academic standards needed to increase the number of students going into engineering and other scientific fields (Bybee, 1997).

The launch of Sputnik in 1957 signaled the science community to initiate programs to address the fear that Americans were falling behind the Soviets in science and technology. The Soviet Union had invested heavily in science and technology in post war years while the United States restructuring efforts in the first half of the century focused mostly on teaching general science and teaching masses of students to prepare for life in society. The United States feared the Soviets hence an improved science education system was pondered to decrease the learning deficit (DeBoer, 1991).

One strategy to advance the United States technical capabilities over the Soviets was to better utilize the gifted and talented youth in the United States. Since the United States freedom was at stake, the Cooperative Committee on the teaching of Science and Math as well as the United States Department of Education (1953) felt additional science specialists were needed. Another approach was to bring back mastery of traditional science disciplines. For the next two decades, the United States government became engaged by financially supporting and backing a more intellectually invigorating science education tactics (DeBoer, 1991). The focus for science became one of discipline, structure, and content as well as science processes. The National Science Foundation (NSF), The National Research Council (NRC), The American Association of Physics Teachers (AAPT), and The National Science Teachers Association (NSTA) all agreed to update physics by moving away from technical applications to a more in-depth concept study. A new course called The Physical Science Study Commission (PSSC) was adopted. A secondary biology course was developed through the collaboration of The National Academy of Science (NAS), the Rockefeller Foundation, and the National Science Foundation (NSF) called The Biological Sciences Curriculum Study (BSCS). The curriculum integrated concepts and their relationships to each other with a problem solving component while it emphasized biology processes. Lab activities in the past included identifying and memorizing structures and their function. The BSCS lab did extra by promoting knowledge about the nature of science and science process through inquiry. Paul DeHart Hurd (1958) identified a link between science and society. He formally coined the contemporary usage *scientific literacy* as an educational restructuring goal during the late fifties and sixties. Hurd considered science to play such a major role in society that it affected economic, political, technological, and personal life issues. His scientific goals for education directly complimented the *Benchmarks* and *Science Standards* because they both tied together the importance of scientific literacy with the incorporation of science and technology's ramifications on society (Bybee, 1997).

Joseph Schwab (1962) was largely responsible for composing the teacher's guidelines for the BSCS curriculum. Schwab stressed learning processes that scientists perform to generate knowledge. Schwab emphasized learning inquiry skills to become more proficient at observing evidence and analyzing textbooks and lectures. The American Chemical Society (ACS) funded by NSF created a new curriculum called the chemical bond approach (CBA). The most important goal of the CBA was to introduce students to inquiry through logical thinking by using chemical theory to explain observations. The American Chemical Society and the NSF formed another program called "CHEM Study" group. This program eliminated the need for double periods in science for resolution of time constraints. The NSF supported summer institutes to prepare teachers for teaching the CHEM Study course. The goal was to furnish students with an increased awareness of the nature of scientific investigations and knowledge generated through the scientific method (DeBoer, 1991).

The 1960's brought about the formation of other curriculum projects funded by the NSF. Curriculum was developed for earth science, physical science, engineering, and elementary science. The 1969 Elementary Science Study (ESS); the 1967 Science-A-Process Approach (SAPA), and the 1970 Science Curriculum Improvement Study (SCIS) were developed through funding by the NSF. These curriculum approaches de-emphasized mastery learning and taught more science processes such as observation, measurement, and prediction. The teacher's role became one of guider and not as much of authoritarian. Content coverage was not as imperative as students learning core science principles and their relationships to one another (Bruner, 1960). E. Karplus and R. Karplus (1970) developed a key strategy for learning called the "Learning Circle." This new teaching strategy was similar to the Herbartian Model which included exploration, concept invention, and application. The structure has undergone some revisions throughout the years; however, they are extremely adaptable in most classrooms. The learning cycle is a functional model to implement the inquiry approach. This three stage cycle used active engagement of students in hands on inquiry and exploration where scientific questions are raised for further investigation. This model was a precursor to the present day inquiry model (Atkin and Karplus, 1962; Rakow, 1986).

Post-Sputnik science curriculum reflected partnerships between educators and scientists. First hand investigations were emphasized in science classrooms reflecting the newer convictions that students should model scientific processes to grasp scientific concepts and ideas (DeBoer, 1991).

In the 1970's, many environmental bills were passed that emphasized the interrelationship between science, technology, and society. During this time Americans communally were very hesitant in accepting innovative scientific and technological advances. For example, during 1979 the *Three Mile Island* nuclear reactor disaster became the root of distrust that new technologies are not safe. Thus, public support for science education and funding declined. Curriculum advancements continued throughout the 70's, but had limited success. In spite of new curriculum ideas, most teachers were still using traditional didactic methods. Students seemed to be mastering facts but not connecting them with any broader meaning or problem solving abilities (Bybee, 1997; NRC, 2000).

Huetlle, Rakow, and Welch (1983) stated that researchers have noted downward spirals in science achievement among 9, 13, and 17 year old youth over a decade's time. The researchers believed the national decline between 1969 through 1982 indicated on some assessments should be of major concern to law makers and educators in this country. By 1983, the United States Department of Education formulated a report through the National Commission on Excellence in Education called *A Nation at Risk*. The report indicated that the American educational system was risking the future of the country by producing a "rising tide of mediocrity" that threatened the United States economic and defense systems. The report corroborated concerns that the United States was plummeting in the educating of students in science, technology, and scientific literacy. Emphasis was placed on high school students receiving three years of science and math as well as attending school longer each day and each year. The document proposed that universities should have higher expectations for their pre-service teacher education programs (NRC, 2001).

Concurrently, in 1983 Ernest Boyer, president of the Carnegie Foundation, wrote the *High School*, which recommended a two year science program founded on biological and physical sciences. Boyer recommended students learn science through discovery which aligns with inquiry processes recommended in the *Science Standards.* Boyer also stated that to become more informed citizens, science curriculum should be integrated through the use of Science, Technology, and Society (STS). He believed, just as *Benchmarks* states, that all students should become scientifically literate (DeBoer, 1991).

The National Assessment of Educational Progress (NAEP) reported in 1986 that the average performance gains of 17 year olds in math and science remained much lower than it was in 1969. Due to concerns from past scientific research findings, Project 2061 through AAAS published *Science for all Americans* (SFAA). Rutherford and Ahlgren (1989) had concerns about the downward direction that science, math, and technology were headed in the United States educational system. They deemed education's highest purpose is for preparing students to reach their greatest potential. Assessments were performed to see how the United States students were doing globally in science and math. The National Assessment of Educational Progress (NAEP) and The International Mathematics and Science Studies (TIMSS) compared our country's performance of students in math and science with other countries. The United States students were considered to be lagging behind other countries. The core of the SFAA publication consists of top recommendations by leading scientists and educators concerning essential learning goals for American students to become scientifically literate in society. Scientific literacy includes science, math, and technology.

SFAA is a policy statement and framework that significantly influenced state, local, and national reform of school science programs. SFAA outlines the basic elements of scientific literacy by covering an array of topics including their connections to one another. Emphasis is placed on key concepts and thinking skills instead of rote memorization and procedures. Some important topics comprise the nature of science, math, and technology including their relationship to one another within the world. This publication insists on accommodating all students. Recommendations were prepared in regards to what all students should comprehend in math, science, and technology upon graduating from high school. *Benchmarks* incorporate and support all the topics in SFAA; however, they specify how students should progress towards scientific literacy. Outcome-based objectives were develop to encompass what all students should know and be able to do in science, math, and technology by the end of grades 2, 5, 8, and 12. The grades are considered check marks for assessing student progress towards scientific literacy goals denoted in SFAA. The *Benchmarks* and the SFAA publications are meant to be used as companion tools for curriculum reformers, school districts, states, and national organizations for developing their own frameworks, syllabi, and curriculum models. The *Benchmarks* lead to momentous changes in the 1990's continuing through to the present. The *Science Standards* (NRC, 1996, 2001) were written as a result of SFAA and the *Benchmarks*. The *Benchmarks* maintain that more collaborative efforts by scientists, college professors, teachers, administrators, politicians, and the community at large increases the likelihood of students success in scientific literacy goals.

The *Benchmarks* have spurred changes down to the state and local levels through improvements in curriculum and instruction. Increased transformation depends largely on administrative support and funding as well as the teachers, the students, and the communities' ability to accept novel changes. Bybee (1993, 1997) and Minstrell and Van Zee (2000) currently research, practice, and maintain many of the philosophical foundations of the *Benchmarks*. These educators support inquiry learning and reflective teaching and training. Overall, additional science classrooms have included hands-on inquiry-based instruction. More classrooms gradually began to illustrate discovery learning by focusing less on concept learning and more on student questioning, predicting, exploring, manipulating, discussing, assessing, and reflecting rather than teacher directed lectures and discussions covering mass quantities of content (Bybee, 1997, 2000; Zemelman, Daniels, and Hyde, 1998).

The *Benchmarks* facilitated curriculum development in becoming more interdisciplinary and intradisciplinary, especially in elementary schools and middle schools. Instruction began to include thematic units to achieve scientific literacy goals more efficiently. The *Benchmarks* instituted a common core of learning, adopted by numerous school districts and later adapted to fit the needs of their diverse learners (AAAS, 1993; Bybee, 1997, 2002). Many middle schools and high schools initiated block scheduling (usually ninety- minute periods) to provide more time for in-depth exploration and construction of student thinking skills for developing better overall conceptual abilities. Thus, more teachers and theorists implemented the constructivist approach to learning. Many classrooms started to incorporate group work, cooperative learning, presentations, and discussions with the teacher's role slowly changing to facilitator from dictator. The *Benchmarks* called for more active and reflective learning initiation for student problem solving to encompass a more scientific scope. Zemelman, Daniels, and Hyde (1998) supported the above ideas and called them *Best Practices*.

Teacher preparation was affected by the *Benchmarks* in several ways. Many colleges and universities required tougher standards for admission into teaching programs. Higher GPA's were necessary for continued matriculation. More core science and math courses were required for secondary science and math certification. Elementary teachers were required to take science methods courses. Pre-service plans began to include more community-based learning and action research projects in order to better prepare teachers for scientific literacy goal implementation for their future classrooms. State teacher's exams were arranged and required to further assure certification of quality teachers. As a result of the *Benchmarks* example of teacher collaboration, school districts increased actual teacher preparation time and helped teachers form learning circles by creating more teacher classroom pullout hours for elementary, middle, and high school levels (AAAS, 1993).

Until the publication of *Science for All Americans* and the *Benchmarks*, little had been accomplished in terms of scientific literacy. More than any other time in the history of science education reform, the collaborative efforts of the producers of *Benchmarks* has realized more lasting and progressive change in approaching the goal of scientific literacy for all Americans. Many more adjustments have occurred in teacher preparation, curriculum, and classroom instruction following the publication of *Benchmarks.* Changes have included process-oriented experiential learning in a multidisciplinary science curriculum which has added up to a more advanced and well-researched constructivist approach to learning. Teachers and students alike are learning the importance of reflection with unique and varied assessments to monitor growth. Through collaboration, current educational researchers and stakeholders have been able to further advance the goal of all citizens becoming scientifically literate.

Scientific Literacy

Science education should enhance students' abilities to become scientifically literate for the United States to further sustain itself lawfully, economically, and remain secure from outside hostilities. In response to the above need for better science literacy, AAAS initiated *Project 2061* in 1986 resulting in the publishing of *Science for All Americans* by Rutherford and Ahlgren (1989). Their vision for scientific literacy and *Benchmarks* offered goals and directives for educators to augment students' abilities to live responsibly in a scientifically literate society. The NRC along with the United States Department of Education, the National Science Foundation, and stakeholders coordinated efforts to establish a framework of *Science Standards* that were published in 1996 and again in 2000 (NRC, 2000).

The NRC (1996) organized the *Science Standards* as a framework for providing criteria that stakeholders at the local, state, and national levels can use to judge the appropriateness of their actions to "serve the vision of a scientifically literate society" (NRC, 1996, p.3). Beerer and Bodzin (2003), Bybee (1997), and the NRC (1996, 2000) agree that scientific literacy has become a substantially essential issue for the citizens of this country to undertake. Having reading, mathematics, and writing skills does not go far enough to continue gains in life-long literacy. The expanded significance of science and technology in today's global society is critical for the United States citizens to properly grasp in order to retain true literacy in today's world. For the sustainability of the United States, the necessitates a great need for the public to become more scientifically, technologically, engineering and mathematically (STEM) trained which will establish the countries' future being one of wealth or of poverty as well as the vulnerability of the national security of the nation (NRC, 1996).

Since the launch of *Sputnik*, the federal government appropriated funding to upgrade the teaching of science which resulted in some new curricular approaches which Rakow (1986) considered to all have a common thread of inquiry. For example, the 3 stage learning model, BSCS, Project 2061, *Benchmarks*, and the *Science Standards* are all inclusive in some form of inquiry methodologies. The *Science Standards* have a premise that science is an active process. The goals include hands-on engagement of students in the process of science. The NRC (1996) refers to process learning as students obtain skills in observing, inferring, experimenting, inquiring, etc. Inquiry is the center-piece to scientific learning and literacy. Inquiry allows students to engage in the same thinking skills and protocols that "real" scientists perform. Thus, inquiry-based science lessons should parallel the methods and thinking processes of today's scientific practitioners (Bybee, 1997; NRC, 1996, 2000).

Historical View of Inquiry

Recommendations from science educators have placed learning through inquiry at the core of science instruction for more active engagement of learners in the processes of science (Schwab, 1962; Rakow, 1986; Rutherford and Ahlgren, 1989; AAAS, 1993; Bybee, 1997; Zemelman, S., Daniels, H., and Hyde, A., 1998; NRC, 1996, 2000; Bodzin and Beerer, 2003). Inquiry in the post-Sputnik science curriculum reflected partnerships between educators and scientists. Firsthand investigations were emphasized in science classrooms reflecting the belief that students should replicate scientific processes to learn scientific concepts or ideas. Both Socrates and Aristotle believed in using inductive reasoning to learn concepts. Aristotle developed protocols for collection and analysis of data that became the basis for scientific inquiry today. Later Rousseau and Pestalozzi encouraged the learner to employ direct observation. John Dewey directly influenced the current science inquiry teaching today by using his Lab School to uphold his notion of "discovery learning" as a key technique for acquiring knowledge. His inquiry school parallels the first wave of inquiry type reforms of the 1950's and 60's. Dewey's discovery approach placed more emphasis on scientific thinking processes to acquire knowledge rather than accentuating only content (DeBoer, 1991).

Furthermore, Atkins and Karplus (1962) expanded learning through discovery by formulating a two stage learning cycle influenced by Jean Piaget's teachings. This teaching methodology was a type of guided discovery or inquiry as the term is coined presently. Later, Karplus worked on a Science Curriculum Improvement Studies (SCIS) which implemented a third learning cycle stage. The three stages were exploration, invention, and discovery. However, by the mid 70's, the stages were clarified so teachers would not misinterpret them. The new names became exploration, concept introduction, and concept application (Karplus et al., 1977). The teaching of inquiry stem directly from the three stage learning cycle incorporated into the science curriculum so that science learning can be kept on the forefront of the rapidly expanding technological advancements in the world. Due to the swift technological changes, transmitting scientific concepts in twelve years or less had become more difficult. Therefore, discovery learning using an inquiry approach is more prudent because students learn logical thinking skills and science process skills rather than voluminous amounts of factual information. Students with proficient inquiry skills have a superior chance to acquire innovative knowledge because such students are more suitably prepared to comprehend the constantly evolving nature of science (Rakow, 1986; NRC, 2000).

Inquiry Today

Inquiry is rooted in constructivism. Learning science is a process of constructing and reconstructing experiential theories previously held by the learner. The learner is continually refining existing knowledge and constructing new interwoven concepts. At the center of constructivist learning theories is the idea that each learner forms their own perceptions of concepts through their past experiences which is then used to guide their understanding and transform meanings. However, they are limited in their conceptions due to the confines of their knowledge base at that time (Duit and Treagust, 1998; Hofer and Pintrich, 1997; Tobin, 1993). Thus, the learner's knowledge changes as their cognitive functioning develops and experiences are filtered through more advanced ways of thinking (Martin, 2003). Additionally, Yager (1991, 1993) posits that learners also need to interact with others, observe, explore, and communicate in order to make sense of new data to further construct and transfer new meaning into their beliefs. Constructivism includes both a personal component as well as an interactive or social component to learning (Bleicher and Lindgren, 2005). A constructivist model for teaching and learning should include a student's prior beliefs, interactions with others, and the building of understanding around big ideas or central concepts (Brooks and Brooks, 1999). Constructivism dovetails with inquiry in that learners are engaged in learning and need to communicate ideas with others in order to fully comprehend what is being learned to make it part of a person's newly constructed library of ideas.

The *Science Standards* recommend inquiry learning be the focus of science instruction (DeBoer, 1991; AAAS, 1993; NRC, 1996; Roehrig and Luft, 2004). Roger Bybee (2002), the director of the Biological Sciences Curriculum Study (BSCS), the executive director of the Center for Science, Mathematics and Engineering Education at the National Research Council, chaired the content working group of the National Science Education Standards use of scientific inquiry in three different but complimentary ways. The implementation of inquiry is used for learning science content, development of science cognitive skills, and utilized as a science teaching methodology. The above views are consistent with the National Science Education Standards (NRC, 1996, 2000).

The inquiry standards specify the skills students needed to inquire as well as to specify the meta-cognitive abilities needed to understand the inquiry process (NRC, 2000). Scientific inquiry (authentic inquiry) refers to the different ways scientists study the natural world and the resultant evidence-based explanations they discover from their own research studies. Inquiry also includes the active learning of skills used by students and teachers to gain knowledge and a gradual conceptual understanding of a range of scientific concepts which incorporates their meaning in the natural world. Inquiry is a complex multi-dimensional process that fosters natural curiosity and provides teachers with a suitable strategy for motivational learning (Minstrell and VanZee, 2000; NRC 1996, 2000; Roehrig and Luft, 2004a). Inquiry involves learning about the nature of science and the discovery processes involved. Inquiry is not a single traditional scientific method approach, however; inquiry is authentic, open-ended, and flexible involving numerous steps to acquire an increasing range of process skills demonstrated through meaningful student investigations. Students learn to observe, question, infer, investigate, hypothesize, review, measure, design experiments, control for variables, use mathematics concepts, to analyze, evaluate, interpret, predict, justify decisions, respond to constructive criticism, and communicate results through critical and logical thinking. Lastly, students should be able to consider alternative explanations for their inquiries. Thus, inquiry is more than just conducting hands-on science activities or experiments as seen in many textbook-based undemanding inquiries (Bybee, 1997; Chinn and Malhotra, 2000; NRC, 2000; Zemelman, Daniels, and Hyde, 1998).

Bybee (2002) believes that science is more than just content knowledge. Scientific inquiry is not as precise and orderly as the misinterpreted scientific method. The misconception many textbooks, science teachers, and general public have about science is that it is a consistent scientific method or format that must be followed from beginning to end starting with a problem and ending with a conclusion. Science is not only a body of knowledge, but a function of authentic practices scientists use to obtain knowledge. Inquiry uses scientific processes such as observation, experimentation, and collaboration that result in evidence that helps answer a scientific question. Scientists begin by asking an engaging question due to observed inconsistencies or insights seen in previous scientific endeavors. Next, they continue to explore and make predictions in order to formulate a hypothesis. Experimenting and data collecting produce feedback to confirm or deny the hypothesis. Hence, scientists are continually reformulating their ideas and altering their investigations to further improve scientific knowledge more deeply.

Consequently, authentic science inquiry is complex and often cyclical in nature (Bybee, 2002). Bybee implements the techniques good scientists utilize by incorporating his BSCS 5 Essential Features of Inquiry model (5E'S) into learning and teaching instruction.

The BSCS 5E Instructional Model

> The *Science Standards* define five essential features of inquiry-based teaching:
>
> Learners are engaged in scientifically oriented questions.
>
> Learners give priority to evidence which enables them to evaluate explanations that address scientifically oriented questions.
>
> Learners formulate explanations and conclusions from evidence to address scientifically oriented questions.
>
> Learners evaluate explanations in light of alternative explanations, in particular those reflecting scientific understanding.
>
> Learners communicate and justify their proposed explanation (Bybee, 1997; Bodzin and Beerer, 2003; NRC, 2000**,** p.14)

Instructional Inquiry Models

Several instructional models of inquiry have been developed to assist teachers (Bybee, 1997; Lawson, 1995; Pizzini, 1996; Stephans, 1994). However, teachers interpret and adapt models differently according to their students' needs as well as their own needs. Literature that discusses teachers' implementation of inquiry indicates the challenges of planning and facilitating the inquiry process in the classroom (Roehrig and Luft, 2004b). Often the primary implementation of inquiry is more teacher-directed due to lack of student experience, but naturally changes to more teacher-guided, and then to more student-directed as students learn to construct more scientific connections through starting partial inquiries (Bybee, 2002).

The dynamics of science teachers' implementation of inquiry is multi-faceted. Carlsen (1993) and Hashweh (1987, 1996), for example, found that inquiry-based instruction is not implemented well unless science teachers have a strong concept knowledge of their discipline which can be more problematic at the elementary level. Teachers often lack the time and administrative support and training to implement inquiry even with strong content knowledge (Roehrig and Kruse, 2005). Understanding concepts must also include the processes and nature of science. Knowledge should be interdisciplinary and non-fragmented for teachers to best instruct science inquiry (Roehrig and Luft, 2004b).

Teacher Beliefs

Another key component in the implementation of science inquiry lessons is the teachers' own epistemological beliefs. Beliefs in the educational realm can include beliefs about students, beliefs about teaching, beliefs about subject matter importance, beliefs about one's own learning, and beliefs about achievement. Most teachers come to the field with traditional high school models of learning that are highly teacher-centered. They are accustomed to learning through drill and rote memorization as a means of learning science subject matter. Accordingly, teachers develop implanted pictures in their heads as to what proper science teaching looks like based upon past experiences. These pictures develop into epistemological beliefs. However, there is a divide between some teachers' epistemological beliefs about science and their inquiry practices in the classroom (Sandoval, 2004).

Asking teachers to teach inquiry without adequate training and modeling causes teachers to become more skeptical about implementing inquiry into their science curriculum. Concomitantly, many teachers had postsecondary science, mathematics, and education instructors who lacked the experience needed to adequately prepare pre-service teachers in presenting an inquiry-based curriculum to their future students (Windschitl and Buttemer, 2000).

> Faculty in science, mathematics, engineering, and technology (SME&T) at the nation's colleges and universities may not be sufficiently aware of these changing expectations to provide the appropriate type and level of instruction needed by students who would be teachers. Nor do most of these faculty have the kinds of professional development experiences in teaching that would enable them to model effectively the kinds of pedagogy that are needed for success in grade K-12 classrooms. Similarly, some faculty in schools or colleges of education, especially those who are engaged with graduate programs, may have had little or no recent direct contact with teachers in classroom environments (NRC, 2001, p. 2).

Many teachers enter teacher preparation programs without experiencing inquiry. Consequently, teachers' epistemological beliefs about science can then greatly impact the execution of science inquiry in the classroom (Windschitl and Buttemer, 2000; Maor and Taylor, 1995). Fang (1996) contends that teachers' classroom presentations are directly impacted by teacher's beliefs about learning and teaching. Teachers' and students' roles in an authentic inquiry-based lesson are different from the traditional classroom. Thus, beliefs about learning and teaching will alter teachers' decisions regarding plans for inquiry in their classrooms. Such beliefs may evoke more reasoning processes that are qualitatively less effective in developing authentic scientific inquiry skills in their students (Chinn and Malhotra, 2000; Magnusson, Krajcik, and Borko, 1999).

Additionally, Borko and Putman (1996) as well as Friedrichsen and Dana (2005) believe that teacher attempts to perform new methodologies such as inquiry are highly influenced by teachers' early beliefs about teaching, learning, and students. In order to get teachers to better employ inquiry in the science classrooms, they need to be taught and supported in examining their own beliefs and whether they align or misalign with reformed-based science teaching methodologies. Supporting teacher reflection about their own beliefs will allow for teachers' knowledge about science and their epistemological beliefs about science to become targets for transformation (Friedrichsen and Dana, 2005). Moreover, teachers' pre-conceived beliefs about inquiry cannot be expected to change without allowing for practice and transfer. An alteration needs to be accomplished for researchers to collaborate with teachers, so that teachers can form learning circles for discussion and fully immerse themselves in experiencing complete authentic scientific inquiry. Thus, educators will grasp the skills and conceptual knowledge necessary to adequately employ new epistemological beliefs concerning inquiry teaching and utilize it as a key science classroom strategy (Crawford, 2007).

Conclusion

A review of the history of science education over the past century has shown trends that cycle overtime, but science educational research and practices do not always transfer enough to stick around. The trend toward science inquiry has become like a rolling stone that continues gathering moss as it advances in time. The need for a more scientifically literate population that can compete globally with advancing technology has generated more collaborative efforts among scientists, researchers, college professors, teachers, politicians, educators, and the community at large. As a result, more advances in scientific literacy have been realized by establishing a national framework or *Benchmarks* for a better educational curriculum to be embedded into our educational culture. The *Standards* were produced based on an inquiry-based framework. For effective implementation of inquiry to be firmly established, additional efforts must be accomplished to enable the allocation of students and teachers to buy into the inquiry techniques as a means to developing an inclusive scientifically literate population. The next key component in continuing the inquiry momentum is through the use of a constructivist approach to learning to help guide students' beliefs. The pre-service and in-service teachers' pre-conceived beliefs about inquiry and science teaching and learning can be adjusted through more experiential authentic scientific endeavors. Pre-service teachers need to undergo tangible science inquiry through the collaboration of college professors/researchers to present teachers with open communication, active reflection, and performance of real life inquiry scenarios. Practice and reflection will permit teachers to wrestle with their own misconceptions about inquiry. Consequently, teachers and students will be enabled to construct new meaning about inquiry as a viable method of learning. Thus, true discovery of science inquiry can become transferred and entrenched into the teachers' core beliefs regarding what constitutes "best practice" in science teaching. Once teachers establish science inquiry into their repertoire of strategically effective teaching routines, students will become more scientifically literate which will enable the United States to compete globally in all future scientific endeavors.

CHAPTER 3

Methodology

Introduction

The primary purpose of this study was to investigate the implementation of inquiry-based instruction in the science classroom between pre-service traditional teachers and pre-service non-traditional teachers. The secondary purpose of the study was to compare whether pre-service teachers' (traditional and non-traditional) pre-conceived epistemological beliefs affect their ability and willingness to teach inquiry over time. The investigation focused on whether different student teacher demographics created a need for new strategies to help pre-service teachers implement inquiry-based science instruction. The following research questions guided this study:

1. Is there a significant difference between pre-service non-traditional teachers versus pre-service traditional teachers and the implementation of science inquiry in the classroom?
2. Is there a significant difference between pre-service teacher type (traditional versus non-traditional) and their pre-conceived beliefs in the execution of science inquiry?

Sample

The population source and sample size came from a convenient sample of local universities within a twenty-five mile radius that trained elementary and secondary science student teachers. Pre-service teachers were chosen based on availability, access, and numbers for convenience of the researcher and the raters. The universities selected were based on the number of student teachers who were teaching science lessons in grades K through twelve and were able to participate during the fall 2008 semester or until the sample size is deemed large enough to show any kind of validity. The researcher found the sample of participants for the investigation by presenting the study to the intern or student teaching offices at various teacher training institutions. A letter (see Appendix D) was sent to each of the following teaching institutions asking if they would like to participate: Lehigh University, Moravian College, Muhlenberg College, Cedar Crest College, DeSales University, Kutztown University, and Villanova University. If there was not a large enough sample size to get statistically significant result with the above universities then the researcher would put the demographic survey and the pre-questionnaire and post-questionnaire via Survey Monkey in addition to the universities in the twenty-five mile radius; however, those pre-service teachers were not observed in their classrooms by a rater due to possible distance constraints. Upon receipt of volunteers the researcher chose applicants based on availability and convenience.

Design

The research study utilized a mixed quantitative and qualitative design. To classify traditional versus non-traditional pre-service science teachers, a demographic study was given to the teachers and divided into traditional and non-traditional based on the demographics. To determine whether a significant relationship existed between teacher classification by demographics and implementation of inquiry the researcher compared demographic data with the execution of inquiry in the classroom.

The research study utilized a mixed methods design to determine whether a significant relationship existed between the effects of the two pre-service teacher types (traditional and non-traditional) and their implementation of inquiry. Also, the study explored whether the two pre-service teacher groups' pre-conceived beliefs affected their ability and willingness to implement science inquiry. To determine whether teachers' pre-conceived beliefs had a significant relationship on inquiry teaching, the researcher compared data from pre-questionnaires and post-questionnaires. Observations of inquiry teaching in the classroom were analyzed. The observations were rated by two trained raters and were collected using a rubric to quantify the data.

Instrumentation

The researcher used several instruments to collect different types of data. The instruments were a teacher demographic survey (see appendix A) and pre-questionnaire and post-questionnaire (see appendix B) designed to evaluate traditional versus non-traditional pre-service teachers as well as their subject matter knowledge, pedagogy, inquiry knowledge, and beliefs. Validity for the instruments came from Celeste Pea's dissertation questionnaires. Celeste Pea (2004) created her questionnaires by adapting work from Lumpe, Haney, and Czerniak (2000) as well as Horizon Research, Inc. (2000). The third and final instrument was the validated Science Teacher Inquiry Rubric (STIR) (Bodzin and Beerer, 2003) (see appendix C) that was used for evaluation of two classroom observations per pre-service teacher. The STIR instrument was utilized to determine the quality and type of inquiry taught. The researcher trained two raters to observe the pre-service teachers while they were teaching two inquiry lessons. They rated subjects using the rubric to collect data. The researcher could later develop a score to quantify the inquiry implementation.

Pilot Study

The pilot study was conducted for training raters and a mini-study was performed to test the logistics and research instrumentation that was utilized during the major research study. The researcher trained the raters, two retired Emmaus High School science teachers, by assisting them in the practice of utilizing the STIR instrument to record their classroom inquiry observations. Raters were trained further with the researcher by watching and recording data from the inquiry lessons of two seasoned science teachers. The raters and the researcher used the STIR rubric to check off the essential features of inquiry that were observed in the lessons. After each lesson, the researcher and two raters went into a separate room and shared their data collected from the rubric to determined whether they maintained at least an eighty-three percent agreement with the expert rater or the researchers' data. The researcher guided and assisted the raters to be more accurate by working out any discrepancies with the raters. The observations and discussions continued until the raters had observed two lessons that matched at least eighty-three percent of the time. After two separate observation days, the raters matched a minimum of two lessons with at least an eighty-three percent accuracy rating.

The researcher contacted Lehigh University, Kutztown University, and Cedar Crest College student teacher supervisors to obtain permission for their students to participate in the pilot study. Ten students agreed to participate, however; only one student teacher completed the entire process due to PSSA testing inhibiting their ability to teach science inquiry lessons. The student teacher who completed the study was a non-traditional secondary science student teacher. During the two month duration of the study, the pre-service teacher completed a demographic survey and a pre-questionnaire.

Next, the subject was observed by the raters while teaching two inquiry lessons. Lastly, the pre-service teacher completed a post-questionnaire survey. One lesson was video-taped and one lesson was observed directly by both raters in the classroom.

Research Procedures

A mixed quantitative and qualitative experimental design was implemented. The researcher obtained the university Human Subjects approval before beginning the study. The researcher sent a letter (appendix D) to various teacher training institutions asking permission for the research study to be implemented at their university/college. After permission was granted, the researcher chose the following institutions: Lehigh University, Kutztown University, Muhlenburg College, and Cedar Crest College based on convenience, access, and sample size within a twenty-five mile radius. The researcher personally followed up with the pre-service teacher supervisors to further explain the study. After the researcher was given the names and emails of interested pre-service teachers, the researcher emailed the pre-service teachers to verify their participation by sending them informed consent forms (appendix F). Informed consent (appendix F) was obtained from each student teacher via email or regular mail. Demographic surveys and pre-questionnaires were distributed to the pre-service teachers and returned to the researcher via e-mail within one week.

Based upon the results of the demographic survey, the researcher divided the student teachers into traditional or non-traditional categories. A letter (appendix E) was given to the pre-service teachers' building principal and master teacher for signature and verification that they understood and approved of the pre-service teachers' involvement in the study. The principals agreed to outside raters coming into their buildings to observe the pre-service teachers.

Observations began during the third through fourth week of teaching assignments. The pre-service teachers were observed teaching one science inquiry lesson by one of the raters. Approximately, during the sixth through eighth week of teaching assignments, the pre-service teachers were observed teaching an additional science inquiry lesson. Pre-service teachers were required to give copies to the raters of their lesson plans from the day before, during, and after the observation including all handouts if pertinent to the observed inquiry lesson. The science inquiry lessons data was collected by trained raters using the STIR instrument (appendix C). In the eighth week of the student teaching, pre-service teachers were e-mailed or personally given a post-questionnaire for completion to send back to the researcher. The paper work was collected and analyzed for quantitative and qualitative results. The researcher analyzed the data using quantitative measures and also looked for recurring themes and patterns to further evaluate the outcomes qualitatively.

Evaluation and Analysis

The research design was a mixed qualitative and quantitative design using a teacher demographic survey (Appendix A) to determine two independent variables (traditional versus non-traditional student teachers) and the dependent variable was the implementation of inquiry. The demographic survey enabled the researcher to discover differences between traditional pre-service teachers versus non-traditional pre-service teachers in order to categorize them. The Science Teacher Inquiry Rubric (STIR) was used to rate the five essential features of inquiry including the amount of teacherdirectedness or student-directedness (Appendix C). Data collected from each STIR Instrument was converted to a numerical score in order to quantify the results for a t-test analysis or an analysis of variance (ANOVA) to discover whether there was a significant difference between traditional versus non-traditional pre-service teachers and their execution of inquiry in the classroom. The statistical design package that was used was the SPSS package for analysis of results. Software called G* Power 3 Analysis was performed in order figure out what the smallest sample size (*N*) could be in order to get valid results from the data.

Assumptions of the Study

The researcher utilized the demographic survey to show an indication of the differences between traditional and non-traditional pre-services teachers. The assumption was that there were enough of both pre-service teacher types to show some significant differences. The researcher defined inquiry based on the literature review and determined the type of science inquiry that was examined in the study. The pre-service teachers had some knowledge of inquiry due to the national science standards that require students to learn science through more inquiry so students can become more scientifically literate citizens. However, the pre-questionnaire was utilized to show the extent of the pre-service teacher's experiences and beliefs about implementing inquiry into their science lessons. The pre-service teachers cooperating teachers would be able to guide their student teachers through the inquiry process's to clarify where the pre-service teachers can improve.

Limitations of the Study

The major limitation of this study was geographical in nature. The limitations were restricted to universities or colleges that had pre-service teachers who decided to participate in the study. Thus, the sample of pre-service teachers was limited to the number of student teachers in the field who were willing to participate during the time of the study. The researcher's bias or beliefs about inquiry and the pre-service science teacher's implementation of inquiry could have affected the analysis. The study was limited to the researcher's sample demographic for a definition of traditional and non-traditional pre-service science teachers. The researcher was not able to control all possible threats to internal validity due to the inability to randomly assign pre-service teachers. The researcher was also not be able to control the external factors such as pre-service teachers being assigned to different school districts with different classes, topics, block schedules, and grade levels of students. Also, depending on the school district's prior use of inquiry with its students, there were varying levels of understanding between the students in the different districts. Finally, demographic differences between districts could have caused limitations.

Summary

There was a need to examine the pre-service teacher preparation programs in order to keep up to date with the national educational standards for teaching and preparing teachers to teach science inquiry processes. The literature demonstrated the history of inquiry and the lack of follow through with the teaching of inquiry. There were many possible reasons that teachers were not implementing science inquiry in the classroom, but few studies had been completed to dissect the reasons in order to examine them more completely. Using a mixed quantitative and qualitative research approach might have enhanced the adoption of authentic scientific inquiry in the classroom. By examining the different types of pre-service teachers and categorizing student teachers into traditional and non- traditional backgrounds according to their demographics, researchers could examine which teachers were more able and willing to implement inquiry. With new knowledge gained from the above research ideas, teacher education programs could utilize the findings to construct better ways to accommodate both types of pre-service teachers to achieve better outcomes for preparing teachers to be inquiring learners and teachers. In order to teach inquiry to students now and in the future, better interventions, modeling, and experience using inquiry will be necessary to appropriately help pre-service teachers with the transformation. Furthermore, information about the effect of teacher epistemological beliefs may have affected the implementation of inquiry. The knowledge about teacher beliefs could enable teacher preparation and in-services to be adapted to meet the teachers along the continuum of their epistemological belief system and allow for the change process to develop carefully in each individual pre-service teacher. In the future, a larger scale and a more longitudinal study could be designed to follow the pre-service teachers into their prospective school districts for a year or two to examine how well they are able to implement inquiry over a much longer duration of time.

Chapter 4

Data Analysis and Findings

Introduction

This chapter focused on the analyses of the implementation of inquiry in the classroom by comparing two types of pre-service teachers and their beliefs about inquiry. A mixed method design was used for this investigation. A descriptive study was completed using a teacher demographic questionnaire. The study first investigated the performance of pre-service teacher's implementation of inquiry-based instruction in the science classroom. The science standards, designed by collaborative partnerships, require science inquiry teaching to be incorporated into the science classroom as a "Best Practice" instructional methodology. As a result, students' acquire a more profound and lasting grasp of science, which simultaneously enhances students' scientific literacy skills, enabling them to make better informed real world decisions as adults (Rutherford and Ahlgren, 1989; AAAS, 1993; Bybee, 1997, 2000; Zemelman, Daniels, and Hyde, 1998; Minstrell, and VanZee (Eds.); 2000; National Research Council, 2000; Klahr and Milena, 2004; Harlow, 2007). The data was collected during the first part of the study by trained raters using an inquiry rubric. For the first question of the study, a *t*-test or ANOVA was used to analyze the statistical implications and results.

The secondary purpose of this study examined the data analysis' results of pre-service teachers' pre-conceived epistemological beliefs about teaching science inquiry lessons. The beliefs of teachers often affect their eagerness and aptitude for incorporating science inquiry into the classroom. Teachers' beliefs and attitudes are crucial for the inclusion of novel teaching strategies. Reforms have been proposed for many decades.

Teachers' beliefs have had an impact on the resultant changes in new methodologies being included in the science classroom curriculum reforms. Constructivist research about learning has revealed that beliefs change when cognitive dissonance occurs between early perceptions about science and new experiences or investigations that provide evidence to the contrary. Consequently, teachers must be the change agents who give students diverse opportunities to immerse themselves in learning through inquiry as a more common method of allowing for students' misconstrued scientific beliefs to be transferred appropriately. Thus, educational reforms need to recognize how and why some teachers adapt science inquiry reforms and not others (Rutherford and Ahlgren, 1989; Maor and Taylor, 1995; Fang, 1996; Hofer and Pintrich, 1997; Loucks-Horsley and Bybee, 1998; Bybee, 2000; National Research Council, 2001; Chinn and Malhotra, 2002; Pea, 2004; Roehrig and Kruse, 2005; Connell, 2007; Abd Hamid, 2006; Brunsell, 2006; Connell, 2007).

This investigation focused on whether different pre-service teacher demographics (traditional or non-traditional) created a need for new pre-service curriculum strategies to support the two types of pre-service teachers appropriately for teaching inquiry-based science instruction. The allowance of inquiry to become part of the intern teachers' repertoire of "Best Practices" is the goal. The hope is that new teachers will continue to employ inquiry techniques after they graduate and obtain their own classrooms. Expectantly, the inquiry strategy will allow for more in depth scientific growth of all pre-service student learning styles. By using a science inquiry approach to learning, teachers will better facilitate students' science comprehension and higher cognitive learning skill sets. Hopefully, a resultant more scientifically literate future population will materialize to enable the United States citizens to generate better informed decisions and compete scientifically and economically in a more global society (NRC, 1996, 2000).

Summary and Discussion of Statistical Findings

The following research questions guide this study:

Research Question One

1. Is there a significant difference between pre-service non-traditional teachers versus pre-service traditional teachers and the implementation of science inquiry in the classroom?

H_0: there is no significant difference between pre-service non-traditional teachers and pre-service traditional teachers and the implementation of science inquiry in the classroom.

Research Question Two

2. Is there a significant difference between pre-service teacher type (traditional versus non-traditional) and their pre-conceived beliefs about the execution of science inquiry in the classroom?

H_0: there is no significant difference between pre-service teacher type (traditional versus non-traditional) and their pre-conceived beliefs about the execution of science inquiry in the classroom.

Sample and Demographics

The population source and sample size of this study came from a convenient sample of pre-service students from local teacher training institutes within a 25 mile radius of Bethlehem, Pennsylvania. The students were all volunteers. The distance chosen was based on the raters' and researchers' ability to drive to the colleges/universities of the students' field experience schools within a reasonable travel time. In reality, there were few pre-service teachers in the field teaching science classes during the time of the study's first two semesters due to state testing in mathematics and reading. Many schools were not teaching science during the time of the field research to focus on practicing for the reading and mathematics state testing. Thus, there were fewer volunteers than anticipated for the study. Appropriately, the researcher sought permission from the university advisor to include all grade level pre-service teacher field experiences in order to obtain a higher *n* value.

To compute a significant sample size (*N)* for the study, an a priori G*power analysis was chosen to ensure enough participants were included in the study for valid significant findings. More specifically, a *t*-test analysis to determine the difference between two independent means (two groups) was run using G* power analysis. The design was two-tailed with an effect size of 1.5 (used a little larger effect size to reach a reasonable *n* value for each of the study's parameters). The probability of the percentage of error was at the 0.05 level with a power of 0.80. The output showed the degrees of freedom (df) to be 16. In order for the sample size to reach the appropriate G* Power, one group of teacher types had to have an *n* value equal to nine, while the second group also needed to have a minimum of *n* equal to nine. The total sample size needed was at least eighteen participants. The actual power was 0.847 for the G*Power analysis. The proper *n* value needed for the research was reached and exceeded for both groups during the study.

The participants in the study came from local Lehigh Valley colleges and universities. The participants were recruited by a written letter sent to the intern or student teaching offices and/or the supervisors of the pre-service teachers. The letter (see Appendix D) inquired as to their students' availability to partake in the study as described in the correspondence. Lehigh University, Muhlenberg College, Cedar Crest College, and Kutztown University's supervisors allowed only volunteer students to join the study. The schools gave the researcher the emails of interested students. The researcher then emailed the students information about the study with the appropriate paperwork attached. The students received the demographic study, the building Principal and cooperating teacher permission for the raters to enter the building, and the informed consent forms (see Appendices A, E, and F).

During the first two semesters of the research, the *n* value for each type of pre-service teacher needed to complete the study with any meaningful statistical significance was not reached. The second two semesters the researcher collected more participants by obtaining permission from the course professors to permit the researcher to explain the study to the students face to face in the pre-service teachers' practicum and not through email. For most of the seminar/practicum classes, the course professors allowed the researcher to take a few extra minutes of class time to converse with the students about the study and enabled the volunteer pre-service teachers time to read and sign the informed consent (see Appendix E), answer the researchers' pre-questionnaire, and answer the demographic study (see Appendices A and B). Those students who did not finish filling out all the information emailed the researcher their paperwork.

At the end of the participants' intern teaching, the researcher returned to the seminar classes to allow participants time in class to complete the post-questionnaire (see Appendix B). Some participants filled the questionnaire out online and emailed it back to the researcher. More pre-service teachers participated in question two, concerning beliefs, than question one, because the students were more apt to fill paperwork out during classroom time and not volunteer for extra work outside of class. It took four semesters to acquire the number of participants needed to reach the minimal *n* value for each teacher type to reach the G*power analysis significance for each question.

The demographic form assisted in determining the difference between the two teacher types. Other information was obtained on the form for future research studies and publications. The chart below shows some important demographics for qualitative examination.

Table 1

Frequency Distributions
Demographics of Pre-Service Teachers

Teacher Demographics (N=39)	**Number**	**Percent**
Gender		
Male	11	28
Female	28	72
Teacher Type		
Traditional	23	59
Non-Traditional	16	41
Grade Level		
Elementary	17	44
Secondary	22	56
Ethnicity		
Caucasian	38	97
African American	0	0
Asian	1	3
Latino/Hispanic	0	0

Design

The research study utilized a mixed methods design. Qualitatively, information was collected by volunteer participants through the demographic survey (see Appendix

A). The questions were designed to help classify traditional versus non-traditional pre-service teachers, determine information about their schools, science background, gender, age ranges, grade levels taught, and previous degrees, as well as other information that could be useful for later research.

To determine whether teachers' pre-conceived beliefs had a significant relationship to teaching science inquiry, data was examined from pre- and post-questionnaires, while using the demographic survey data to qualitatively categorize the non-traditional versus the traditional pre-service teachers. The questionnaires were measured quantitatively using a Likert scale format ranging from one to four points or one to five points with the larger number being of higher value. The assigned numbers increased in value from lower beliefs about teaching inquiry or understanding of inquiry science teaching to the strongest inquiry beliefs having the higher point values. After the pre-service teachers filled out the pre-questionnaires, they emailed the raters dates and times they were available for observation.

The next step in the research the raters observed the pre-service teachers' science inquiry lessons using the STIR rubric to rate each lesson. Each pre-service teacher had two lessons observed, one early on in their teaching and one later in their field experience. Evidence was gathered for quantitative analysis. The two raters were recently retired science teachers from the Emmaus School District. The practice training for rating used the STIR rubric and spanned two half days of observing veteran teachers' science lessons in a local school district. After each classroom observation, the researcher and the two raters met in the teachers' lounge to compare their results. Their STIR check sheets were reviewed together until there was a consensus on comprehending the proper method for rating science inquiry using the STIR rubric. The researcher checked for an agreement of at least 83% or higher range with the rubrics' match to the expert rater (the researcher) to meet the standard for inter-rater reliability. The raters and the expert rater were able to obtain an average of 83% and higher match in agreement during the trainings which met the requirement for reaching the appropriate inter-rater reliability.

The first day observing the classroom teacher there were some inconsistencies due to a steep inquiry rubric learning curve by one of the raters. That rater had one observation sheet with an agreement of only a 67% match to the expert rater score. The resulting poor agreement from the one observation was cleared up after further instruction was given to both raters. Some misunderstandings were discovered with the key ideas in some of the rubrics' boxes. More importantly, the researcher learned in discussions after the lowest rubric observation of each rater that the raters knew the first teacher being observed extremely well. The raters anticipated what the observed teacher was going to do the next day to finish the inquiry, which caused the raters to mark-off some of the boxes not observed in the classroom lesson that day. The researcher explained in the planning room that the ideas in each box had to be seen or heard only in the allotted classroom time for them to be marked off in the higher inquiry rubric box. For further clarification, the researcher gave clear clue words for the particular boxes that raters were having difficulty discerning while observing the science inquiries. The extra instruction seemed to solidify the ratings of each rater. Additionally, one rater went home and did more research on Bybee's five essential features of inquiry.

Notably, a post hoc analysis for inter-rater reliability was performed using SPSS to ensure the earlier hand calculated percentage measurements were considered reliable matches amongst the raters' rubric matches to the expert rater's matches.

Table 2

Chart of Inter-Rater Reliability Scores

Rater	Mean Reliability to Expert	Range
1	89.5%	67 - 100%
2	83.25%	67 - 100%
3	91.5%	83 - 100%

With the lengthy time needed for data collection of four semesters, one of the raters dropped out after two semesters. A replacement volunteer rater was found who are a recently retired public school elementary teacher and principal from New Jersey. The training for the newest rater was performed using the same process that was explained earlier in this paper for the first training. Fortunately, the new rater was able to meet the inter–rater reliability expectations with the match to the expert rater every time. The first rater who did not drop out matched with the expert rater again to meet the appropriate inter-rater reliability as shown in the chart above.

At the end of the students' field experience, the participants filled out the post-questionnaire. The questionnaires included sections about standards, beliefs, preparedness, instruction, student motivation, environmental human factors, environmental socio-cultural factors (policy and cultural norms of the schools), design environment (facilities and equipment), and goals or benchmarks. All of the above factors could affect the outcome of the pre-service teachers' beliefs and ability to teach inquiry instruction. The above questions included any factor that could affect the beliefs of the pre-service teachers before their field experiences or after their field experiences.

Instrumentation

Several instruments were utilized to collect different types of data. The instruments included a teacher demographic survey (see Appendix A), a pre- and post-questionnaire (see appendix B) designed to evaluate traditional versus non-traditional pre-service teachers' beliefs about science inquiry, science subject matter knowledge, pedagogy, inquiry knowledge, school culture, and space as well as the school administrative and teacher support for performing inquiries. The pre- and post-questionnaire instruments were created by Pea's dissertation questionnaires. Pea (2004) developed her questionnaires by adapting work from Lumpe, Haney and Czerniak (2000) as well as Horizon Research, Inc. (2000). The new instrument was restructured to meet this study's needs.

The new tool was further validated by experts in the field. One of the experts was the past president of the National Biology Teachers Association as well as the science department head in their school district. For further evaluation of the revised instrument, two veteran science teachers, who performed inquiry in their classrooms; gave feedback about the instruments validity. Using the experts' feedback, the questionnaire was further improved. A former long term biology chair from Lehigh University who was a member of the dissertation committee, and the rest of the dissertation committee members made comments and suggestions for updating and appropriately adapting the questionnaire. Therefore, the instrument was completed with recommendations for refinement and validated by experts in the field. A pilot study using student teachers was completed to further detect and correct any additional flaws that the students might not comprehend.

The third instrument used was a validated Science Teacher Inquiry Rubric (STIR) (Bodzin and Beerer, 2003) (see Appendix C). The rubric was used to evaluate two different science inquiry pre-service teacher classroom observations. The STIR instrument determined the quality and type of inquiries taught along a continuum. The rubric examined if the inquiries were more teacher-centered, student-centered or somewhere in between (Beerer and Bodzin, 2004).

Research Findings

To answer the first research question, an analysis of a two independent sample *t*-test (analysis of variance) was performed to statistically assess if there was a significant difference ($\alpha = .05$) between pre-service non-traditional teachers versus pre-service traditional teachers and the implementation of science inquiry as measured by the mean scores on the STIR rubrics. Two classroom observations were rated using the STIR rubric for all participants. The scores for each observation rubric were summed and divided by two. The analysis was run using SPSS. Levenes' test for equality of variance was checked for the assumption of equal variance. If the significance was larger than .05 than equal variance is assumed. However, looking at the output for the Levenes' test in the assumed variance row, the p value was 0.26 which is significant. According to the rule, the p value is not greater than .05. The assumption of variance was violated. Thus, the variance is not assumed. Therefore, the equal variance not assumed on the chart below must be examined for significance. The analysis in the *t*-test showed *p* equals 0.00 ($p < .001$). Thus, there was a significant difference in the mean scores between traditional pre-service teachers (*M* = 11.48, *SD* = 2.34) versus non-traditional pre-service teachers (*M* = 14.45, *SD* = 1.42). The confidence levels were at 95%.

Table 3

Mean Scores of STIR Observations by Teacher Types

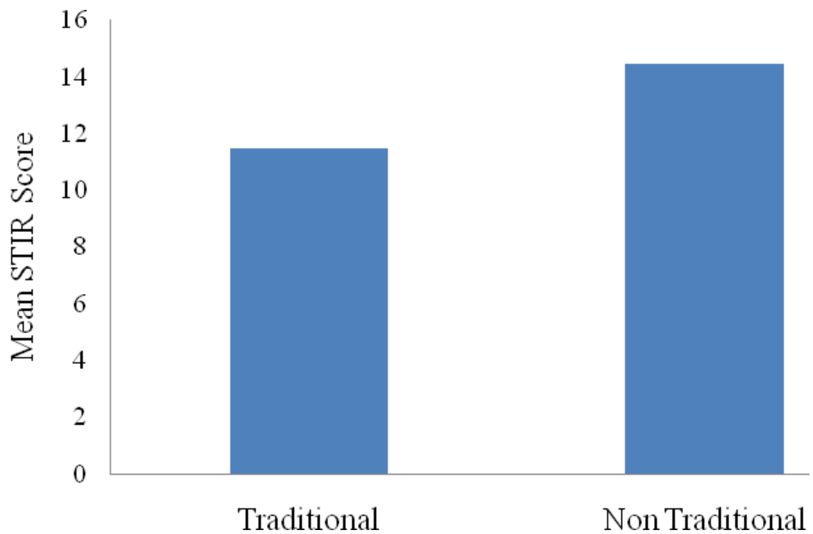
Teacher Type	N	STIR Mean Score	Std. Deviation	Std. Error Mean
Traditional	16	11.48	2.34	0.58
Non-Traditional	10	14.45	1.42	0.45

Table 4

Comparison of Mean Scores (t-Test) of STIR Observations

	Levene's Test for Equality of Variances		t-test for Equality of Means				
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Equal variances assumed	5.62	.026	-3.60	2	.001	-2.97	.823
Equal variances not assumed			-4.03	23.99	.000	-2.97	.737

Figure 1. Mean STIR Scores of Traditional vs. Non-Traditional



Literature that discusses teachers' implementation of inquiry indicates the challenges of planning and facilitating the inquiry process in the classroom (Roehrig and Luft, 2004b). Often the primary implementation of inquiry is more teacher-directed due to lack of student experience, but naturally changes to more teacher-guided. Lastly, inquiries are meant to become more student-directed as students and teachers learn through experience how to construct more scientific connections by starting to practice with partial inquiries (Bybee, 2002). The demographic study showed that many of the non-traditional pre-service teachers had more experience teaching or working in laboratory or science research settings before changing plans to become science teachers. Windschilt (2001) backs the evidence found in the results of the study. He purports that even if participants are eager to use inquiry; only applicants in his study with prior experience in longer term research studies as undergraduates/ graduates or similar experiences as professionals seemed to be able to engage their students in much richer student inquiries. The above idea validates the significant difference found between the traditional students who are younger with less life experiences to draw upon for teaching science inquiry. The non-traditional pre-service students and their varied life experiences allowed for more time to construct and reconstruct ideas which helped to lessen the learning curve and permitted for extra time for transfer to employ science inquiry as a teaching methodology.

The second question examined whether there was a significant difference between pre-service teacher type (traditional versus non-traditional) and their pre-conceived beliefs in the execution of science inquiry. A pre-questionnaire was given to the participants before their field experience and a post-questionnaire was given afterwards. The questionnaires were given at two different times which allowed for the comparison of the participants beliefs over time. The field experience's two observations were rated at different times to determine if more time teaching in the classroom made a difference in the pre-service teachers' beliefs and their ability/willingness to teach science inquiry. The questionnaires have extra questions for further qualitative examination to determine whether there were any other commonalities or patterns that emerged to explain findings of significance or no significance during the analysis of the teacher beliefs' results.

Chapter Five will address the researchers' assessments of the questions. However, quantitative analysis was performed to see if there were any significant differences found in teacher beliefs among the two teacher types over time through the use of the questionnaires.

The results of the two questionnaires given at two different times (one before field experience and one at the end of the experience) enabled the researcher to run a repeated measures analysis of variance (ANOVA) to test for differences between the two questionnaires over time. The repeated measures ANOVA was used because it tests the equality of means like an ANOVA, but further measured the dependent variable over time. Another reason a repeated measure ANOVA was utilized was due to a recruitment problem in obtaining a larger sample size. A repeated measure ANOVA was most reasonable to use because each person is measured under a number of conditions by taking the questionnaire over two different times. In this research design, the individual differences can be eliminated or lessened with the between group differences (The University of Texas at Austin, 1997). When performing a repeated measures analysis, assumptions of multivariate and bivariate normality must be checked and met. The researcher checked the multivariate and bivariate normality for the following:

Multivariate Normality

- Skewness & Kurtosis (-2 and 2)
- Normal probability plots were checked; how closely data followed probable normal distribution; and
- Scatter Plots; looked to see the data did not contain outliers, looked for an oval shape to the scatter plot upon visual observation using SPSS. All the conditions above were met.

The researcher checked the Bivariate Normality and the homogeneity of Covariance Matrices-Box Test. The following assumptions were made: Skewness and kurtosis for both pre- and post-tests fell within the ±2 range. Normal probability and scatter plots of pre- and post-test data were visually inspected and no problems were observed. The assumption of bivariate normality was met using Box's test of equality of covariance matrices (p = .931).

The repeated measures analysis was run with SPSS to compare non-traditional and traditional pre-service teachers' inquiry beliefs at pre-test and at post-test. Using pair-wise comparisons, the test of simple effects of teacher type was performed at the .05 level of significance. The table below shows the descriptive statistics of the pre- and post-questionnaires. As seen below, the findings showed no significant difference between the beliefs of non-traditional pre-service teachers and traditional pre-service teachers.

Table 4

Mean Scores of Traditional vs. Non-traditional Pre-service Teacher Beliefs at Pre-test and Post-test

	Teacher Type	Mean	Std. Deviation	N
Pre-test1	Traditional	329.30	22.73	23
	Non-Traditional	323.63	20.53	16
	Total	326.97	21.76	39
Post-test2	Traditional	337.00	23.014	23
	Non-Traditional	337.38	24.58	16
	Total	337.15	23.35	39

Table 5

Univariate Tests of Traditional and Non-Traditional Pre-service Teacher Beliefs

Time		Sum of Squares	df	Mean Square	F	Sig.
1	Contrast	304.36	1	304.36	0.636	0.430
	Error	17692.62	37	478.18		
2	Contrast	1.33	1	1.33	0.002	0.961
	Error	20711.75	37	559.78		

Note: each F tests the simple effects of Traditional and Non-Traditional teacher beliefs within each level combination of the other effects shown. These tests are based on the linearly independent pair-wise comparisons among the estimated marginal means.

As shown in the table above, there was no significant difference in beliefs between pre-service traditional teachers at time one (*M* = 329.30, *SD* = 22.73) and non-traditional teachers (*M* = 323.63, *SD* = 20.53) at pre-test ($F_{1,37}$) = .636, *p* = .430). There was also no significant difference in beliefs between pre-service traditional teachers at time two (*M* = 337.00, *SD* = 23.01) and non-traditional teachers (*M* = 337.38, *SD* = 24.58) at post-test ($F_{1, 37}$) = .002, *p* = .961).

Past research has shown that teachers develop embedded pictures about science teaching and learning constructed by their prior belief systems based upon previous experiences. These deep rooted visions develop into their core epistemological beliefs. However, there is a divide between some teachers' epistemological beliefs about science and their inquiry practices in the classroom (Sandoval, 2004). Asking teachers to teach through inquiry without adequate training and modeling might cause them to become dubious about employing inquiry into their science curriculum. Their skepticism is related to whether their prior science learning experiences and the methods of science teaching was taught to them differently than through inquiry (Tobin, 1993; Hofer and Pintrich, 1997; Duit and Treagust, 1998; Windschitl and Buttemer, 2000). The above explanations could allude to some of the reasons the study's outcome might have showed no significant difference between teacher types and their beliefs about teaching science inquiry.

Conclusion

The purpose for the study was to examine whether or not two different pre-service teacher types were able to implement science inquiry into their lessons during their field experience. Secondly, research examined whether the pre-conceived beliefs of two different teacher types (traditional or non-traditional) affected their willingness and ability to teach science inquiry. The final analysis was presented in this chapter. The validated STIR rubric was used to determine if there was any difference between two different pre-service teachers and their teaching of science inquiry lessons during their field experience. Using a *t*-test, the alternative hypothesis was confirmed. Therefore, a significant difference was found between pre-service traditional and non-traditional teachers' ability to teach science inquiry lessons.

The second research question examined whether there was a significant difference between pre-service traditional teachers versus pre-service non-traditional teachers and their pre-conceived beliefs about teaching science inquiry. The pre- and post-questionnaires were given over time, (the beginning and the end of the field experience) so a repeated measures ANOVA was performed to determine whether the null hypothesis was met or not. The repeated measures analysis showed no significant difference between the science inquiry beliefs of the pre-service traditional versus the non-traditional teachers during their field experience. The null hypothesis was accepted. Qualitatively, some incremental differences in beliefs were detected while observing various frequency outcomes from the questionnaires. The pre-service teachers in many cases did confirm overall higher Likert scale scores on the post- versus the pre-questionnaire, although there were some with the opposite effect. However, quantitative analysis proved there was not a significant enough difference between the two teacher types and their inquiry beliefs.

This study was conducted to determine if there was a need to update the pre-service teaching curriculum to better accommodate for two different types of student demographics that have emerged at many universities or colleges. Researchers suggested there is a need for more experiences and role modeling of inquiry in students' college curriculum coursework to allow for better implementation of inquiry into their future science classrooms (Windschitl and Buttemer, 2000). However, from the studies' demographics, and STIR results, better classroom science inquiry instructional methods or authentic lab experiences are needed additionally for the traditional pre-service teachers than for more of the non-traditional teachers to enable better inquiry transfer..

Chapter Five more closely inspects the needs of the pre-service students and the possible reasons that a significant difference was found in the first research question between the two teacher types and not in the second question the study examined.

Chapter 5

Interpretation of Data and Conclusions

Introduction

Over the past few decades, there have been serious concerns about the path the United States has taken in science and mathematics education. This study sought to find out some of the reasons the educational system in the United States has been less competitive than other nations particularly in science (AAAS, 1993; NRC, 1996, 2000, 2001; Hobson, 2000). How the science inquiry-based reform movements were progressing in pre-service training institutions were investigated, in particular the types of student teachers that were most likely to adopt these reform efforts.

Two questions were examined concerning pre-service teachers and the teaching of science inquiry in the classroom during field experiences. The first question was whether there was a significant difference between pre-service non-traditional teachers versus pre-service traditional teachers and the implementation of science inquiry in the classroom? The findings showed the null hypothesis was not accepted. Therefore, there was a significant difference between the two pre-service teacher types and the implementation of science inquiry in the classroom. The second question examined whether there was a significant difference between pre-service teacher types (traditional versus non-traditional) and their pre-conceived beliefs in the execution of science inquiry in the classroom? The null hypothesis was accepted meaning there was no significant difference. The reasons for the findings will be discussed in the sections below.

Discussion of Findings

With the initiation of the Science Standards (NRC, 1996, 2000) in the past two decades, the reform efforts reintroduced the importance of including inquiry into the science curriculum. Two purposes for science reform were to advance students' tests scores as compared to other countries and to help produce more scientifically literate adults in society (NRC, 1996, 2000; Minstrell and VanZee, 2000; Roehrig and Luft, 2004a).

The National Mathematics Advisory Panel (NMP, 2008) recommended more studies be performed on "*Best Practices*." The report claimed that much of the research conducted as part of the reform efforts was deficient in valid empirical research. Despite these findings the National Council of Teachers of Mathematics (NCTM) and the National Science Foundation (NSF) still believe that teaching through reform practices using a student-centered approach will enhance student understanding of the nature of science instead of just learning factoids. A constructivist approach for conceptual understanding is recommended to focus on problem solving to achieve better mathematically and scientifically literate students. The dilemma with teaching reform practices in science and mathematics' classes is the turmoil surrounding the identification of genuine reform methodologies. Some suggest that the measurements attest to the fact that science inquiry-based teaching methods were considered inadequately conducted. Researchers noted difficulties connecting reform-based teaching practices with improved student learning (Jong, Pedulla, Reagan, Salomon-Fernadez, and Cochran-Smith, 2010).

Many of the reform studies compared teachers' use of reform methods versus non-reform methods to examine what impact science inquiry-based reforms had on students' learning. Additionally, studies show that non-traditional teaching through science inquiry indicate better student progress than traditional teaching methods where students are taught to think they must look for the " right " answer (ARC Center, 2003; Klein, Hamilton, McCaffrey, Stecher, Robyn and Bourroughs, 2000; Senk and Thompson, 2003). Unfortunately, many studies made the supposition that teachers were all teaching with the correct inquiry reform methodologies. The measurements for the studies were all teachers' self-reports which are not as reliable as other types of analyses (Jong et al., 2010).

One of the few research programs sponsored by the NSF focused on pre-service teachers and their pre-service curricular planning, including the pupils attitudes, was a program called Collaboratives for Excellence in Teacher Preparation Program (CETP). Some of the participant pre-service teachers were taught using open-ended inquiry including "manipulatives" for mathematics, while others used traditional teaching methods such as drill or memorization tactics. The aforementioned program was an example of research that compared two types of teaching, but used qualitative analysis. The CEPT study contained the same limitations that Jong et al. (2010) identified as being qualitative survey-oriented designs. Outside raters were not used for classroom observations.

In the CEPT survey above, the students preferred traditional teaching methodologies versus reform-based inquiry. Students were taught through memorization of facts and cook book labs with only one correct answer. Accordingly, solving problems through inquiry were initially difficult and more time consuming for students because they had to learn to think more conceptually about science. Students did not have the true sense of the nature of science and were not scientifically literate through merely memorizing facts. Furthermore, Osborne (2009) agreed with the CEPT surveys' students' opinions about learning through inquiry. He objected to the assertion included in the 5E inquiry model that high school students had the capability to evaluate or analyze scientific content to obtain explanations. He considered such higher level thinking skills to be better suited for the college level students. Jong et al. (2010) were concerned when educators used the above qualitative studies to criticize inquiry-based teaching reforms, because these studies did not depict why students' preferred traditional teaching. Researchers did not identify and study the source of the students' preference for the traditional teaching methodology. There were challenges caused by past research explanations being largely anecdotal in nature and containing students and teachers' inherently limited self reports. The above reasons confirmed a need for more effective use of science inquiry instrumentation measurements in research studies (Jong et al., 2010).

The lack of clarity in past research findings prompted this current investigation to use a mixed methods design. This dissertation examined pre-service teachers conducting science inquiry in their classrooms. Due to the lack of empirical quantitative data, a validated tool called the STIR instrument was included. Observations of pre-service teachers' capacity for teaching using the five essential features of inquiry were measured through direct observations performed by trained raters who used the STIR instrument. The above rubric was not utilized for teacher reflection as was the case with the experiment by Beers and Bodzin (2003). The measurements with this research were triangulated with other instruments to ensure better results. The STIR instrument enabled the raters to pinpoint where along an inquiry continuum the pre-service teachers were performing. The next measurement was qualitative. A demographic survey was used for the comparison of pre-service teacher participant types. Lastly, pre- and post-questionnaires were adapted from another instrument on inquiry beliefs (Pea, 2004). Conversations held by the raters or the researcher with the pre-service teachers or the mentor teachers included some additional qualitative evidence.

The lack of research on the effect beliefs have on science inquiry prompted the testing of pre-service teachers' beliefs in this study. The researcher's own experience found a need for a study on pre-service teacher types (traditional versus non-traditional) willingness to teach science inquiry. The inquiry belief questionnaires (see Appendix B) included many factors that could influence pre-service teachers' beliefs concerning the adoption of science inquiry methodologies. The comparison of traditional versus non-traditional pre-service science teachers has become more relevant in research because of teacher shortages in some states which permit more non-traditional paths to certification in science and mathematics (Latterell, 2009). For science standards to be properly adopted in the current era, the need to discuss how pre-service teachers commit to teaching science inquiry is pertinent for proper adoption of the science standards.

Implications

The finding of no significant difference in pre-service teachers' beliefs regarding science inquiry teaching had many implications due to the outcome. The student teachers were all volunteers with the exception of one practicum class in which the professor gave class time for the researcher to invite all students to fill out the pre- and later post-questionnaires. Some student teachers were able to fill out the pre- and post-questionnaires in class, enabling the researcher to get a few extra student teachers to answer the questionnaires who might not normally be interested. Many of the non-traditional students did not participate in the observations for the first question.

The first research question concerning whether there is a significant difference in science inquiry implementation between the two teacher types, (traditional versus non-traditional) showed that over time the latter scored higher on the STIR instrument. The demographic survey was used to qualitatively group and analyze differences in pre-service teachers. Findings from the survey revealed that most non-traditional student participants had some type of laboratory experience, some additional science experience, some type of prior science degree, or had some previous teaching experience, but were now obtaining science certification. The non-traditional pre-service teachers had prior knowledge due to their advanced socio-cultural experiences in science which may have enabled them to transfer inquiry learning more easily. Consequently, the non-traditional pre-service teachers were at a greater advantage for adopting inquiry teaching methods into their science lesson at higher inquiry levels of Bybee's' 5E's (Rebello and Zollman, 2005).

The ability to use greater contextual levels of inquiry, as shown by the results on the STIR rubric, revealed that their prior science work enabled them to have a higher confidence level for implementing inquiry then the non-traditional less experienced pre-service teachers. The districts that were more amenable to letting university research be performed could have been more current in "Best Practices" and permitted more science inquiry to be taught. If the districts were more open-minded and supportive of science-based reforms, then the pre-service teachers would be more eager to accommodate the science inquiry process. Pre-service teachers would have been able to experience first-hand that science inquiry teaching was a learning process for both the student and the teacher. Both teacher types would have had a greater ability to transfer inquiry. The task of inquiry preparation and teaching would not seem to be as daunting of a task for the provision of richer student teaching experiences (Harlow, 2007).

A couple of pre-service traditional student teachers started the paper work process, but could not finish the research because their cooperating teacher or school district did not want any university research taking place in their schools. Other qualitative findings from the raters and/or the researcher emerged when some traditional elementary pre-service teachers who wished to participate, spoke to raters/researcher to gather preliminary information or to attempt to coordinate participation in the study. The pre-service teachers admitted having a hard time convincing their cooperating teachers that they could complete the content that was needed for the PSSA testing, while using science inquiry lessons during a reading or mathematics lesson.

In order to attain more study participants before the PSSA testing included science, the researcher and the raters asked some of the possible participants to propose to their cooperating teachers whether they could teach interdisciplinary lessons during mathematics and reading lessons and incorporate science inquiry into the subjects. These pre-service teachers did their best to include inquiry, but did not have adequate assistance from their cooperating teachers which made it more difficult for the traditional pre-service teachers to score higher on the rubric. Findings showed that younger age with less life experience outside the classroom could have hindered the traditional pre-service teachers from acquiring higher mean scores under less then supportive environmental factors as was a common theme that emerged in the beliefs questionnaires. The less difficulty at getting traditional pre-service teachers to get involved in the study showed these teacher types were more willing to try inquiry and perhaps the non-traditionals, who did not have any science or past teaching experience, just did not believe in inquiry and did not want to waste time being involved. Not having a random sample and only using volunteers was problematic. Thus, a key component was missing in the teacher preparation programs for one of the pre-service teacher types in gaining more interest about the importance of learning inquiry through practice. It is essential for the colleges or universities to train their pre-service students to fit different learning needs to help all of their students to construct a positive belief system about inquiry.

The finding that the non-traditional student teachers showed a significant difference in their execution of inquiry does advise curriculum developers that their lessons are not enabling both teacher types to transfer inquiry into their teaching. The teacher preparation programs should update their curriculum to better accommodate the needs of all students in order for them to practice science inquiry uniformly. The curriculum should include more authentic science experiences for all students or inquiry may not be transferred into practice by all pre-service teachers. If school districts and institutions of higher learning collaborated on conducting inquiry research with pre-service teachers, then it would be more likely for curriculum improvements to occur in science. Also, by being more supportive by incorporating more inquiry practice into the pre-service curriculum, people's beliefs can be transformed by having the time to uncover the importance of teaching science inquiry methodologies. The integration of science inquiry permanently into their repertoire will become a mainstay for pre-service teachers. The future student teachers could become more scientifically literate citizens and encourage more of their own students to entertain the idea of going into a science field. The United States could then make progress in catching up to leading countries in the sciences.

Limitations

The demographics of the study were limited geographically to the Lehigh Valley area in Pennsylvania. The institutions who took part in this study were limited to those who had teacher preparation programs with students willing to volunteer for the study. Fewer schools wanted to participate than were anticipated. Some of the universities and colleges did not want to participate in the study because Lehigh University was a competing school for student teacher placements. During the time of the study, many area colleges or universities did not have enough, if any student teachers in the field teaching science education on any level. Initially, secondary students were more difficult to get involved in the study and the lower numbers for some of the elementary involvement was in part due to the PSSA (Pennsylvania System of School Assessment) testing in mathematics and language arts. Many of the school districts where students were practice teaching were not given any time for science instruction to be taught.

The PSSA testing did not start for science until the last semester of the data collection portion of the study. During the last two semesters of data collection, the researcher was finally able to get more elementary schools involved in the research, because science was finally included in the state testing for that school year. Thus, state testing became a hindrance. Another reason for the difficulty in getting more elementary teachers involved was because their mentor teachers were more worried about content for the tests rather than the quality of science processes and thinking skills. Many teachers had no choice in their ability to include inquiry lessons due to the principals' rules and the schedules teachers followed to make Adequate Yearly Progress (AYP) on the high stakes testing. The amount of state and federal money that school districts and specific buildings were allotted, hinged on how well their student's tested. The above reason made it difficult to get a larger pool of applicants. Districts did not think taking more time to teach science inquiry would translate into improved state test scores. Teaching had been turned into drill and practice to teach primarily for content.

Another limitation of participants was the few non-traditional students that volunteered to participate in the science inquiry observations. The lack of choosing from a random sample was a limitation. Some reasons the non-traditional pre-service teachers were less willing to be involved in the study might have been that as a group, they may not have been as interested in inquiry. For example, less inquiry modeling in their own education may have diminished their comfort levels for teaching inquiry in their classrooms. They might have also had more outside responsibilities then the traditional pre-service teachers, which encroached on their preparation time. An observation was made by a supervisor and science methods teacher that some non-traditional teachers were unwilling to give up total control of their class which made it difficult for students to learn through a science inquiry method. The use of lecture and cook book labs were more common in the above classrooms.

The last couple of semesters when the researcher was permitted to take time out of the supervisors' practicum to meet the pre-service teachers and explain the study, the numbers of students that were interested in participating in the research rose. Most of the students were at least willing to complete the questionnaire. The practicum professors gave their students time to fill out questionnaires, once in the beginning of the semester, and then at the end of the semester. The traditional students who were more likely to be observed teaching inquiry in the classrooms, were also more likely to complete both questionnaires on science inquiry beliefs. The non-traditional students' participation rate on the beliefs questionnaires was still lower than the participation rate for the traditional pre-service teachers. The participation rate for both teacher types was sufficient for the G*power analysis to have significance. In talking with some of the participants, the raters and researcher found that some of the school districts did not want anyone in their buildings observing their student teachers. Some of those students were disappointed their schools would not let them participate.

Limitations in controlling for external validity were due to the inclusion of many grade levels, class types, and topics. The number of participating student teachers was limited. Therefore, to obtain enough participants for*G Power significance, the researcher, with advice from the advisor, used kindergarten through twelfth grade pre-service teachers' classes.

Concurrently, there were limitations that might have confounded the pre-service teachers' beliefs due to some of the contextual environmental factors in the schools including administrative support, cooperating teacher support, technical support, classroom feasibility, parental support, equipment, and supplies. Two of the biggest limiting factors identified from the questionnaires were the lack of class time and the type of equipment available. The participant teachers in the elementary classes were more likely to teach and believe in inquiry if their classrooms and their co-ops used Full Option

Science System (FOSS) kits. The external variables due to the use of a multitude of school districts and the participation of different colleges or universities who taught science methods differently were not able to be controlled in this study.

The researcher’s bias towards using inquiry in the classroom is a limitation. Due to the triangulation of the study, this bias should not present a significant problem with the results.

Recommendations

This research could be performed better if there was a larger scale study. If the study was completed within one large university with more pre-service science students all taught by the same methods teacher and same pre-service science supervisor, additional threats to external validity would be lessened. If all the cooperating teachers were told that their student teachers were going to be part of a research study concerning the implementation of science inquiry methodologies ahead of time, more cooperating teachers would allow their pre-service teachers to teach science inquiry. Limiting the study to include only secondary science or only elementary science lessons would decrease the variables on class type, content, and age for future research.

The raters for the research had excellent backgrounds in inquiry, supervising and/or evaluating teachers’ lessons. They were all teachers themselves and one was later a principal. The findings for question number one of this study, comparing two teacher types and their implementation of inquiry, were noteworthy due to the high inter-rater reliability. Performing a more in-depth qualitative analysis of the questionnaires would reveal more trends and additional research evidence to add to the quantitative study. Then a quantitative analysis could be performed dividing each section on the pre-and post-questionnaire for an exploratory factor analysis.

Future Research

Revisions in this research described above could tighten the study. Perhaps more significant results could be discovered if the study numbers were larger using universities throughout the United States, on the east Coast, or at least in one entire State. Furthermore, a longitudinal study following student teachers into their first year teaching assignments could provide new findings about the retention of science inquiry teaching and learning. Funding would be needed to undertake a larger study.

The study would be more concise if all the cooperating teachers had some prior science inquiry training. The student teachers' master teachers would use inquiry methodologies in their classrooms with the belief that inquiry is an adequate teaching tool for improving science literacy for their pre-service teachers. The school districts in the study would need to be accountable by providing the master teachers adequate time, equipment, and support for teaching science inquiry. If school districts and institutions of higher learning collaborated on conducting inquiry research using pre-service teachers, then curriculum improvements in science inquiry implementation could be adopted more readily, and beliefs about inquiry could become more positive.

Comparing other types of teacher demographics using the STIR instrument would supply more information about the curricular needs for science inquiry implementation. For example, an inquiry with just elementary student teachers or only secondary science teachers would have fewer variables. The study findings could cause the role of science inquiry in the elementary schools to increase. Younger students could adopt inquiry earlier and then students would be better prepared to understand science better conceptually in secondary schools.

Another study could be undertaken using only non-traditional pre-service teachers to determine if there were other factors involved. The design could be changed to a quantitative experimental design with a control group and experimental group. A better understanding of the findings in this research study's first question could be available with the above examples of future research.

Summary

Since there has been a need for our educational culture to buy into the teaching of science inquiry-based reform methods to reach science literacy for all citizens, this study examined two different types of pre-service teachers and whom will implement science inquiry more readily and why. The science *Standard*s include inquiry as an important methodology to use in the science classrooms. Students taught by the inquiry approach become more interested in science and become more scientifically literate. The goal for the United States' students is to compete scientifically with the top nations in today's more global society. The "Best Practices" written for science include inquiry through a constructivist approach as one of the preferred methods of teaching science. These students will be prepared to conceptualize science more readily through their life experiences and reflect/think more like scientists.

The research study showed a need for younger or traditional student teachers to have more experiences with inquiry in order for them to implement inquiry as well as the non-traditional pre-service teachers. If college students in their pre-student teaching experiences can practice more science inquiry techniques in their classrooms, then perhaps more pre-service student teachers, whether non-traditional or traditional, would show an increase in beliefs about the usefulness of inquiry. Beliefs could change when the students feel more confident about their ability to transfer and incorporate science inquiry into their own classrooms. Hopefully, this dissertation research will be the catalyst for examining science inquiry teacher preparation curriculum by more empirical research methods.

This study showed a need for pre-service teachers to experience science differently in college than they do presently. Today's non-traditional pre-service teachers have had life experiences that enable them to improve science inquiry teaching performances greater than the traditional student teachers. If all pre-service teachers were given the opportunity to experience live science field work, use science inquiry in their science classes, and use inquiry in more of their education classes, then all pre-service teachers would have an equal chance to transfer science inquiry into positive beliefs.

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Appendix A

Appendix A: Demographic Survey

Instructions: You may use a pencil or ink pen to complete this survey. Answer the following questions to the best of your ability.

1. First Name ____
2. Last name ____
3. Invent a four digit ID using the month of your birth and last two digits of your phone number (insert a zero if less than ten, i.e., if January, use 01) ________________
4. Hometown City ___________________________
5. Hometown State __________________________
6. Zip code _____________________
7. E-mail _________________
8. Hometown High School ______________________________
9. School name (where you are currently teaching) _______________________________
10. School address ____
11. School city ___________________
12. School state __________________
13. School zip ____________________
14. School phone # ____________________
15. Position (check the appropriate title)

    ____ Pre-service teacher

    ____ Student teacher

    ____ Teacher

    ____ Science supervisor

    ____ Other

16. Indicate your sex: _____Male _____Female

17. Are you: ______ American Indian or Alaskan Native
______ Asian
______ Black or African-American
______ Hispanic or Latino
______ Native Hawaiian or Other Pacific Islander
______ Caucasian

18. What year were you born?

_____Before 1950 ____1950-1960 ____1961-1970 ____1971-1980

____1981-1986 ____1987 and above

19. How many years have you been teaching including this year?

____0 ____1-3 ____4-6 ____ 7-10 ____11 or more

20. What grades are you presently student/field teaching for this study?

____

21. What is the length of time you have to teach one science lesson?

____

22. Do you have each of the following degrees?

Bachelors ___ Yes ___ No

Masters ___ Yes___ No

Doctorate ___ Yes___ No

Other ___ Yes___ No

23. Please circle the subject(s) for each of your degrees.

Biology/Life Science	Bachelors	Masters	Doctorate
Chemistry	Bachelors	Masters	Doctorate
Earth/Space Science	Bachelors	Masters	Doctorate
Physics	Bachelors	Masters	Doctorate
Other science, please specify: _____________	Bachelors	Masters	Doctorate

Science Education (any science discipline) Bachelors Masters Doctorate
Other, please specify: ____________________ Bachelors Masters Doctorate

24. What type of learner do you consider yourself?

______ Visual _____ Auditory _____ Kinesthetic _____ Linguistic _____ Other

Explain ____

25. Is your school:

_____ Rural _____ Suburban _____Urban

26. Are you currently student/field teaching? ___ Homogeneous Group

___ Heterogeneous Group

27. What are the ability levels of students in your class?

____General ____ College prep ____ Honors _____Other

Explain ____

28. How do your students compare to the students in the school as a whole?

____Below average ____ Average ____ Above average _____ Other

Explain____

29. Are there any students with special needs in this class?

____ Yes ____ No ____ Don't know Explain___________________

30. Are there any students for whom English is not their first language?

____Yes ____No ____Don't know Explain_________________

31. Are there any students with learning disabilities?

____Yes ____No ____Don't know

32. Is student absenteeism or mobility a problem in this class?

____Yes ____No

33. How many males are in the class used for this study? ________

How many females are in the class used for this study? ________

Appendix B

Appendix B: Pre and Post Questionnaire

A. Standards

1. How familiar are you with the National Science Education Standards (N), state standards (S), and district standards (D)? Place an X in appropriate box for each set of standards.

Rating	N	S	D
Not at all familiar			
Somewhat familiar			
Fairly familiar			
Very familiar			

2. Please place an X to indicate the extent of your agreement with the overall purpose of the goals of the National Science Education Standards (N), state standards (S), and district standards (D).

Rating	N	S	D
Strongly disagree			
Disagree			
No opinion			
Agree			
Strongly agree			

3. Place an X to show the extent that you have implemented the recommendations for the National Science Education Standards (N), state standards (S), and district standards (D)?

Rating	N	S	D
Not at all			
To a minimal extent			
To a moderate extent			
To a great extent			

4. Does your cooperating/master teacher implement inquiry into their science lessons?
   ______ Yes _______ No

Explain____

B. In reference to your beliefs about science teaching place an X to indicate how you feel about each of the following statements.

	Beliefs	Strongly do not believe	Do not believe	No opinion	Believe	Strongly believe
A	The control over what is learned in science should be the responsibility of the teacher.					
B	I enjoy science teaching.					
C	I consider myself a "master" science teacher.					
D	In the classroom teachers are the prime dispensers of knowledge that students need.					
E	Students need to have a foundation of basic concepts about science that are best taught through rote memorization of terms and the facts about science.					
F	Science teaching should be student-centered (e.g. students actively participate in learning via asking questions, engaging in experimental design, and formulating explanations).					
G	It is important to use a variety of instructional strategies to meet the needs of all students.					
H	It is not important to use a variety of assessment strategies to assess students' conceptual understanding.					
I	Written lab reports can improve the students' understanding of science concepts.					

C. Please place an X to indicate how well prepared you are to do each of the following in your science instruction.

	Preparedness	**Not adequately prepared**	**Somewhat prepared**	**Fairly well prepared**	**Very well prepared**
A	Teacher helps students learn science using unifying concepts and processes (e.g. systems, order, and change).				
B	Teacher implements the district's science curriculum.				
C	Teacher makes connections between science and other disciplines.				
D	Teacher leads their class using inquiry at least 50% of the time.				
E	Teacher listens and asks questions as students work in order to gauge their understanding.				
F	Teacher uses the textbook as a resource rather than the primary instructional tool.				
G	Teacher instructs students who have limited English proficiency.				
H	Teacher recognizes and responds to student cultural diversity.				
I	Teacher encourages participation of all science students.				
J	Teacher involves parents in their child's science education.				

D. Please place an X to indicate how often you believe you include each of the following in your science instruction.

	Instruction	Never	Rarely (e.g. A few times per year	Sometimes (e.g. once or twice a month	Often (e.g. once or twice a week	All or almost all science lessons
A	Introduce content through guided instruction					
B	Pose open-ended questions					
C	Engage students in whole class discussions					
D	Require students to supply evidence to support their claims					
E	Ask students to explain concepts to each other					
F	Ask students to consider alternative explanations					
G	Guide students to the "right answers"					
H	Allow students to use class time to complete their homework					
I	Allow students to help plan lessons					
J	Students listen and take notes during teacher presentation					
K	Watch a science demonstration					
L	Read from a text book in class					
M	Answer textbook or worksheet questions					
N	Collect, record, and /or analyze data					

E. Think about your plans for your science lessons for the entire pre-service teaching experience. Place an X to indicate how much emphasis you believe each of the following impacts the motivation of your students.

	Student Motivation	**None**	**Minimal emphasis**	**Moderate emphasis**	**Emphasis**
A	Use of imitations of real life events and processes via group interactions and computer simulation to increase students' interest in science				
B	Connect science to future study and/or careers				
C	Use lectures to make science engaging				
D	Work in cooperative groups				
E	Learn about the relationship between science, technology, and society				
F	Gives students regular opportunities to think about what they have learned in science				
G	Prepare for standardized tests				
H	Enable students to take control of their own learning				
I	Let students design and implement their own investigations				
J	Do hands-on or laboratory science activities or investigations				
K	Watch audio visual presentations (e.g. video- tapes, CD ROMS, T.V., films, etc.)				
L	Use of technology (calculators, computers, probes, etc.)				
M	Work on extended science investigations or projects (a week or more in duration				
N	Take quizzes or tests				

F. Context beliefs:
Suppose your goal is to be the most effective science teacher possible during this school term. Listed below are a number of school environmental support factors that may have an impact on the above goal. In each row please place an X to indicate the degree to which you believe each factor will allow you to become a more effective science teacher.

	Environmental Human Factors	**Strongly disagree**	**Disagree**	**Undecided**	**Agree**	**Strongly agree**
A	Are assigned students who can work well in cooperative groups					
B	Have students who come to class motivated to learn					
C	Have students who are willing to take control of their own learning					
D	Have students who are looking for the right answer					
E	Have support from other teachers (e.g. peers, lead teacher, mentor, and department head)					
F	Have support using inquiry from cooperating or master teacher					
G	Have support from computer technicians and other technological support					
H	Obtain minimal support from principals, science supervisor, and guidance counselors					
I	Have support from the superintendent and school board (e.g. vision, rewards, funding, and recognition)					
J	Have minimal support from parents and community					
K	Have involvement of college/university (e.g. science and education faculty, graduate students)					

F. Context beliefs (continued):
Suppose your goal is to be the most effective science teacher possible during this school term. Listed below are a number of school environmental support factors that may have an impact on the above goal. In each row please place an X to indicate the degree to which you believe each factor will allow you to become a more effective science teacher.

	Environmental Socio-Cultural Factors (policy and cultural norms)	**Strongly disagree**	**Disagree**	**Undecided**	**Agree**	**Strongly agree**
A	Have policies that support science teaching					
B	Have state and national guidelines for science education					
C	Have team planning time with other teachers					
D	Have limited community involvement					
E	Have student support for tutoring and homework (e.g. after school homework, hotline, and internet website)					
F	Have extended class time(e.g. block scheduling, double periods)					
G	Have increased planning time					
H	Have special programs/professional development to address diversity (e.g. culture ,language, ethnicity, content knowledge, pedagogical skills, and technical skills)					
I	Have an increase in course teaching load					
J	Have a reduction in required teaching content					
K	Have a reduction in class size					
L	Have a variety of classroom assessment measures					

F. Context beliefs (continued):
Suppose your goal is to be the most effective science teacher possible during this school term. Listed below are a number of school environmental support factors that may have an impact on the above goal. In each row place an X to indicate the degree to which you believe each factor will allow you to become a more effective science teacher.

	Design Environment: (facilities/equipment)	**Strongly disagree**	**Disagree**	**Undecided**	**Agree**	**Strongly agree**
A	Have more permanent science equipment (e.g. microscopes, glassware,)					
B	Have more technology equipment (e.g. sensors, probes, graphing, and calculators)					
C	Have limited technology access (e.g. computers, software, and internet).					
D	Have better classroom physical environment (e.g. room size, proper furniture, sinks, and safety features)					
E	Have expendable science supplies (e.g. paper, chemicals).					
F	Have hands-on science kits					
G	Have science curriculum materials (e.g. texts, lab manuals or activity books)					

G. Science Standards:
Suppose your goal is to be the most effective science teacher possible during this school term. Listed below are number of factors related to your district's science goals and benchmarks that may have an impact on the above goal. Please place an X to indicate the degree to which you believe each factor will enable you to be a more effective science teacher.

	Goals, benchmarks	**Strongly disagree**	**Disagree**	**Undecided**	**Agree**	**Strongly agree**
A	Clearly defined and age appropriate					
B	Have attainable and measurable benchmarks					
C	Content is aligned with assessments					
D	Relevant to the achievement of all types of learners and students					
E	Cannot easily be taught in the time allotted					
F	Can be implemented with a variety of instructional strategies					
G	Can be easily assessed to show student's true growth.					
H	Promote inquiry-based learning that is more student-centered and less teacher-centered					
I	Include ongoing support and instructional materials.					
J	Promote articulation and continuity across grades					

Adapted by Patricia O'Donnell from Pea, C. H. (2004). *Teachers' beliefs about science teaching and context factors: Implications for teaching and learning science at the middle school level* (Unpublished doctoral dissertation). George Mason University, Virginia.

Appendix C

Appendix C: Science Teacher Inquiry Rubric (STIR)

Directions: Reflect on the science lesson that you taught today. In your reflection, consider each of the following categories and the six statements on the left, written in bold. After looking at each bold statement, assess today's science instruction based on the categories delineated for statement. Place one "X' in the corresponding cell for each bold-faced statement. If there is no evidence of one of the statements in today's lesson, place a slash through the bold-faced statement. When you are finished, you should have 6 total responses.

Learner Centered ⟷ Teacher Centered

Learners are engaged by scientifically oriented questions.					
Teacher provides an opportunity for learners to engage with a scientifically oriented question.	Learner is prompted to formulate own questions or hypothesis to be tested. ☐	Teacher suggests topic areas or provides samples to help learners formulate own questions or hypothesis. ☐	Teacher offers learners lists of questions or hypotheses from which to select. ☐	Teacher provides learners with specific stated (or implied) questions or hypotheses to be investigated. ☐	No evidence observed. ☐
Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.					
Teacher engages learners in planning investigations to gather evidence in response to questions.	Learners develop procedures and protocols to independently plan and conduct a full investigation. ☐	Teacher encourages learners to plan and conduct a full investigation, providing support and scaffolding with making decisions. ☐	Teacher provides guidelines for learners to plan and conduct part of an investigation. Some choices are made by the learners. ☐	Teacher provides the procedures and protocols for the students to conduct the investigation. ☐	No evidence observed. ☐
Teacher helps learners give priority to evidence which allows them to draw conclusions and/or develop and evaluate explanations that address scientifically oriented questions.	Learners determine what constitutes evidence and develop procedures and protocols for gathering and analyzing relevant data (as appropriate). ☐	Teacher directs learners to collect certain data, or only provides portion of needed data. Often provides protocols for data collection. ☐	Teacher provides data and asks learners to analyze. ☐	Teacher provides data and gives specific direction on how data is to be analyzed. ☐	No evidence observed. ☐

Appendix C:

Learners formulate explanations and conclusions from evidence to address scientifically oriented questions.					
Learners formulate conclusions and/or explanations from evidence to address scientifically oriented questions.	Learner is prompted to analyze evidence (often in the form of data) and formulate own conclusions/ explanations. ☐	Teacher prompts learners to think about how analyzed evidence leads to conclusions/explanations, but does not cite specific evidence. ☐	Teacher directs learners' attention (often through questions) to specific pieces of analyzed evidence (often in the form of data) to draw conclusions and/or formulate explanations. ☐	Teacher directs learners' attention (often through questions) to specific pieces of analyzed evidence (often in the form of data) to lead learners to predetermined correct conclusion/explanation (verification). ☐	No evidence observed. ☐
Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.					
Learners evaluate their conclusions and/or explanations in light of alternative conclusions/ explanations, particularly those reflecting scientific understanding.	Learner is prompted to examine other resources and make connections and/or explanations independently. ☐	Teacher provides resources to relevant scientific knowledge that may help identify alternative conclusions and/or explanations. Teacher may or may not direct learners to examine these resources, however. ☐	Teacher does not provide resources to relevant scientific knowledge to help learners formulate alternative conclusions and/or explanations. Instead, the teacher identifies related scientific knowledge that could lead to such alternatives, or suggests possible connections to such alternatives. ☐	Teacher explicitly states specific connections to alternative conclusions and/or explanations, but does not provide resources. ☐	No evidence observed. ☐
Learners communicate and justify their proposed explanations.					
Learners communicate and justify their proposed conclusions and/or explanations.	Learners specify content and layout to be used to communicate and justify their conclusions and explanations. ☐	Teacher talks about how to improve communication, but does not suggest content or layout. ☐	Teacher provides possible content to include and/or layout that might be used. ☐	Teacher specifies content and/or layout to be used. ☐	No evidence observed. ☐

Appendix D

Appendix D:

Dear Student Teacher Supervisor:

I am a doctoral student at Lehigh University conducting research for my dissertation on the implementation of science inquiry by pre-service teachers during their student teaching experience under the supervision of Dr. Lynn Columba, associate professor of Education at Lehigh University. I am looking for pre-service or student teacher volunteers who will be teaching 4^{th} through 12^{th} grade to take part in my study.

The purpose of the study is to observe and analyze the implementation of the Five E Instructional Model of Inquiry into science lessons. Participation in the study will include the following:
The pre-service teachers will be asked to complete a short demographic survey which will be distributed during student teaching practicum or via email with ample time to complete. Attached to the demographic survey will be a pre-questionnaire on inquiry. Each student teacher will be observed by a trained rater while teaching two separate science inquiry lessons. Observation will be performed in the middle and towards the end of one of the student teaching assignments. At the conclusion of the observation a post-questionnaire on inquiry will be distributed to each student teacher via email with ample time to complete. All data collected will be kept in a secure, locked office. Only the researcher, two raters, and graduate advisor will have access to this office. The data will be destroyed after one year or returned to the student teacher upon request.

The possible benefits of participation in this study are to help contribute to science teaching and research pertaining to pre-service teachers. This experience can also be included on the participants resume to show future employers that they demonstrate good initiative by enhancing their learning curve and helping to improve their profession.

The student teacher's participation will be voluntary and they should feel free to withdraw from this study at any time without jeopardizing any relationship with Lehigh University. However, all students who participate to completion, as well as their master teachers, will have their names placed in a drawing for several exciting prizes.

After talking with your student teachers and or cooperating master teachers can you please get back to the researcher with a list of any student teachers who are interested. Please be sure to include their email addresses so that they may be contacted with more information in order to make an informed decision about participation. Thank you for taking the time to read this letter and letting your student/pre-service teachers learn about this exciting opportunity to take part in teacher preparation research. If you have any questions about this study, please feel free to call the researcher, Patricia O'Donnell at 610-865-3399 or email her at plo204@lehigh.edu or you may call Dr. H. Lynn Columba at Lehigh University College of Education (610) 758-3230.

Sincerely,

Patricia O'Donnell. M. Ed

Appendix E

Appendix E:

Dear Building Principal and Cooperating Teacher:

I am a doctoral student at Lehigh University conducting research for my dissertation on the implementation of science inquiry by pre-service teachers during their student teaching experience under the supervision of Dr. Lynn Columba, associate professor of Education at Lehigh University. I am looking for student/pre-service teacher volunteers who will be teaching 4^{th} through 12^{th} grade to take part in my study.

The purpose of the study is to observe and analyze pre-service teacher implementation of the Five E Instructional Model of Inquiry into science lessons. Participation in the study will include the following:
The pre-service teachers will be asked to complete a short demographic survey, and a pre-questionnaire and post-questionnaire on inquiry. Each pre-service teacher will be observed by a trained rater while teaching two separate science inquiry lessons. Observations will be performed in the middle and towards the end of one of the student teaching assignments. All observations and data collection will be confidential. Participants will be given a code number for identification. All data collected will be kept in a secure, locked office. Only the researcher, two raters, and graduate advisor will have access to this office. The data will be destroyed after one year or returned to the student teacher upon request.

The possible benefits to participation in this study are to contribute to science teaching and research pertaining to pre-service teachers. This experience can also be included on the participants resume to show future employers that they demonstrate initiative by enhancing their learning curve and helping to improve their profession.

The student teacher's participation will be voluntary and they should feel free to withdraw from this study at any time without jeopardizing any relationship with Lehigh University. However, all students who participate to completion, as well as their master teachers, will have their names placed in a drawing for several exciting prizes.

Lehigh University would like your permission to allow the following pre-service teacher ________________________ as well as their master teacher ________________________ to participate in this exciting research endeavor. I understand that I am allowing one of two raters to enter my building for observational research purposes of the above pre-service teacher.

____

Building Principal

____

Pre-service Master/ Cooperating Teacher

Thank you for taking the time to read this letter and letting your student/pre-service teachers participate in this exciting opportunity to take part in teacher preparation research. If you have any questions about this study, please feel free to call the researcher, Patricia O'Donnell at 610-865-3399 or email her at plo204@lehigh.edu or you may call Dr. H. Lynn Columba at Lehigh University College of Education (610) 758-3230.

Sincerely,

Patricia O'Donnell. M. Ed

Appendix F

Appendix F:

INFORMED CONSENT FORM

I, ____, hereby agree to participate as a participant in the dissertation/pilot study by Patricia O'Donnell under the supervision of Dr. H. Lynn Columba Associate Professor of Education at Lehigh University. It has been explained to me that the purpose of the study is to observe and analyze the implementation of the Five E Instructional Model of Inquiry into science lessons. This study will also examine the differences between implementation of inquiry by a variety of pre-service teachers.

I understand that my participation will include the following:
I will be asked to complete a demographic survey which will be distributed during student teaching practicum with ample time to complete. Attached to the demographic survey will be a pre-questionnaire (test) on inquiry. I will be observed while teaching two science inquiry lessons. Observation will be performed in the middle and towards the end of my student teaching assignment. At the conclusion of the observation I will be given a post-questionnaire (test) on inquiry which will be distributed at the student teaching practicum with ample time to complete. All data collected will be kept in a secure, locked office. Only the researcher and graduate advisor will have access to this office. The data will be destroyed after one year. I understand that my name will be substituted with a four digit ID number that I have created (i.e. the month of your birthday [January= 01] and last two digits of your phone number).

I agree to be a participant in this study and will implement science inquiry into lessons as expected by National and State Science Standards. I agree to have a researcher observe me implementing inquiry in my classroom.

I understand that the possible benefits to my participation in this study are to contribute to my professional knowledge and experience in order to obtain information about the implementation of inquiry into the science lesson by pre-service student teachers. I understand that any data or answers to questions will remain confidential with regard to my identity.

I understand there will be minimal risk involved in participating in this study. The minimal risk includes giving up some of my free time to complete the instruments as well as any discomfort I may feel while being observed.

I understand that my participation is voluntary and that I am free to withdraw from this study at any time without jeopardizing my relationship with Lehigh University.

If I have any questions about this study, I may call Dr. H. Lynn Columba at Lehigh University College of Education (610) 758-3230.

I understand I may report any problems which result from my participation in this study to Ruth L. Tallman, Office of Research and Sponsored Programs, Lehigh University, (610) 758-3024.

I have read and understand the foregoing information.

____
Date

____
Participant's signature

I, the undersigned, have defined and fully explained the investigation to the above subject.

____
Date

____
Investigator's Signature

Appendix G

Appendix G: Vita

PATRICIA L. O'DONNELL
648 Dorothy Avenue
Bethlehem, PA 18015
E-mail: plo204@lehigh.edu
(610) 865-3399

Education

Ed.D. Foundations/Science Education, (2011). Lehigh University, Bethlehem, PA
Science Supervisory Certificate, Lehigh University, Bethlehem, PA, 1992
M.Ed. Secondary Education/Science, Lehigh University, Bethlehem, PA, 1989
Certification Secondary General Science, Lehigh University, Bethlehem, PA, 1988
Certification Secondary Education/Biology, Kutztown University, Kutztown, PA, 1986
B.S. in Biology, Villanova University, Villanova, PA, 1986

Professional Qualifications

Instructional II Secondary Educational Certification, Biology/General Science, PA, NJ

Professional Positions

2004- Present	**Doctoral Student (**including completion of comprehensive exams/ dissertation proposal/defense of dissertation w/committee)
2005	**Educational Researcher -** Education Department, Lehigh University, Bethlehem, PA - First year implementation of the Exploring Life web-based biology inquiry curriculum at Emmaus High School.
1992-1994	**Full-Time Doctoral Student** (includes residency)
1992-1993	**Researcher** – Molecular Biology Department, Lehigh University, Bethlehem, PA, DNA isolation of *Clostridium difficile*.
1992-1994	**Graduate Assistant –** Lehigh University, Bethlehem, PA, Lab Assistant-science methods course; Coordinate science workshops.
1987-1993	**Head Women's Cross Country & Assistant Track Coach** Lehigh University, Coached two individual Cross Country Conference champs and team championship,1992 Patriot League Coach of the Year.
1990-1992	**Assistant Professor of Education,** Kutztown University, Kutztown, PA Taught educational foundations, science methods courses; supervised science student teachers; practicum.
1986-1990	**Biology/Physical Science Teacher,** Northampton Jr. H.S., Northampton, PA, ninth grade, all learning levels
1989	**Lab Researcher –** Molecular Biology, Lehigh University, Factors affecting protoplast regeneration of *Thermomonospora.*

National Publications

O'Donnell, P., & Frick, A.,(2010). Speedy Gonzales. In Math by the Month, E. Hendris-Martin (Ed). *Teaching Children Mathematics. 16(8), 456-457*

Columba, L., O'Donnell, P., Sanchez, Y**., (**2011). A dime at a time. In Math by the Month, E. Hendris-Martin (Ed.). *Teaching Children Mathematics. 17(6), 340-341*

Honors

2006-2011	College of Education Scholarship Award, Lehigh University
2011	RSDSA Newsletter, *Person of Hope*
2011	Her Longest Race, *Sweet Charity*, Good Shepherd Publication

2009 College of Education Student Research Poster Symposium: *The implementation of science inquiry: Pre-service traditional teachers, non-traditional teachers and epistemological beliefs.*

1994-1995 Who's Who in American Education

1992 Patriot League Cross Country Coach of the Year, Team Champions, NYC

1990 Who's Who Among America's Teachers

1988- Education Loan Forgiveness Program, PA Science Teachers

National Professional Presentations/ National Reviewer

Reviewer: National Science Teachers Association Conference, Proposal Reviewer (2009), San Francisco, CA, 2010**.**

"Pre-service science teachers using inquiry-instruction: Demographics and beliefs." School Science and Mathematics Association, Annual Convention, Fort Meyers, FL, Nov. 4, 2010

"Pre-service science teachers using inquiry-based instruction: Demographics and beliefs." School Science and Mathematics Association, Annual Convention, Reno Nevada. October, 2009.

"The implementation of science inquiry: Pre-service traditional teachers, non-traditional teachers and epistemological beliefs." College of Education Student Research Poster Symposium, Lehigh University, Bethlehem, PA, 2009

"Student Teacher Demographics and Beliefs: Do They Affect Science Inquiry Implementation?" Co-presented with Lynn Columba, School Science and Mathematics Association, Annual Convention, Raleigh-Durham, NC, Nov. 2008.

Curriculum Development

Curriculum Development for Science Methods curriculum to meet NCATE standards, Kutztown University, Kutztown, PA, 1991-1992

Curriculum Development for 9th grade Physical Science Program, Northampton School District, Northampton, PA, 1987

Initiated, developed and implemented a Science Club for 8th and 9th grade students, Northampton School District, 1988-1990

Professional Development

School Science and Mathematics Association, Annual Convention, Fort Meyers, FL, Nov. 4, 2010

School Science and Mathematics Association, Annual Convention, Reno, Nevada October, 2009.

The National Association of Biology Teachers, Northeast Regional workshop, Spring Mountain Lodge, Reeders, PA, 2009

School Science and Math Association, Annual Convention, Raleigh-Durham, NC, Nov. 13 -15, 2008

Professional Affiliations

Association of Supervision and Curriculum Development
National Science Teachers Association
National Association of Biology Teachers
Phi Delta Kappan
School Science and Mathematics Association

Community Affiliations

Lehigh University Choral Union